



# South Eastern CFRAM Study UoM14 Preliminary Options Report

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# TABLE OF CONTENTS

<b>ABBREVIATIONS</b>	<b>V</b>
<b>1 INTRODUCTION</b>	<b>1-1</b>
1.1 GENERAL INFORMATION ON THE SOUTH EASTERN CFRAM STUDY	1-1
1.2 FLOOD SOURCES	1-3
1.2.1 Fluvial Flooding	1-3
1.2.2 Coastal Flooding	1-3
1.3 SOUTH EASTERN CFRAM STUDY ACTIVITIES	1-3
1.3.1 Preliminary Flood Risk Assessment	1-5
1.3.2 Data collection	1-5
1.3.3 Flood Risk Review	1-5
1.3.4 Surveys	1-5
1.3.5 Hydrological Analysis	1-5
1.3.6 Hydraulic Analysis	1-6
1.3.7 Flood Risk Assessment	1-6
1.3.8 Development of Flood Risk Management Options	1-6
1.3.9 Environmental Assessment	1-6
1.3.10 Communications Activities	1-7
1.3.11 Preparation of Flood Risk Management Plan	1-7
1.4 PURPOSE OF THE PRELIMINARY OPTIONS REPORT	1-7
1.5 INTRODUCTION TO THE OPTIONEERING PROCESS	1-8
<b>2 DATA COLLECTION</b>	<b>2-1</b>
2.1 BACKGROUND MAPPING	2-1
2.2 RECEPTORS	2-1
2.3 FLOOD HAZARD	2-2
2.4 SURVEY DATA	2-3
2.5 ECONOMIC ASSESSMENT	2-3
<b>3 SPATIAL SCALES OF ASSESSMENT</b>	<b>3-1</b>
3.1 UNIT OF MANAGEMENT SSA	3-1
3.2 SUB-CATCHMENT SSA	3-2
3.3 AFA SSA	3-2
3.4 SPATIAL SCALES OF ASSESSMENT FOR UoM14	3-2
<b>4 FLOOD RISK ASSESSMENT</b>	<b>4-1</b>
4.1 FLOOD RISK MAPS	4-6
4.2 FLOOD CELLS	4-8
<b>5 DAMAGE ASSESSMENT</b>	<b>5-1</b>
5.1 DAMAGE ASSESSMENT GUIDELINES	5-1
5.2 RECORDING DAMAGE ASSESSMENT DATA	5-2
5.3 CATEGORISATION OF PROPERTIES	5-3
5.4 PROPERTY FLOOR LEVEL	5-5
5.5 FLOOD DEPTH OF PROPERTIES	5-5
5.6 FLOOD DAMAGE TO PROPERTIES	5-6
5.7 INTANGIBLE DAMAGES, UTILITY AND EMERGENCY COSTS	5-8
5.8 ANNUAL AVERAGE DAMAGE AND PRESENT VALUE DAMAGE	5-9
5.9 COASTAL FLOODING	5-11
5.10 DEFENDED FLOOD DAMAGES	5-11
5.11 BENEFIT	5-11
5.12 CAPPING BENEFIT	5-12
5.13 DAMAGE ASSESSMENT REVIEW	5-13
<b>6 FLOOD RISK MANAGEMENT METHODS</b>	<b>6-1</b>
6.1 STANDARD OF PROTECTION	6-1
6.1.1 Residual Risk	6-1
6.2 LIST OF FRM METHODS	6-2
6.3 BASELINE CONDITION	6-3
6.3.1 Drainage Districts (Local Authorities)	6-3
6.3.2 Arterial Drainage (OPW)	6-4
<b>7 ASSESSMENT OF FRM METHODS</b>	<b>7-1</b>

7.1	SCREENING FRM METHODS .....	7-2
7.1.1	Shortlisting FRM Methods .....	7-2
7.1.2	Technical Screening .....	7-2
7.1.3	Do Nothing .....	7-2
7.1.4	Additional Maintenance .....	7-3
7.1.5	Do Minimum .....	7-3
7.1.6	Sustainable Planning and Development Management .....	7-3
7.1.7	Land Use Management .....	7-4
7.1.8	Storage .....	7-5
7.1.9	Improvement of Channel Conveyance .....	7-6
7.1.10	Hard Defences .....	7-7
7.1.11	Relocation of Properties .....	7-7
7.1.12	Diversion of flow .....	7-7
7.1.13	Flood Warning/Forecasting .....	7-8
7.1.14	Public Awareness Campaign .....	7-9
7.1.15	Individual Property Protection .....	7-9
7.1.16	Other Works .....	7-9
7.1.17	Economic Screening .....	7-10
7.1.18	Environmental and Social Screening .....	7-11
7.2	DEVELOPING POTENTIAL FRM OPTIONS .....	7-12
7.2.1	Identifying possible FRM options .....	7-12
7.2.2	Option effectiveness .....	7-12
7.2.3	Benefit Cost Analysis .....	7-12
7.3	ASSESSMENT OF POTENTIAL FRM OPTIONS (MCA PROCESS) .....	7-13
7.3.1	Criteria and Objectives .....	7-14
7.3.2	Scoring Options .....	7-16
7.3.3	Weighting objectives .....	7-17
7.4	PREFERRED FRM OPTIONS .....	7-17
7.4.1	No potential options .....	7-18
7.5	FUTURE CHANGE ASSESSMENT ALONGSIDE OPTION DEVELOPMENT .....	7-18
<b>8</b>	<b>OPTIONEERING OF UOM14 SPATIAL SCALE OF ASSESSMENTS .....</b>	<b>8-1</b>
8.1	UoM14 UoM .....	8-1
8.2	BARROW SUBCATCHMENT .....	8-1
8.3	ALLENWOOD AFA .....	8-1
8.4	ATHY AFA .....	8-1
8.5	CARLOW AFA .....	8-1
8.6	CASTLEDERMOT AFA .....	8-1
8.7	DAINGEAN AFA .....	8-1
8.8	GRAIGUENAMANAGH AFA .....	8-1
8.9	LEIGHLINBRIDGE AFA .....	8-1
8.10	MONASTEREVIN AFA .....	8-1
8.11	MOUNTMELICK AFA .....	8-1
8.12	NEW ROSS AFA .....	8-1
8.13	PORTARLINGTON AFA .....	8-1
8.14	PORTLAOISE AFA .....	8-1
8.15	RATHANGAN AFA .....	8-1
8.16	SUNCROFT AFA .....	8-1
<b>9</b>	<b>SUMMARY OF FRM OPTIONS .....</b>	<b>9-1</b>
<b>10</b>	<b>REFERENCES .....</b>	<b>10.1</b>

## APPENDICES

Appendix A – Athy AFA additional information

Appendix B – Carlow AFA additional information

Appendix C – Castledermot AFA additional information

Appendix D – Graiguenamanagh AFA additional information

Appendix E – Leighlinbridge AFA additional information	
Appendix F – Mountmellick AFA additional information	
Appendix G – Portarlinton AFA additional information	
Appendix H – Portlaoise AFA additional information	
Appendix I – Suncroft AFA additional information	

## LIST OF FIGURES

Figure 1.1 - South Eastern CFRAM Study Area .....	1-2
Figure 1.2 – South Eastern CFRAM Study activities .....	1-4
Figure 1.3 - UoM14 AFA Locations and Extents .....	1-8
Figure 1.4 - Optioneering process .....	1-10
Figure 3.1 – UoM14 Sub-catchment SSAs .....	3-4
Figure 4.1 - Extract from cultural heritage risk map .....	4-6
Figure 4.2 – Extract from economic activity map .....	4-7
Figure 4.3 - Extract from economic risk density maps .....	4-7
Figure 5.1 - MCM's depth damage data for detached houses .....	5-1
Figure 5.2 - Example shapefile with attribute table showing damage assessment data .....	5-2
Figure 5.3 - The MCM's depth damage data for a detached house .....	5-7
Figure 5.4 - Example damage curve .....	5-10
Figure 7.1 - Assessment of FRM methods flow chart .....	7-1

## LIST OF TABLES

Table 2.1 - Background Mapping data .....	2-1
Table 2.2 - Receptor data .....	2-1
Table 2.3 - Flood Hazard data .....	2-2
Table 2.4 - Survey data .....	2-3
Table 2.5 - Economic Assessment data .....	2-3
Table 3.1 – List of SSAs in UoM14 .....	3-3
Table 4.1 - Flood risk receptor groups .....	4-1
Table 5.1 - MCM property types .....	5-3
Table 5.2 - Categorisation of properties data .....	5-4
Table 5.3 - Property threshold data .....	5-5
Table 5.4 - Flood depth of properties data .....	5-6
Table 5.5 - Converting pound sterling to euro using the PPP 2010 values from OECD website .....	5-7
Table 5.6 - Conversion rates to current year prices using CPI from CSO Ireland website .....	5-7
Table 5.7 - Flood damage to properties data .....	5-8
Table 5.8 - Intangible damages and emergency cost data .....	5-9
Table 5.9 - AAD and PvD data .....	5-11
Table 5.10 - Capping damages data .....	5-12

Table 5.11 - Capping damages data .....	5-13
Table 7.1: Summary of FRM Applicability to SSA .....	7-10
Table 7.2 - Additional costs to FRM options.....	7-11
Table 7.3 - Criteria and Objectives of the MCA.....	7-15
Table 9.1 – Summary of Preliminary Options Identified at AFA SSA within UoM14.....	9-2

## 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 14 (UoM14) is located within the South Eastern CFRAM study area (Figure 1.1). The UoM14 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 UoM14. 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

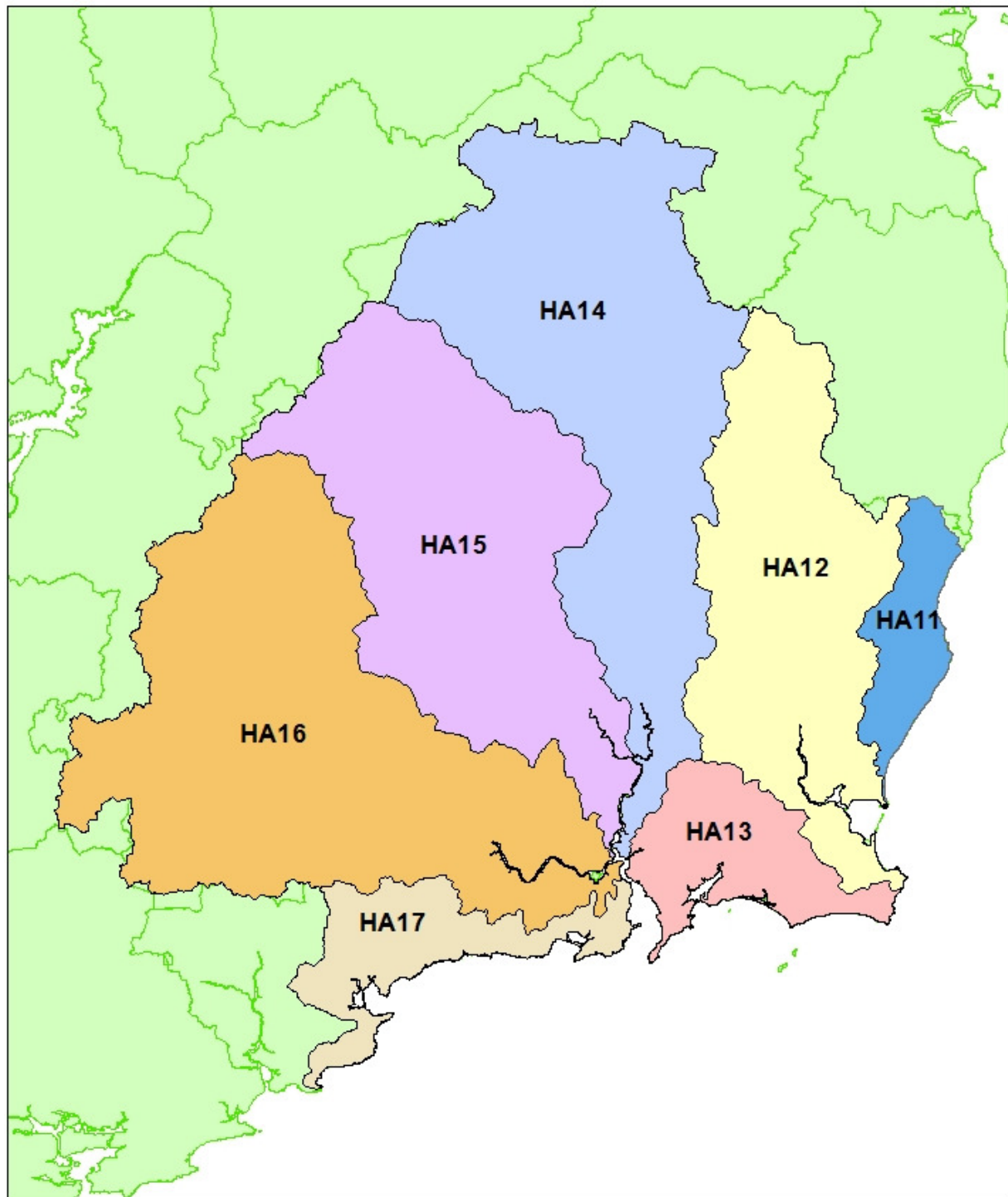
As shown in Figure 1.1, the South Eastern CFRAM Study Area covers approximately 12,857 km<sup>2</sup> and includes six Units of Management; UoM11 (Owenavorrhagh), UoM12 (Slaney and Wexford Harbour), UoM13 (Ballyteigue-Bannow), UoM14 (Barrow), UoM15 (Nore) and UoM17 (Colligan-Mahon). UoM16 (Suir) is covered by the Suir pilot CFRAM Study and covers an area of approximately 3,542 km<sup>2</sup>.

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.southeastcfрамstudy.ie](http://www.southeastcfрамstudy.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**

\*UoM 16 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 flood risk from the sea is expected to increase over the coming decades.

## **1.3 SOUTH EASTERN CFRAM STUDY ACTIVITIES**

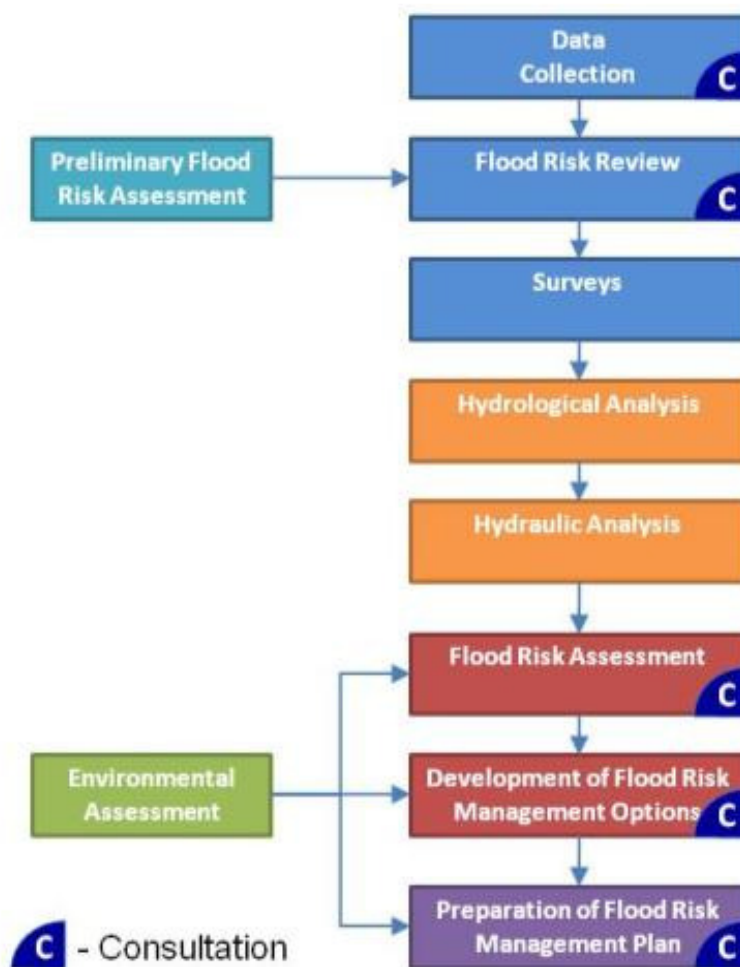
To achieve the study objectives the South Eastern CFRAM Study has carried out a range of activities. Each activity, while focusing on a specific task, is connected to and informs the other activities. Figure 1.2 summarises the activities involved in the study and how they relate to each other.

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 was to identify areas where the risks associated with flooding might be significant. The PFRA provided 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](http://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.eastcfframstudy.ie](http://www.eastcfframstudy.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.southeastcfframstudy.ie](http://www.southeastcfframstudy.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 UoM14 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 UoM14 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 of 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 UoM14 (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 UoM14.

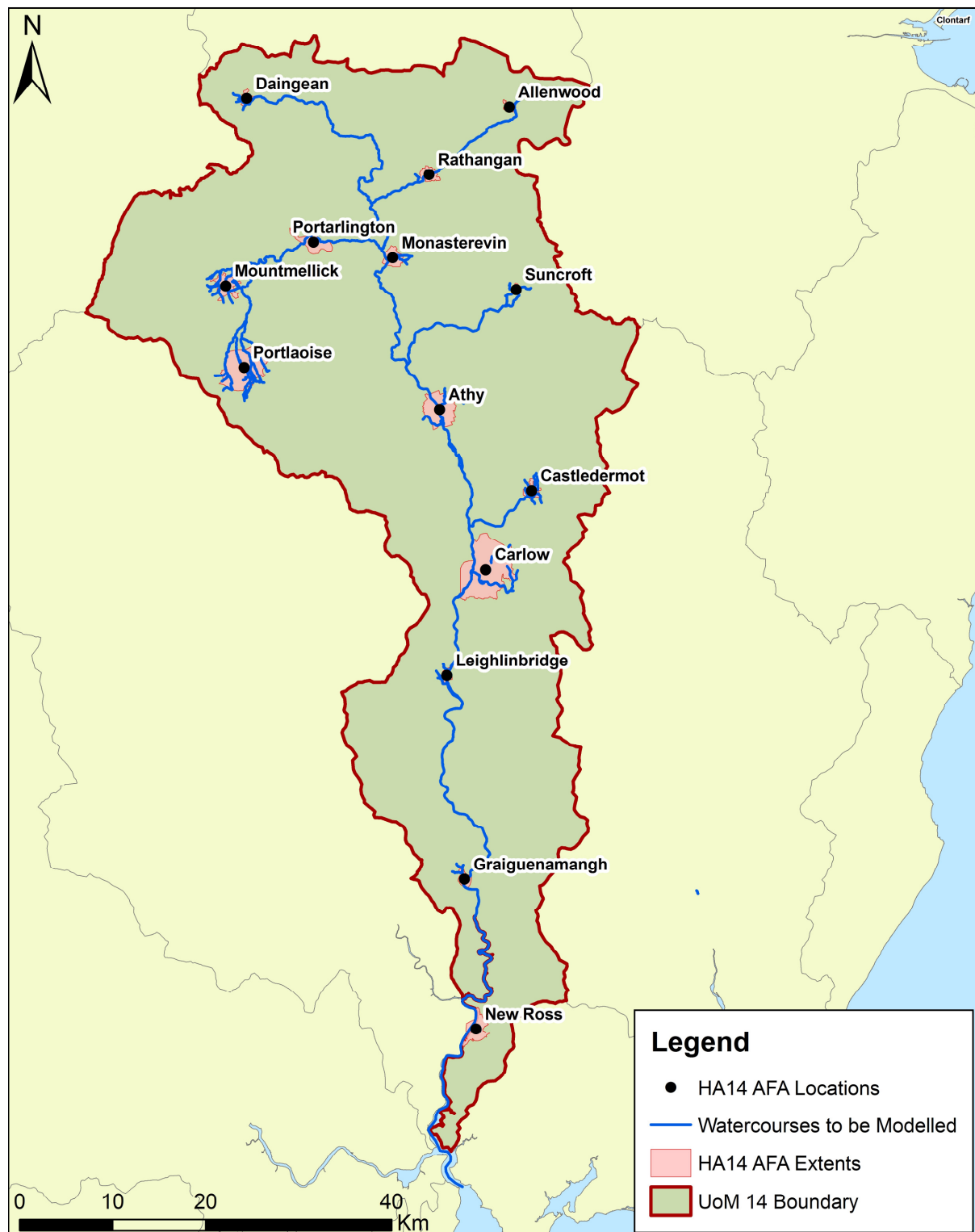


Figure 1.3 - UoM14 AFA Locations and Extents

## 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 UoM14;
- 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 SSAs 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).

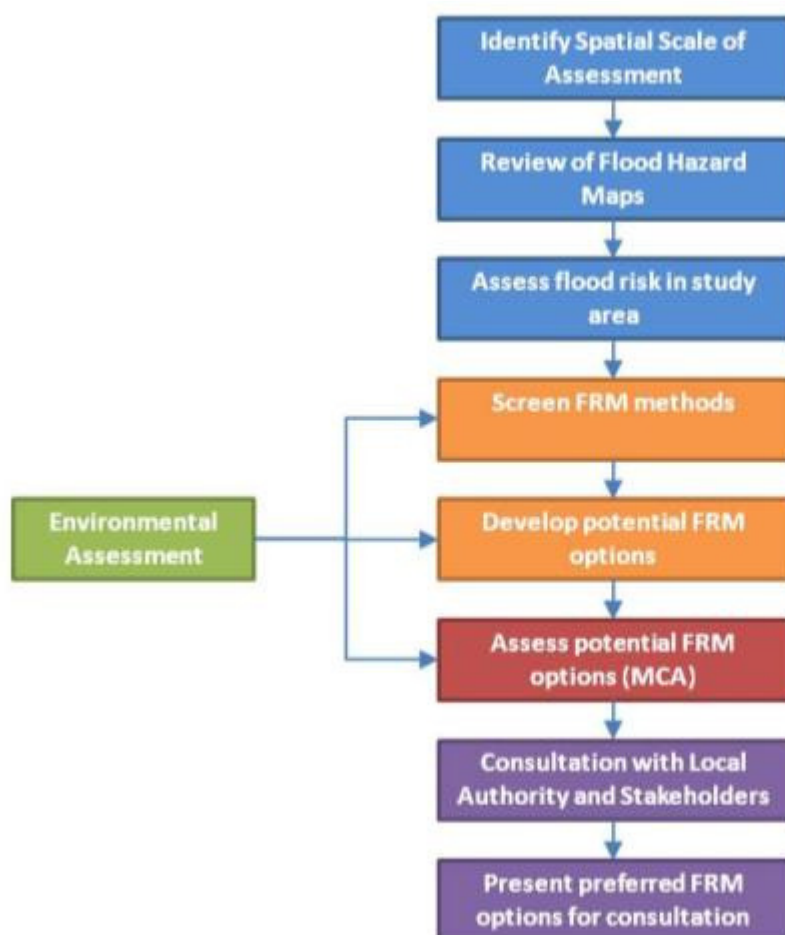


Figure 1.4 - Optioneering process

## 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 for 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

UoM14 contains of 14 Areas for Further Assessment (AFAs). These AFAs are situated along, or in proximity to, the River Barrow and its tributaries the River Lerr, Philipstown River, Triogue River and Boherbaun. Rathangan AFA within UoM14 does not have flood risk in the 0.1% AEP design fluvial event and therefore optioneering has not been undertaken for this area. New Ross AFA has also not be optioneered as a FRM scheme is currently being implemented. . The remaining 12 AFAs within UoM14 all have 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 UoM14. This could theoretically consist of FRM options within each of the at risk AFAs or one overarching FRM option within UoM14 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 UoM14 (Barrow) is one of six UoM.

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 UOM14**

A review was carried out for UoM14 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 UoM14.

**Table 3.1 – List of SSAs in UoM14**

SSA	Name	AFAs within SSA		
<b>UoM</b>	UoM 14	All		
		Daingean	Monasterevin	Mountmellick
		Portarlinton	Portlaoise	Allenwood
		Athy	Daingean	Monasterevin
		Mountmellick	Portarlinton	Portlaoise
		Allenwood		
		Athy	Carlow	Castledermot
		Daingean	Leighlinbridge	Monasterevin
		Mountmellick	Portarlinton	Portlaoise
		Allenwood		
		Athy	Graiguenamanagh	Castledermot
		Daingean	Leighlinbridge	Leighlinbridge
		Monasterevin	Mountmellick	Portarlinton
		Portlaoise	Allenwood	
<b>Sub Catchment</b>	Barrow Reach 5	New Ross		
<b>AFA</b>	Allenwood			
<b>AFA</b>	Athy			
<b>AFA</b>	Carlow			
<b>AFA</b>	Castledermot			
<b>AFA</b>	Daingean			
<b>AFA</b>	Graiguenamanagh			
<b>AFA</b>	Leighlinbridge			
<b>AFA</b>	Monasterevin			
<b>AFA</b>	Mountmellick			
<b>AFA</b>	New Ross			
<b>AFA</b>	Portarlinton			
<b>AFA</b>	Portlaoise			
<b>AFA</b>	Rathangan			
<b>AFA</b>	Suncroft			

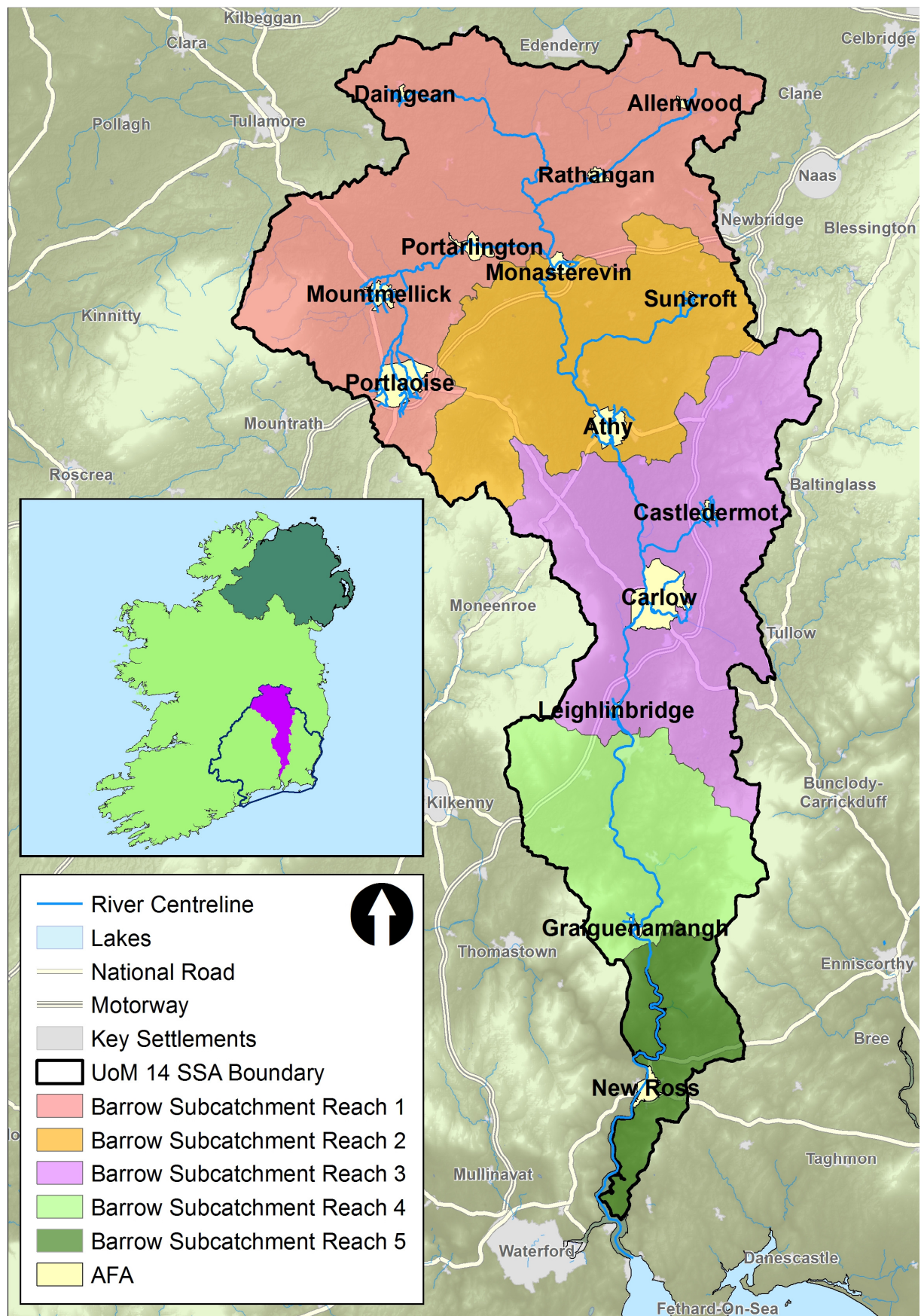


Figure 3.1 – UoM14 Sub-catchment SSAs

## 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 UoM14 is summarised in Table 4.2.



**Table 4.2 Flood Risk Analysis UoM14**

Type of Risk	Flood Risk for Design AEP (1% Fluvial & 0.5% Coastal) Event						
	Allenwood AFA	Athy AFA	Leighlinbridge AFA	Castledermot AFA	Daingean AFA	Graiguenamanagh AFA	Carlow AFA
Current Scenario (Present Day)							
Event Damage (€)	16,976	7,978,744	8,697,463	1,345,667	69,133	11,472,562	3,146,811
No. Residential Properties at Risk	2	75	42	12	9	24	32
No. Business Properties at Risk	0	24	15	6	0	40	3
No. Utilities at Risk	0	0	0	0	0	0	2
No. Major Transport Assets at Risk	1	23	4	8	7	10	22
No. Highly Vulnerable Properties at Risk	0	1	0	0	0	0	1
No. of Social Infrastructure Assets at Risk	1	39	23	3	5	23	33
No. Environmental Assets at Risk	1	5	2	2	1	3	11
No. Potential Pollution Sources at Risk	0	0	0	0	0	0	0
Mid-Range Future Scenario							
Event Damage (€)	131,095	19,179,545	13,388,186	6,633,480	1,137,171	13,794,904	57,802,731
No. Residential Properties at Risk	6	155	47	18	10	37	590
No. Business Properties at Risk	0	53	22	9	2	46	90
No. Utilities at Risk	0	0	0	0	0	0	3
No. Major Transport Assets	4	22	5	10	7	13	59



Type of Risk	Flood Risk for Design AEP (1% Fluvial & 0.5% Coastal) Event						
	Allenwood AFA	Athy AFA	Leighlinbridge AFA	Castledermot AFA	Daingean AFA	Graiguenamanagh AFA	Carlow AFA
at Risk							
No. Highly Vulnerable Properties at Risk	0	1	2	1	0	0	1
No. of Social Infrastructure Assets at Risk	1	42	24	8	5	24	46
No. Environmental Assets at Risk	1	5	2	2	1	4	11
No. Potential Pollution Sources at Risk	0	0	0	0	0	0	0
High-End Future Scenario							
Event Damage (€)	2,334,757	61,696,356	21,327,108	7,819,371	1,482,725	20,858,394	174,732,957
No. Residential Properties at Risk	44	324	52	20	12	48	933
No. Business Properties at Risk	6	97	26	10	3	51	251
No. Utilities at Risk	0	0	0	1	0	1	4
No. Major Transport Assets at Risk	6	32	7	12	7	14	91
No. Highly Vulnerable Properties at Risk	0	5	4	1	0	0	1
No. of Social Infrastructure Assets at Risk	1	55	25	16	5	25	51
No. Environmental Assets at Risk	1	5	2	2	1	4	11
No. Potential Pollution Sources at Risk	0	0	0	0	0	0	0

Type of Risk	Flood Risk for Design AEP (1% Fluvial & 0.5% Coastal) Event						
	Monasterevin AFA	Mountmelick AFA	New Ross AFA	Portarlinton AFA	Portlaoise AFA	Rathangan AFA	Suncroft AFA
Current Scenario (Present Day)							
Event Damage (€)	469,312	4,126,812	56,884 Fluvial 557,333 Coastal	15,642,032	5,417,478	0	1,331,812
No. Residential Properties at Risk	8	40	0 Fluvial 16 Coastal	102	63	0	15
No. Business Properties at Risk	5	5	1 Fluvial 7 Coastal	42	13	0	3
No. Utilities at Risk	0	1	0 Fluvial 0 Coastal	0	0	0	0
No. Major Transport Assets at Risk	5	13	0 Fluvial 4 Coastal	12	20	1	5
No. Highly Vulnerable Properties at Risk	0	0	0 Fluvial 0 Coastal	0	1	0	0
No. of Social Infrastructure Assets at Risk	11	12	3 Fluvial 10 Coastal	19	21	5	2
No. Environmental Assets at Risk	4	3	5 Fluvial 5 Coastal	8	9	2	2
No. Potential Pollution Sources at Risk	0	0	0 Fluvial 0 Coastal	0	0	0	0
Mid-Range Future Scenario							
Event Damage (€)	1,371,204	14,580,282	7,289,711 Fluvial	69,241,293	21,653,558	0	1,881,204

Type of Risk	Flood Risk for Design AEP (1% Fluvial & 0.5% Coastal) Event						
	Monasterevin AFA	Mountmelick AFA	New Ross AFA	Portarlinton AFA	Portlaoise AFA	Rathangan AFA	Suncroft AFA
			44,563,708 Coastal				
No. Residential Properties at Risk	24	193	31 Fluvial 39 Coastal	258	200	0	20
No. Business Properties at Risk	7	23	61 Fluvial 112 Coastal	72	49	0	3
No. Utilities at Risk	0	1	9 Fluvial 8 Coastal	0	7	0	0
No. Major Transport Assets at Risk	7	24	15 Fluvial 21 Coastal	44	34	1	6
No. Highly Vulnerable Properties at Risk	0	1	0 Fluvial 2 Coastal	0	1	0	0
No. of Social Infrastructure Assets at Risk	12	13	11 Fluvial 33 Coastal	25	23	5	2
No. Environmental Assets at Risk	4	3	5 Fluvial 5 Coastal	8	9	2	2
No. Potential Pollution Sources at Risk	0	0	0 Fluvial 1 Coastal	0	0	0	0
High-End Future Scenario							
Event Damage (€)	11,587,369	33,022,698	55,555,576 Fluvial 72,258,687 Coastal	89,448,151	83,385,407	927,753	2,976,202

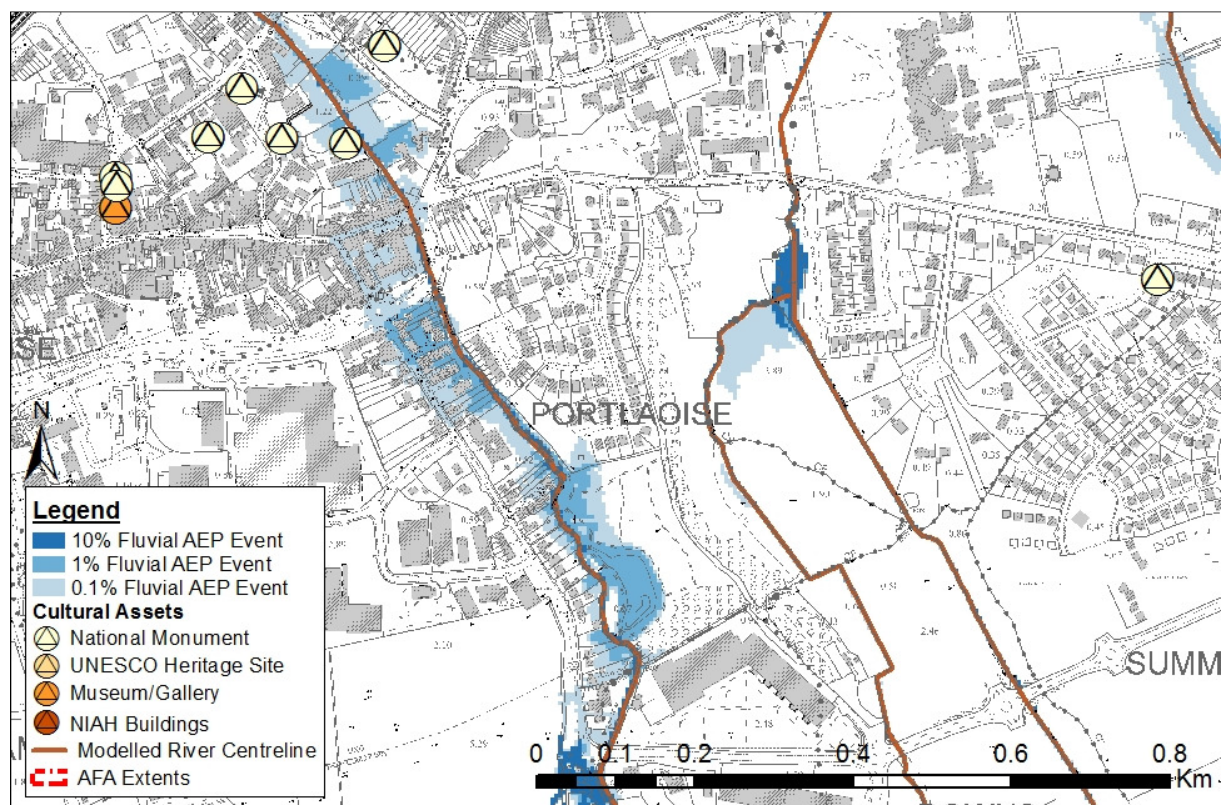
Type of Risk	Flood Risk for Design AEP (1% Fluvial & 0.5% Coastal) Event						
	Monasterevin AFA	Mountmelick AFA	New Ross AFA	Portarlington AFA	Portlaoise AFA	Rathangan AFA	Suncroft AFA
No. Residential Properties at Risk	49	385	46 Fluvial 62 Coastal	313	968	6	26
No. Business Properties at Risk	14	41	120 Fluvial 130 Coastal	108	81	7	3
No. Utilities at Risk	0	1	9 Fluvial 8 Coastal	0	15	1	0
No. Major Transport Assets at Risk	9	33	20 Fluvial 26 Coastal	58	72	2	7
No. Highly Vulnerable Properties at Risk	1	3	2 Fluvial 2 Coastal	0	5	0	0
No. of Social Infrastructure Assets at Risk	15	17	18 Fluvial 39 Coastal	30	33	6	2
No. Environmental Assets at Risk	4	3	5 Fluvial 5 Coastal	8	9	2	2
No. Potential Pollution Sources at Risk	0	0	0 Fluvial 1 Coastal	0	0	0	0

## 4.1 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

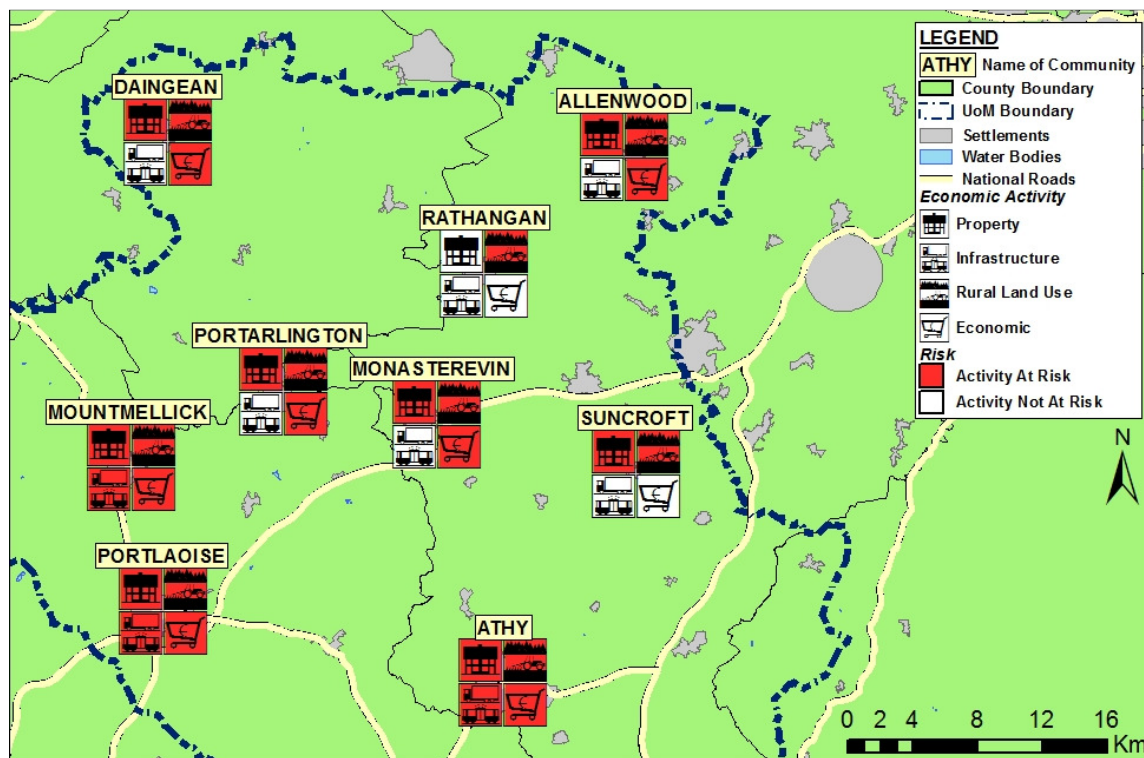
The social, environmental, cultural heritage and economic risk maps display the various receptors within each AFA. Their proximity to the flood extents and therefore the level of risk can be ascertained by these maps. Figure 4.1 presents an example of a cultural heritage risk map in Portlaoise.



**Figure 4.1 - Extract from cultural heritage risk map**

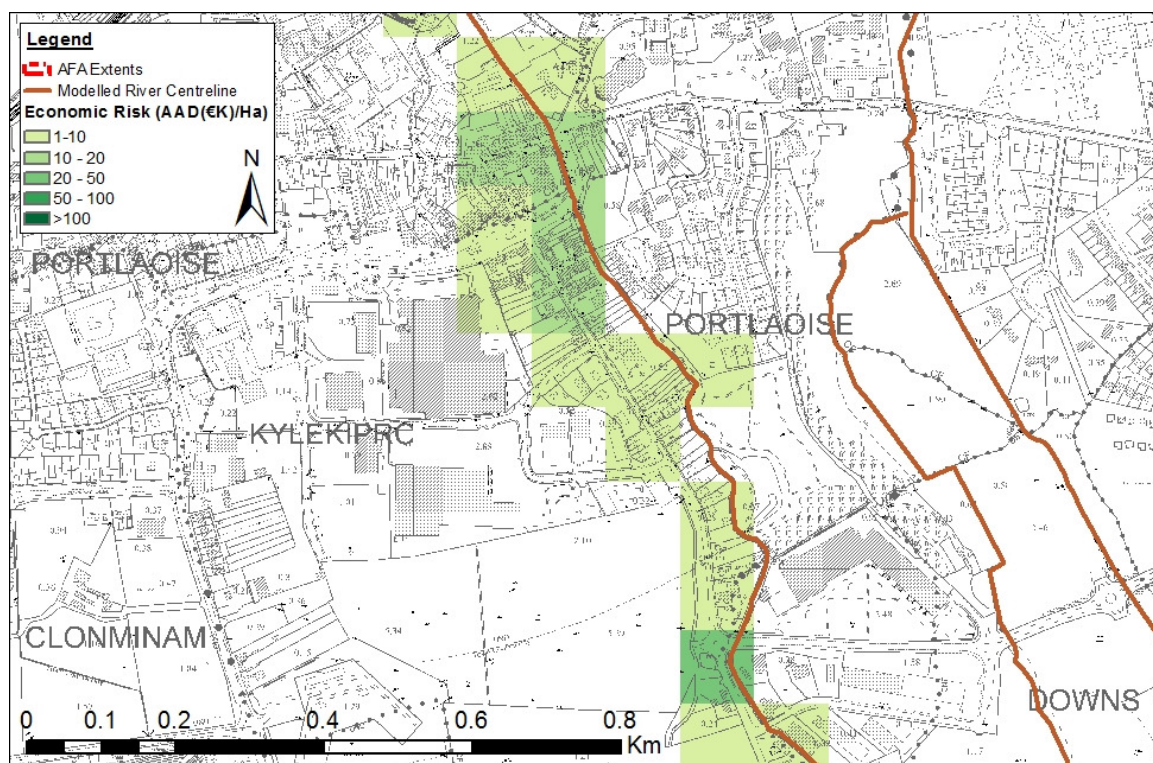
The economic activity maps present the nation's economic activity in four categories; property (residential properties), infrastructure (transport and utilities), rural land use and economic (commercial properties). Where an economic activity is at risk in any AFA it is highlighted on the map. Figure 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 UoM14 AFAs is summarised within Section 8.



**Figure 4.3 - Extract from economic risk density maps**

## 4.2 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 risk in an AFA 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 UoM14.

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.

	DETACHED LAND USE CODE 11															
	2010 PRICES															
	FLOOD DURATION MORE THAN 12 HOURS															
	DEPTH ABOVE UPPER SURFACE OF GROUND FLOOR															
Components of damage	-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	1572.84	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 5.1 - 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.

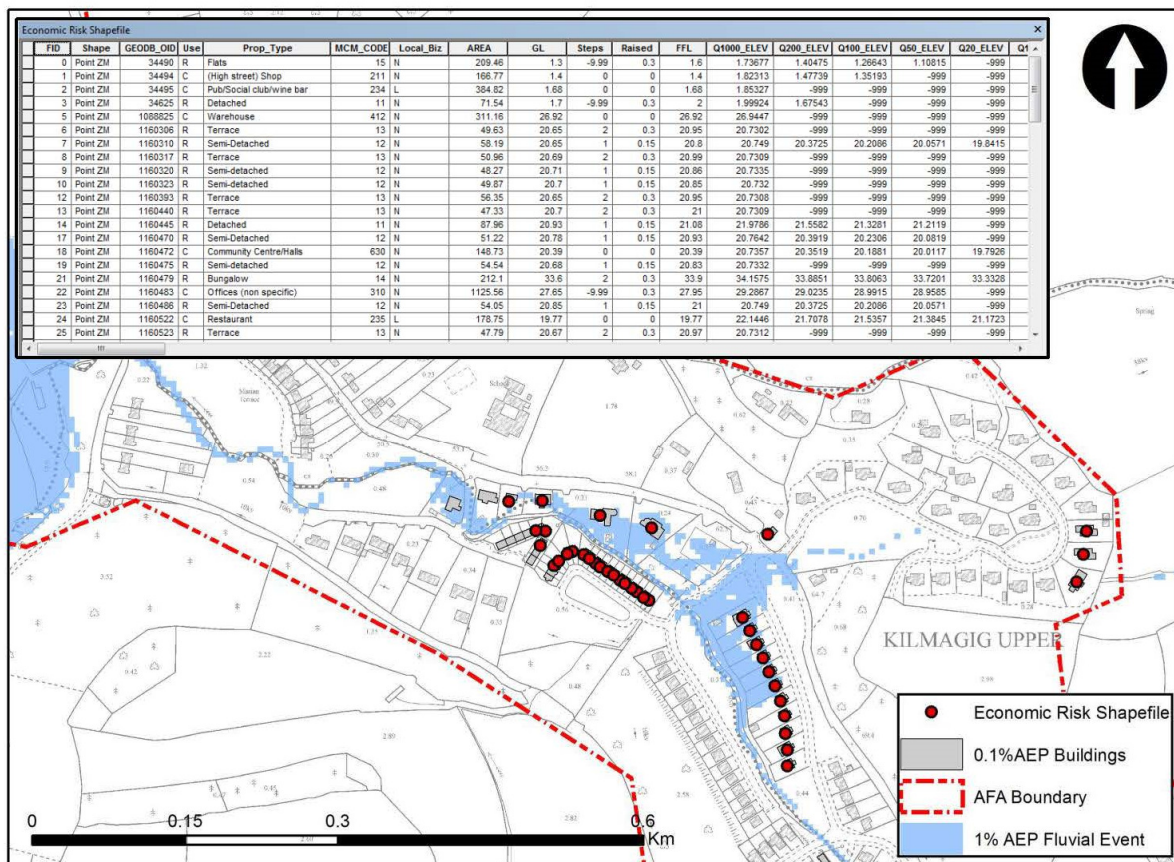


Figure 5.2 - Example shapefile with attribute table showing damage assessment data

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	<b>Leisure</b>	51
Semi Detached House	12	Hotel	511
Terrace House	13	Boarding House	512
Bungalow	14	Caravan Mobile	513
Flat	15	Caravan Static	514
<b>Shop/Store</b>	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	<b>Sport</b>	52
Outdoor market	217	Sports Grounds and Playing Fields	521
Indoor Market	218	Golf Courses	522
<b>Vehicle Services</b>	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
<b>Retail Services</b>	23	<b>Public Building</b>	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
<b>Office</b>	3	Museum	670
Offices (non-specific)	310	Law court	680
Computer Centres (Hi-Tech)	311	Church	690
Bank	320	<b>Industry</b>	8
<b>Distribution/Logistics</b>	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

Property Type	MCM code	Property Type	MCM code
Warehouse (ambient goods)	412	<b>Miscellaneous</b>	9
Warehouse (frozen goods)	413	Car Park	910
		Public Convenience	920
		Cemetery/Crematorium	930
		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, UoM14 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 <sup>2</sup> ), calculated using the OSi building

Data type	Attribute name	Data details
		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 floor 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														
	DEPTH ABOVE UPPER SURFACE OF GROUND FLOOR														
Components of damage	-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	
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	8666.9	8666.9	8666.9	8666.9	8666.9
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
<b>US - UK</b>	0.667
<b>US - Ire</b>	0.853
<b>UK - Ire</b>	1.279

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

	CPI
<b>2006</b>	100
<b>2010</b>	101.2
<b>Apr-13</b>	106.4
<b>2010 - 2013</b>	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 has 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

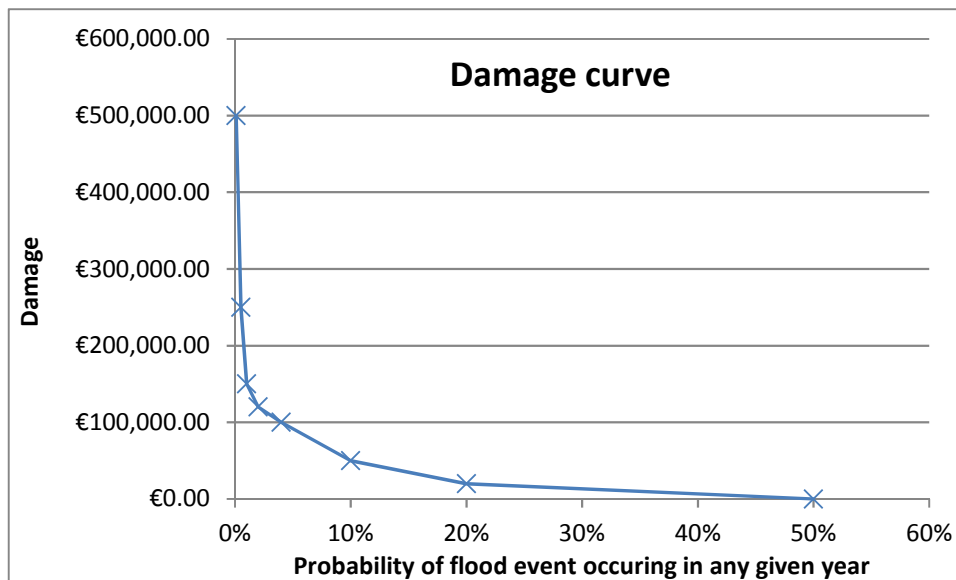
Thus far in the process, damages have been assigned to each property for each flood event. In order to gain an appreciation of the economic risk the overall damage needs to be calculated. This is represented by assessing the likelihood of each of these flood events occurring in any given year and applying 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 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 were 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 UoM14.

#### 6.3.1 Drainage Districts (Local Authorities)

There are thirteen Drainage Districts located within UoM14:

- Ballyadams,
- Barrow,
- Burren,
- Douglas,
- Douglas-Laois,
- Greese,
- Irey,

- Kildare,
- Kilmannock,
- Lerr,
- Quinagh,
- Rathangan and
- Triogue.

Drainage Districts represent areas where the Local Authorities have responsibilities to maintain watercourse channels and therefore contribute to maintaining the existing regime. In relation to UoM14 virtually all of the modelled main watercourses north of Carlow are contained within Drainage Districts and as such the activities within the Drainage Districts contribute significantly to the maintenance of the existing regime affecting the Daingean, Mountmellick, Portarlinton, Rathangan, Monasterevin, Athy Castledermot and Carlow AFAs. Activities within the Drainage Districts also contribute to the maintenance of the existing regime in other parts of UoM14 that were not identified as AFAs.

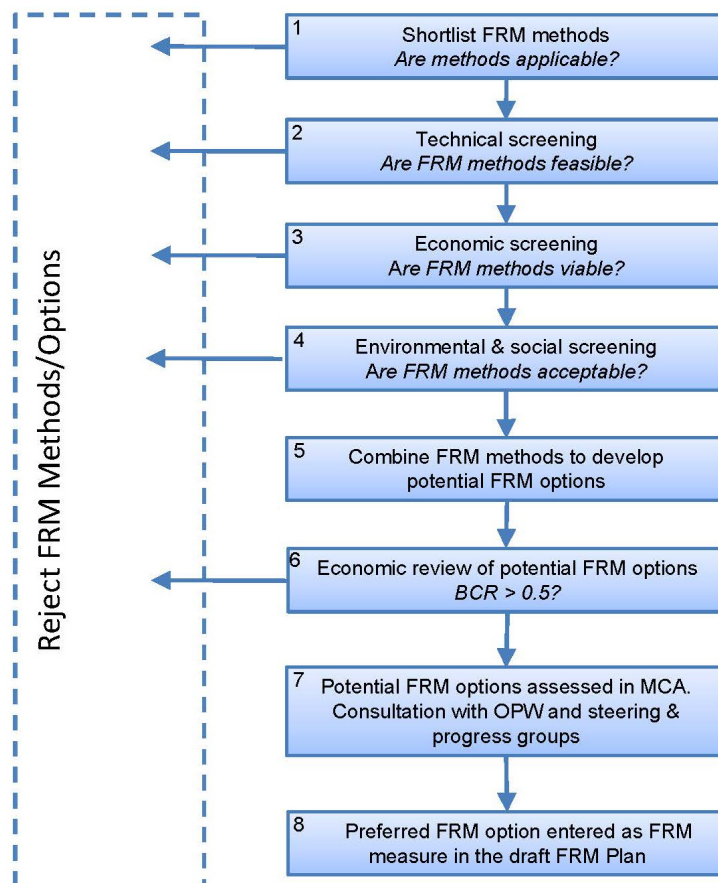
### **6.3.2 Arterial Drainage (OPW)**

There are no Arterial Drainage Districts located within UoM14:



## 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 UoM14 and a raster dataset in 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-catchments/AFAs (generally at the downstream extent of a UoM for example Waterford Estuary) 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 100km<sup>2</sup> would be required as per the World Meteorological Organization guidelines, however this density 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 was 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 only 20% of the damage was assumed to be avoided over the life time of the scheme. Where the flood depth to a property was greater than 0.6m this method was considered technically unfeasible 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	Sub-Catchment	AFA
Do Nothing	✗	✗	✓
Additional Maintenance	✗	✗	✓
Do Minimum	✗	✗	✓
Planning and Development Control	✓	✗	✗
Building Regulations	✓	✗	✗
Catchment Wide SuDs	✓	✗	✗
Land Use Management	✓	✓	✓
Strategic Development Management	✓	✗	✗
Storage	✗	✓	✓
Improvement of Channel Conveyance	✗	✓	✓
Hard Defences	✗	✓	✓
Relocation of Properties	✗	✗	✓
Diversion of Flow	✗	✗	✓
Flood Warning/Forecasting	✓	✓	✓
Public Awareness Campaign	✓	✗	✗
Individual Property Protection	✗	✗	✓
Other Works	✗	✗	✓

### 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 as 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. The 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 to account 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 identify preferred options to incorporate in the draft FRM 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  $\geq 0.5$  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 of measures during 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. 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 UOM14 SPATIAL SCALE OF ASSESSMENTS**

The following sections detail the findings of the optioneering process applied to the various areas within the three SSAs in UoM14.

- 8.1 UOM14 UOM**
- 8.2 BARROW SUBCATCHMENT**
- 8.3 ALLENWOOD AFA**
- 8.4 ATHY AFA**
- 8.5 CARLOW AFA**
- 8.6 CASTLEDERMOT AFA**
- 8.7 DAINGEAN AFA**
- 8.8 GRAIGUENAMANAGH AFA**
- 8.9 LEIGHLINBRIDGE AFA**
- 8.10 MONASTEREVIN AFA**
- 8.11 MOUNTMELICK AFA**
- 8.12 NEW ROSS AFA**
- 8.13 PORTARLINGTON AFA**
- 8.14 PORTLAOISE AFA**
- 8.15 RATHANGAN AFA**
- 8.16 SUNCROFT AFA**

## 8. OPTIONEERING OF SSA'S

### 8.1 UoM14 Optioneering of FRM Options

Name	Local Authority	SSA	Status	Date
UoM14	Laois, Kildare, Carlow, Kilkenny, Wexford <ul style="list-style-type: none"> <li>• Allenwood AFA</li> <li>• Athy AFA</li> <li>• Carlow AFA</li> <li>• Castledermot AFA</li> <li>• Daingean AFA</li> <li>• Graiguenamanagh AFA</li> <li>• Leighlinbridge AFA</li> <li>• Monasterevin AFA</li> <li>• Mountmellick AFA</li> <li>• New Ross AFA</li> <li>• Portarlinton AFA</li> <li>• Portlaoise AFA</li> <li>• Rathangan AFA</li> <li>• Suncroft AFA</li> </ul>	UoM	Final	16/06/2016

#### 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

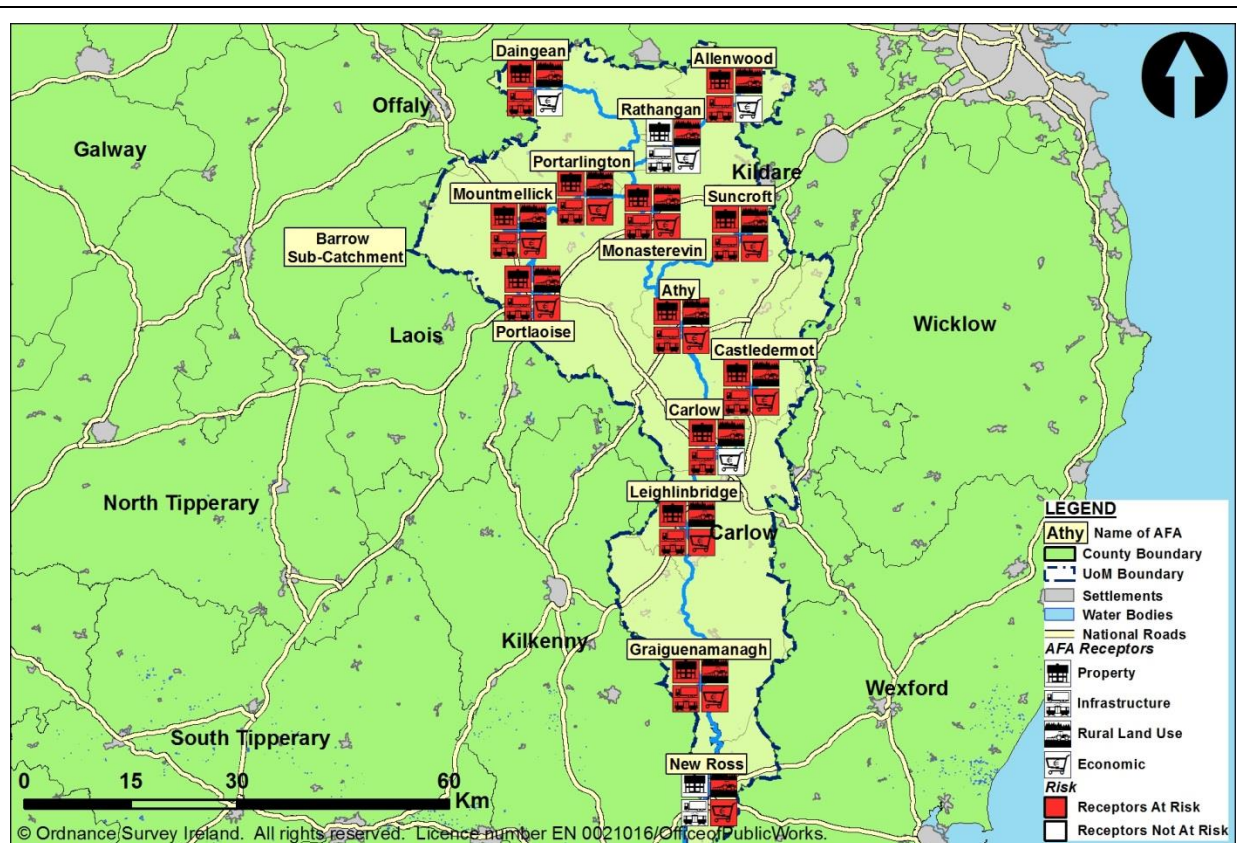


Figure 8.1.1 UoM14 Flood Risk during a 1% AEP Fluvial Flood Event

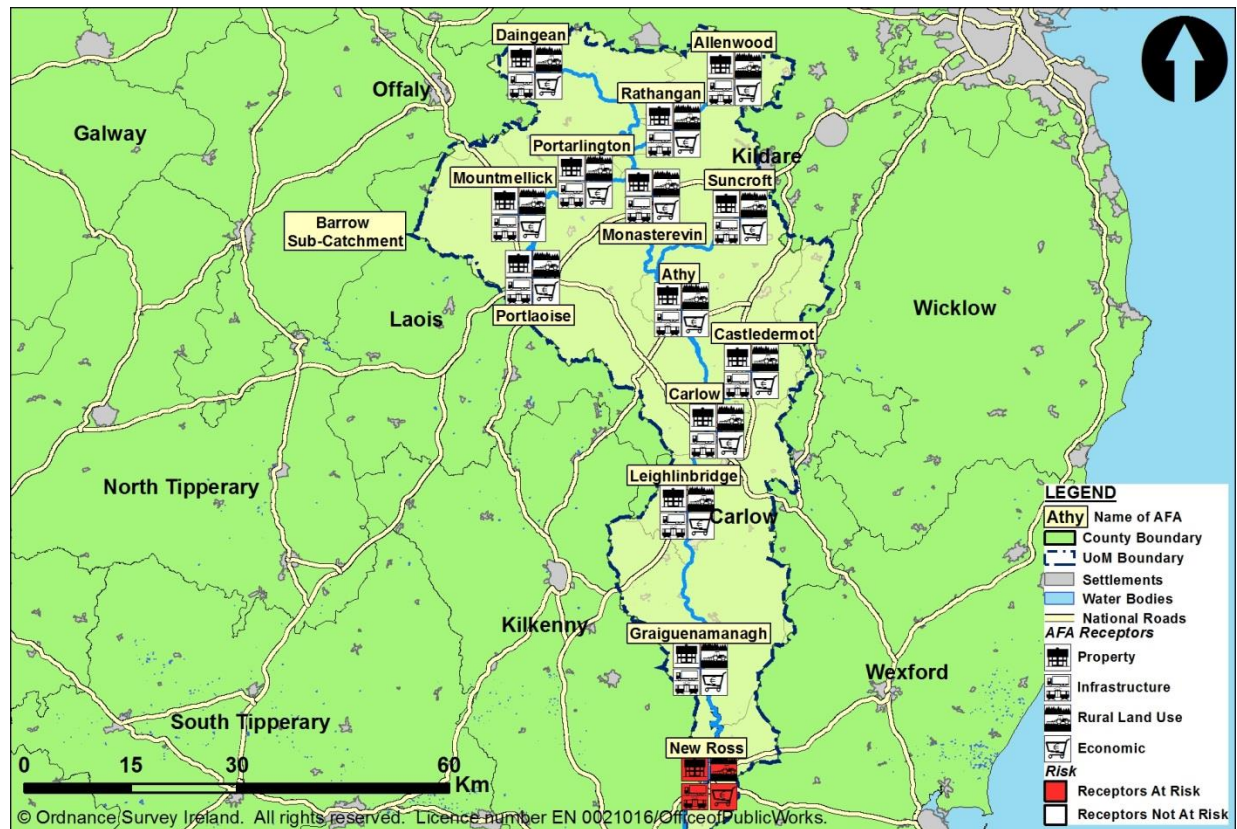


Figure 8.1.2 UoM14 Flood Risk during a 0.5% AEP Coastal Mechanism 1 Flood Event

Figures 8.1.1 and 8.1.2 summarise the flood risk on the main economic activities within UoM14. During a 1% AEP fluvial flood event residential properties are affected within all AFAs with the exception of Rathangan and New Ross. Infrastructure is affected within all AFAs with the exception of Rathangan and New Ross. Economic activities are affected within all AFAs with the exception of Daingean, Allenwood, Rathangan and Carlow.

During a 0.5% AEP coastal flood event (mechanism 1) residential properties, infrastructure, economic activities and rural land are affected within the New Ross AFA.

In Graiguenamanagh, Leighlinbridge, Portarlinton, New Ross and Suncroft AFAs the onset of non-residential property damage occurs in the 50% AEP event and in Castledermot AFA damage commences in the 10% AEP event, in Athy, Monasterevin and Mountmellick AFAs damage first occurs in the 2% AEP event and in Portlaoise AFA damage first occurs in the 1% AEP event.

In Athy, Graiguenamanagh, Portarlinton and Suncroft AFAs the onset of residential property damage occurs in the 50% AEP event and in Castledermot and New Ross AFAs damage commences in the 10% AEP event, in Daingean and Monasterevin AFAs damage first occurs in the 5% AEP event, in Leighlinbridge and Portlaoise AFAs damage first occurs in the 2% AEP even and in Allenwood, Carlow and Mountmellick AFAs damage first occurs in the 1% AEP event.

There is no damage to properties in Rathangan AFA during a 1% AEP event.



**8.1.3 Monetary Benefit Within the AFAs in UoM14**

	Athy AFA	Carlow AFA	Castledermot AFA	Daingean AFA	Graiguenamanagh AFA
Annual Average Damage (AAD)	€1,409,463	€394,872	€79,821	€3,451	€1,672,771
Present Value Damage (pvD)	€30,278,083	€8,482,650	€1,714,722	€74,134	€35,934,469
Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP	1% AEP	1%AEP
Number of Properties Benefiting from Design SoP	99	35	18	9	64
Minimum Present Value Benefit	€28,031,926	€1,446,270	€1,159,408	€38,322	€ 34,049,882
Capped Minimum Present Value Benefit	€13,544,560	€846,524	€1,140,087	€38,322	€ 10,260,826

	Leighlinbridge AFA	Monasterevin AFA	Mountmellick AFA	Portarlinton AFA	Portlaoise AFA
Annual Average Damage (AAD)	€1,349,944	€19,729	€899,092	€1,213,295	€311,012
Present Value Damage (pvD)	€28,999,499	€423,815	€19,096,465	€26,063,992	€6,681,152
Standard of Protection (SoP)	1%AEP	1% AEP	1% AEP	1%AEP	1%AEP
Number of Properties Benefiting from Design SoP	57	13	45	144	76
Minimum Present Value Benefit	€27,275,124	€284,593	€16,025,706	€22,109,882	€3,440,673
Capped Minimum Present Value Benefit	€3,905,896	€284,593	€4,717,397	€13,624,398	€3,335,332

	Allenwood AFA	New Ross AFA	Rathangan AFA	Suncroft AFA
Annual Average Damage (AAD)	€1,752	€72,771	€0	€142,578
Present Value Damage (pvD)	€37,636	€1,563,273	€0	€3,062,863
Standard of Protection (SoP)	1%AEP	1% AEP	1%AEP	1% AEP
		0.5% AEP		
Number of Properties Benefiting from Design SoP	2	0	0	23
		0		
Minimum Present Value Benefit	€8,306	€0	€0	€2,731,561
		€0		
Capped Minimum Present Value Benefit	€8,306	€0	€0	€2,166,455
		€0		



Fluvial risk



Coastal Mechanism 1



Coastal Mechanism 2

**8.1.4 Monetary Damage for Present Day and Future Scenarios Within the AFAs in UoM14**

	Athy AFA	Carlow AFA	Castledermot AFA	Daingean AFA	Graiguenamanagh AFA
AAD (present day scenario)	€1,409,463	€394,872	€79,821	€3,451	€1,672,771
AAD (MRFS)	€1.43million	€5,398,701	€230,230	€286,358	€2,168,743
AAD (HEFS)	€11.03million	€20,956,849	€579,130	€341,375	€4,771,919

	Leighlinbridge AFA	Monasterevin AFA	Mountmellick AFA	Portarlinton AFA	Portlaoise AFA
AAD (present day scenario)	€1,349,944	€19,729	€899,092	€1,213,295	€311,012
AAD (MRFS)	€2,412,518	€117,792	€2,050,108	€12,853,496	€1,501,275
AAD (HEFS)	€5,246,985	€577,520	€5,644,723	€25,016,743	€9,207,326

	Allenwood AFA	New Ross AFA	Rathangan AFA	Suncroft AFA
AAD (present day scenario)	€1,752	€72,771	€0	€142,578
AAD (MRFS)	€2,265	€2,244,762	€25	€350,061
AAD (HEFS)	€204,737	€27,090,956	€40,662	€691,183

### 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**

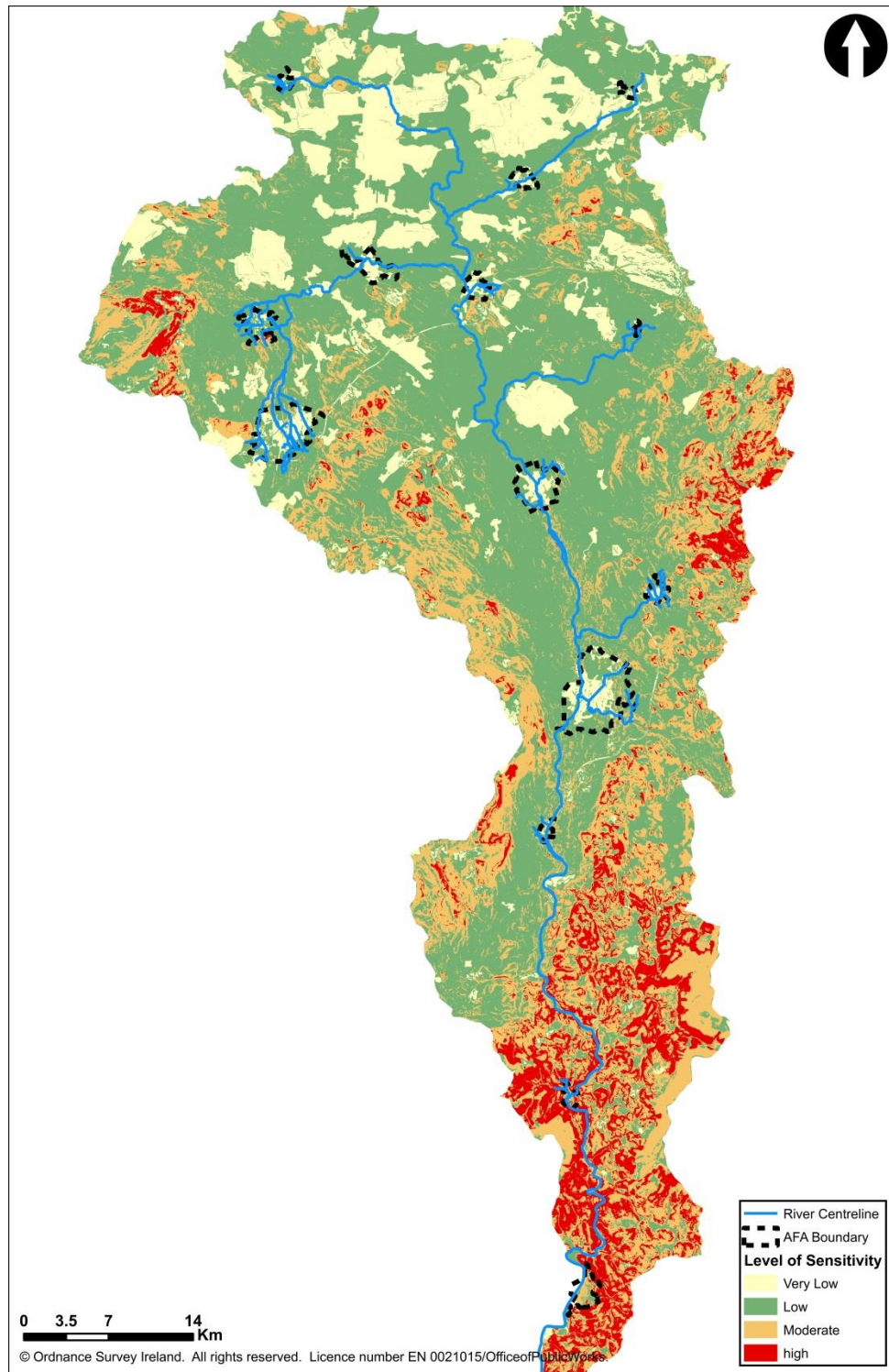
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage Screening	Social Screening
Planning and Development Control	✓	✓	✓	✓
Building Regulations	✓	✓	✓	✓
Sub-catchment Wide SuDs	✓	✓	✓	✓
Land Use Management	✓	✓	✓	✓
Strategic Development Management	✓	✓	✓	✓
Flood Warning/Forecasting	✓	✓	✓	✓
Public Awareness Campaign	✓	✓	✓	✓
✗ - Reject    ✓ - Progress    ? - Progress, potential impacts identified    for ! - 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 UoM14.				
Method	Tech	Econ	Env	Soc
Building Regulations	✓	✓	✓	✓
This method manages future flood risk for new development and is applicable throughout UoM14.				
Method	Tech	Econ	Env	Soc
Sub-catchment Wide SuDs	✓	✓	✓	✓
This method manages future flood risk for new development and is applicable throughout UoM14.				
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 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 UoM14. Figure 8.1.3 shows the output of Land Use Management screening for UoM14. The output largely shows UoM14 is unsuitable for Land Use Management methods with the exception of a southerly portion of the UoM. 13.4% of the 3,025km<sup>2</sup> catchment was classed as Very Low sensitivity to reducing runoff, 53.5% was classed as Low sensitivity, 24.8% was classed as Moderate sensitivity and 8.3% was classed as High sensitivity.



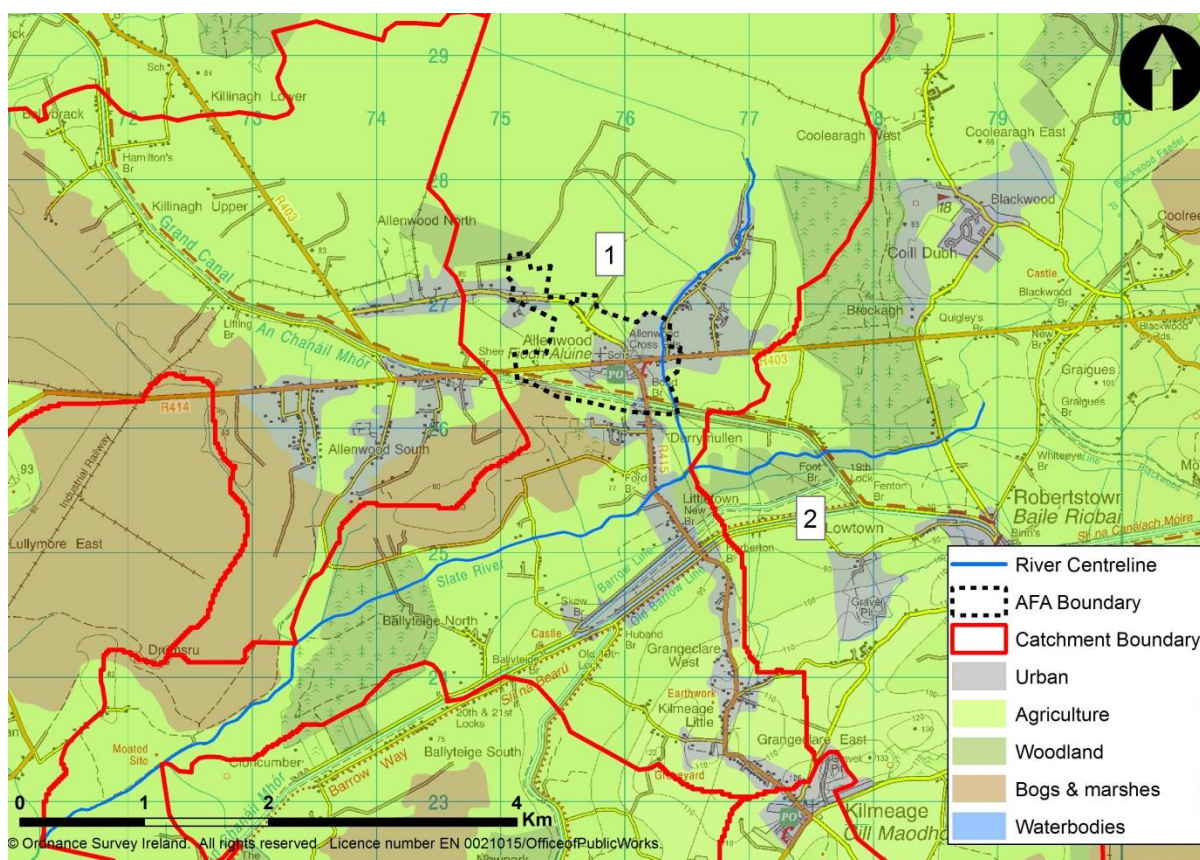
**Figure 8.1.3 UoM14 Land Use Management Screening Results**



This method is not feasible at UoM SSA, nor for any UoM14 Sub-catchments, 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.

### Allenwood AFA

The Allenwood AFA spans across 2 sub-catchments as shown in Figure 8.1.7. All the properties at risk during a 1% AEP fluvial flood event are located in sub-catchment 1; the sub-catchment area was calculated to be  $14.4\text{km}^2$ . The land use is found to be predominantly agricultural and the sub-catchment is classified as very low sensitivity for reducing runoff, see Figure 8.1.3. Also the Allenwood sub-catchments are relatively level throughout.

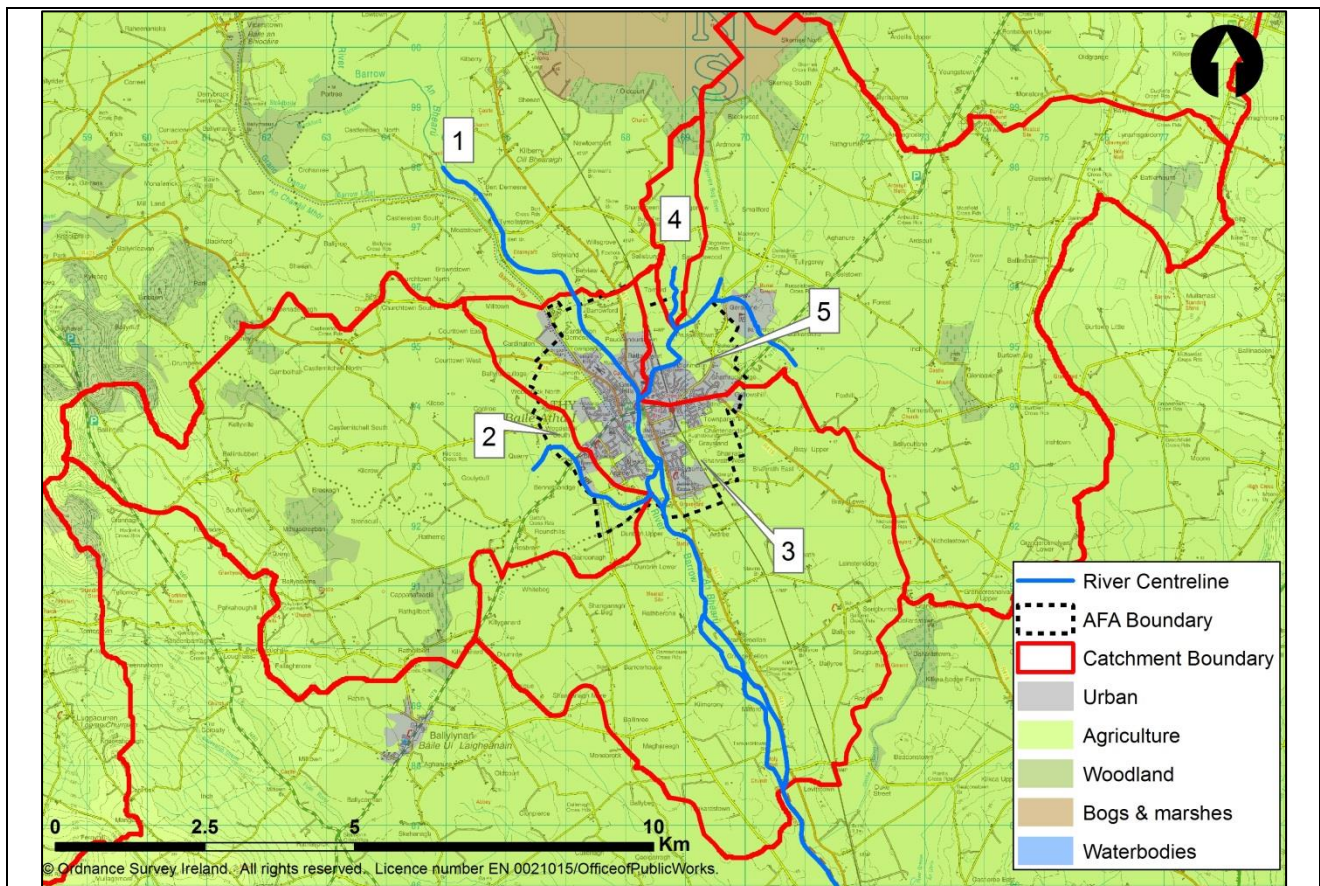


**Figure 8.1.4 Land use of Allenwood catchments**

The characteristics of sub-catchment 1 do not provide favourable conditions to make land use management an effective method in managing the flood risk. Although the land use is largely agricultural, the sensitivity to reducing runoff and the topography indicate that this area is not suitable. Therefore this method was rejected from the screening process.

### Athy AFA

The Athy AFA spans across 5 catchments as shown in Figure 8.1.7. All the properties at risk during a 1% AEP fluvial flood event are located in catchments 3 and 5; the catchment areas are approximately  $44.4\text{km}^2$  and  $51.9\text{km}^2$  respectively. The Athy urbanised area is divided between catchments 2, 3 and 5. The remaining surrounding area is predominantly agricultural. The Athy catchment terrain is relatively level throughout, with the terrain only becoming elevated at the western edge of catchment 2.



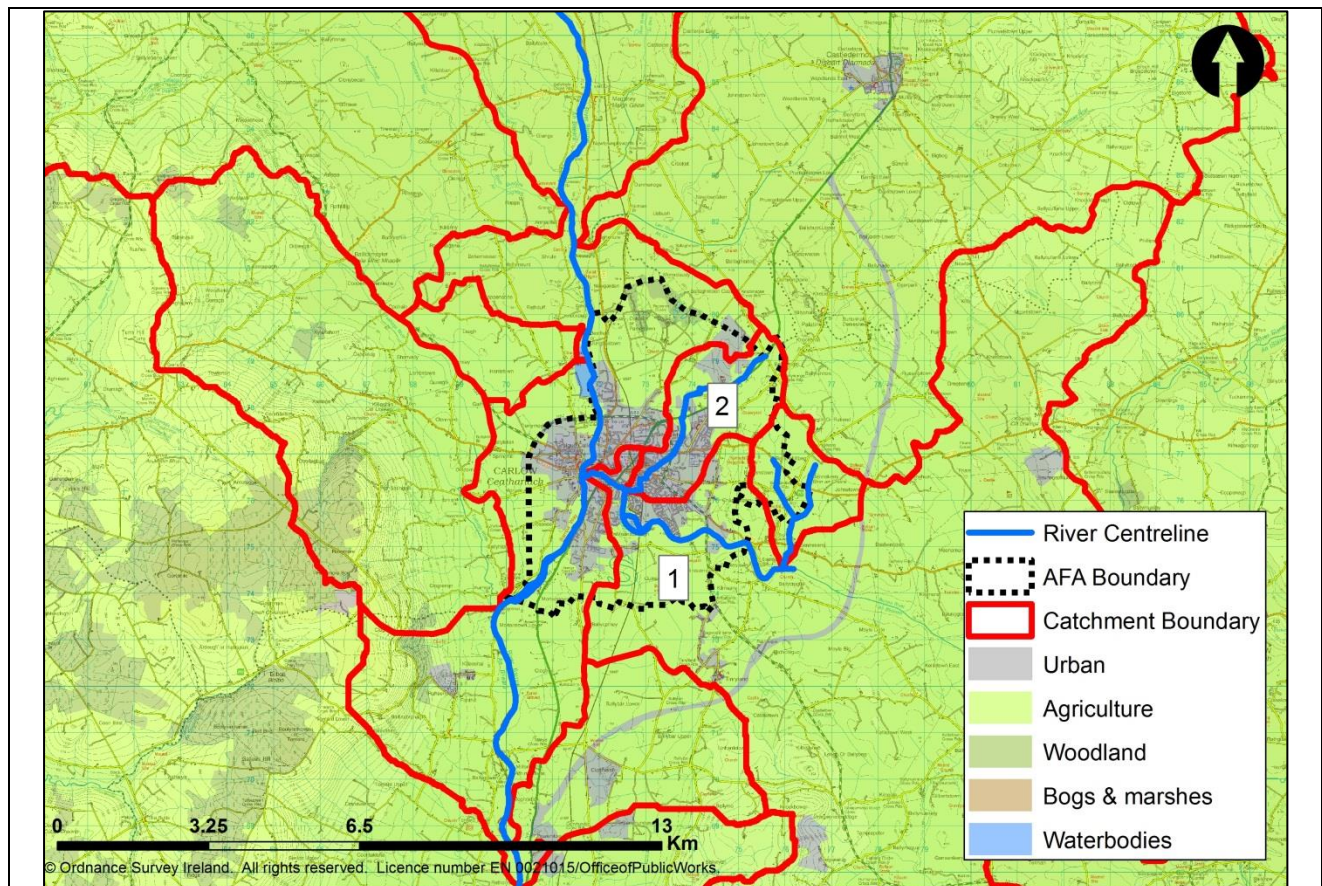
**Figure 8.1.5 Land use of Athy catchments**

Although, the characteristics of the surrounding Athy catchments provide favourable conditions in terms of effective land use management and subsequent flood risk amelioration. The spatially large-scale ( $>24\text{km}^2$ ) associated with the Athy catchments would require a large number of NFM features to make the method effective. This would therefore be a technically complex method to apply and monitor, with a large number of stakeholders and land owners to liaise with potentially making implementation of this method difficult. Consequently the Athy AFA and surrounding catchments were screened out as being unsuitable as a pilot study.

#### **Carlow AFA**

The Carlow AFA spans across 4 catchments as shown in Figure 8.1.7. All the properties at risk during a 1% AEP fluvial flood event are located in catchments 1 and 2; these catchment areas were calculated to be  $180.7\text{km}^2$  and  $6.3\text{km}^2$  respectively. Land use within catchment 1 is mainly agricultural, while urbanisation predominates catchment 1. The Carlow catchment terrain is relatively level throughout.





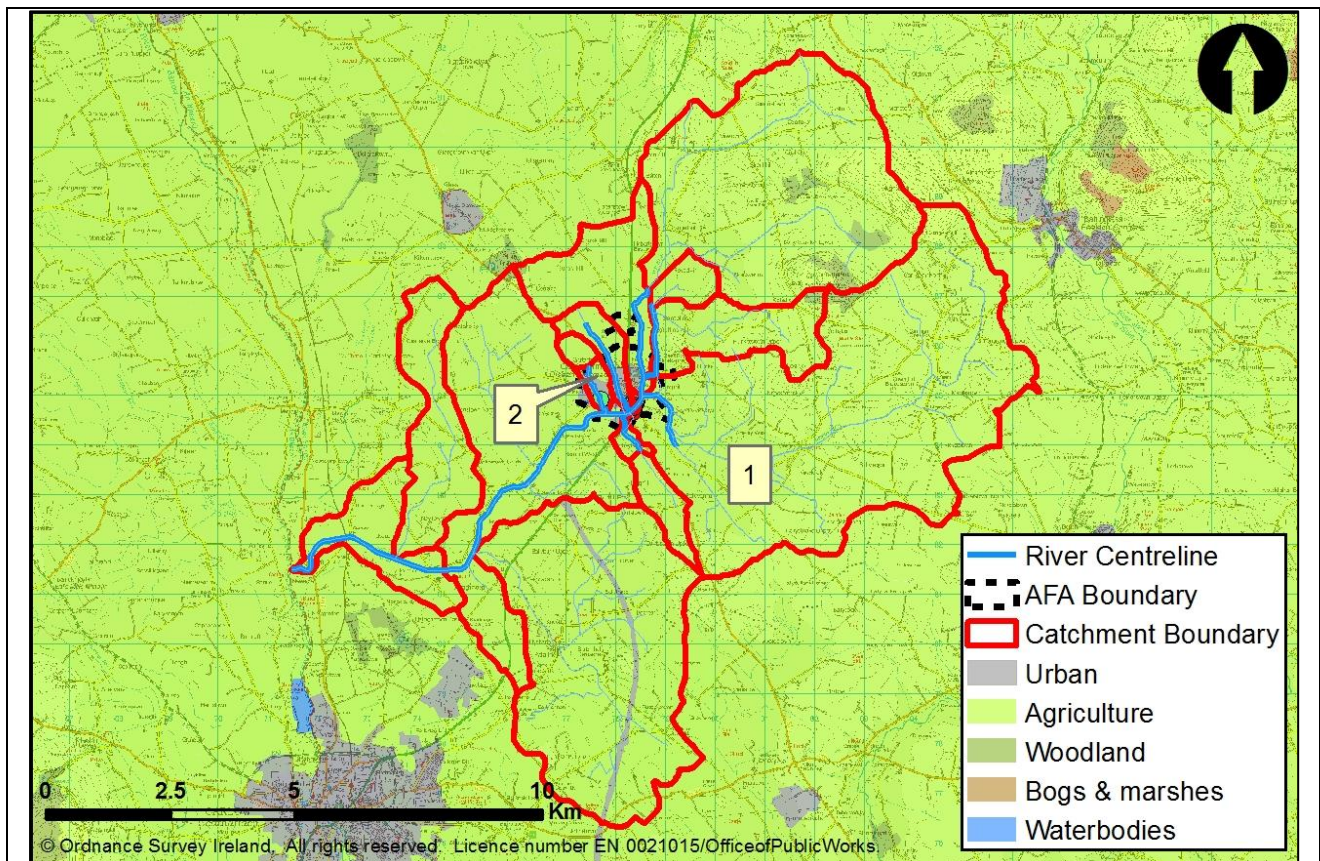
**Figure 8.1.6 Land use of Carlow catchments**

The spatially large-scale ( $>24\text{km}^2$ ) associated with the Carlow catchment 1 would require a large number of NFM features to make the method effective. This would be a technically complex method to apply and monitor and the large number of stakeholders and land owners to liaise with would make implementation of this method difficult. Although, catchment 2 would be favourable in terms of spatial scale, the predominance of urbanisation within this catchment would render land use management unfeasible. Considering that there would be little benefit in the application of land use management for flood risk amelioration, the Carlow AFA and surrounding catchments were screened out for this method.

#### **Castledermot AFA**

The Castledermot AFA spans across 14 catchments as shown in Figure 8.1.7. All the properties at risk during a 1% AEP fluvial flood event are located in catchments 1 and 2; the catchment areas were calculated to be  $31.4\text{km}^2$  and  $0.9\text{km}^2$  respectively. The land use is found to be predominantly agricultural although some significant urban areas are identified in some catchments, particularly catchments 2. The Castledermot catchments are generally steeper in the upper catchments and become flatter in the urbanised areas within the AFA where the at risk properties are located.





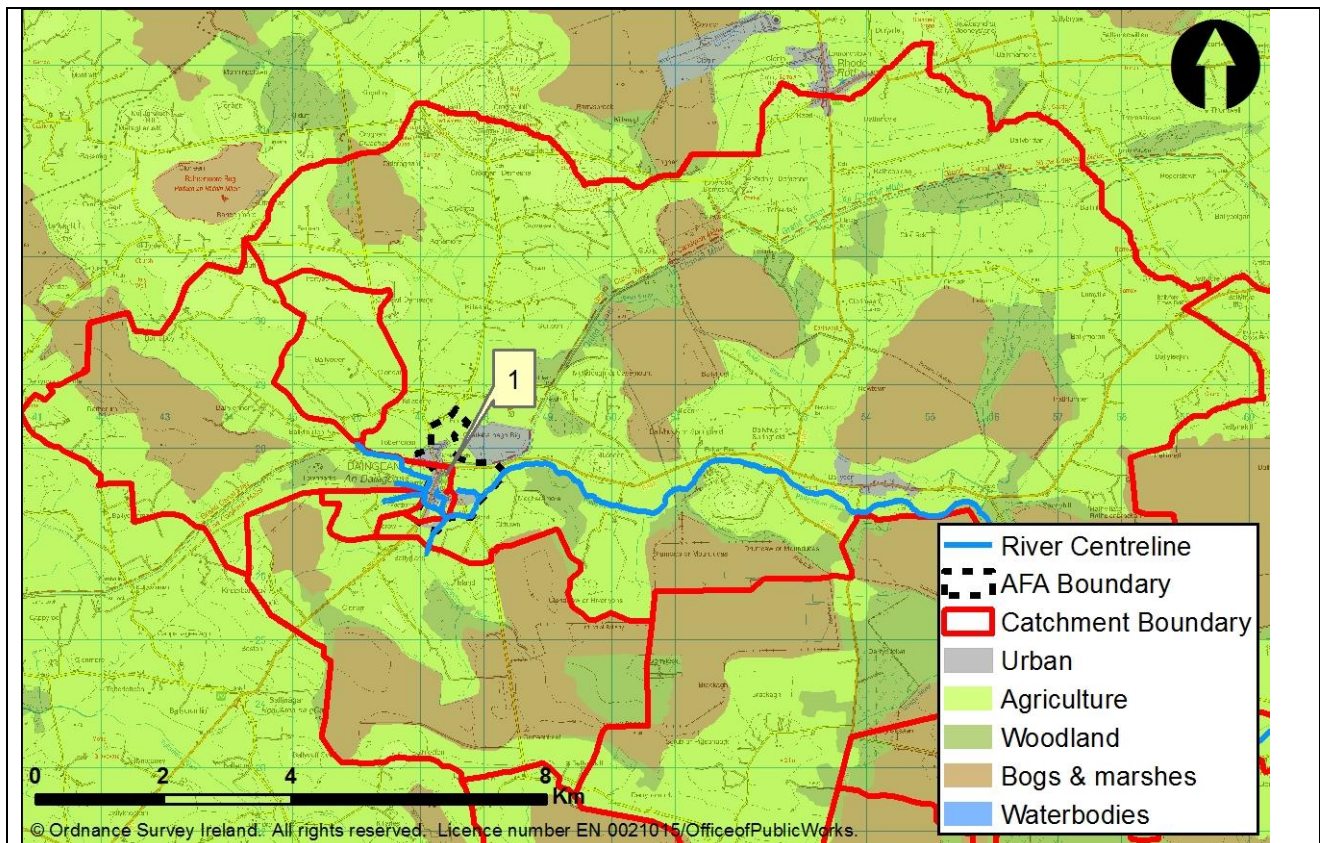
**Figure 8.1.7 Land use of Castledermot catchments**

The characteristics of the Castledermot catchments provide favourable conditions to make land use management an effective method in managing the flood risk. However the scale of the catchments in Castledermot would make this method technically complex if it was taken forward as a pilot study as a substantial number of techniques would have to be adopted in order to achieve the required peak flow reduction. The number of stakeholders involved would also be high due to the number of landowners involved. This catchment is not considered suitable and therefore this method was rejected from the screening process.

#### **Daingean AFA**

The Daingean AFA spans across 6 catchments shown in Figure 8.1.8. All the properties at risk during a 1% AEP fluvial flood event are located in catchment 1. The area of this catchment was calculated to be approximately 18.4km<sup>2</sup>. Land use within all the surrounding catchments is mainly agricultural, with large areas of bogs and marshes. There is also a significant urban area identified in catchment 1. The Daingean catchments are generally steeper in the upper catchments and become flatter in the urbanised areas within the AFA where the at risk properties are located.





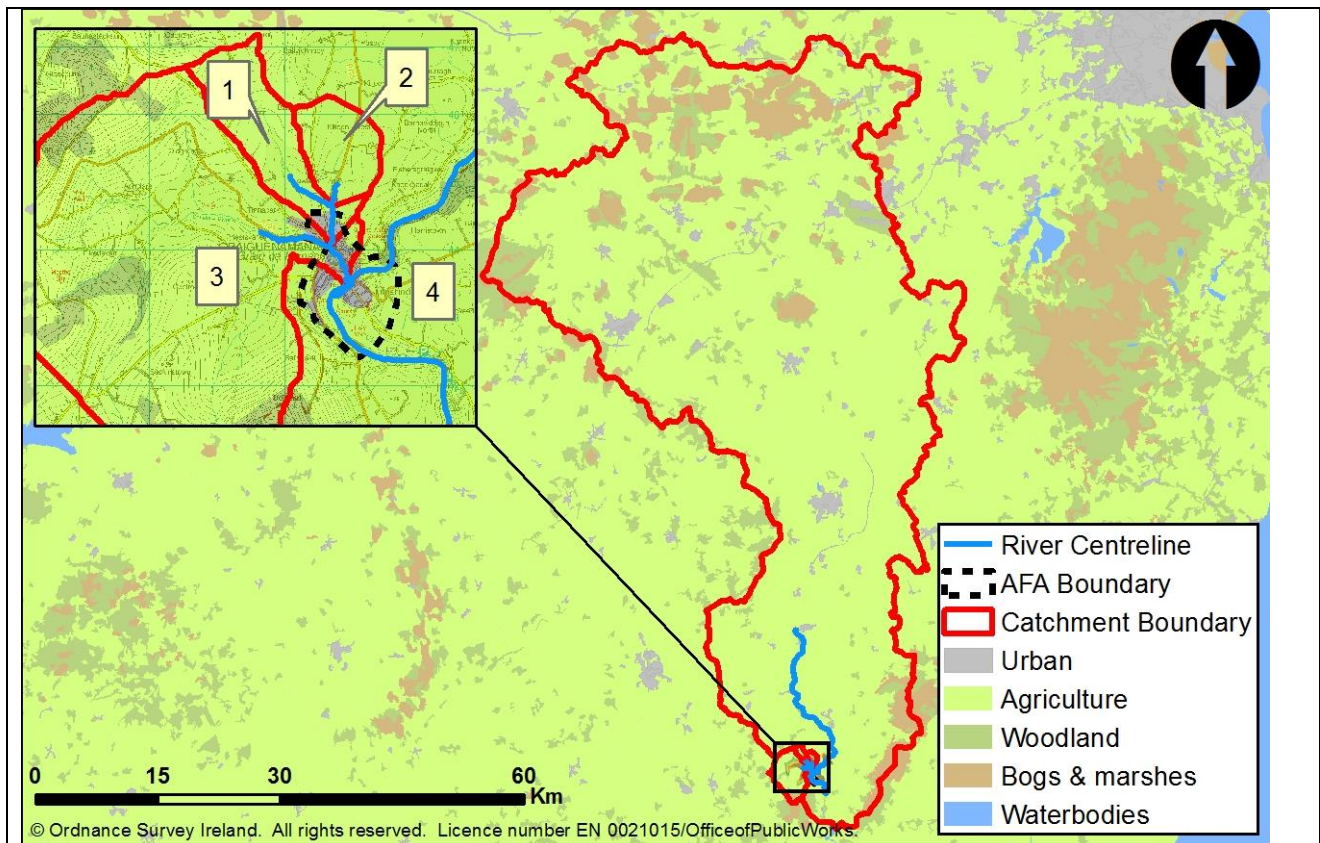
**Figure 8.1.8 Land use of Daingean catchments**

The land use management works could potentially impact on the environmental designations within the vicinity of the AFA, however these are not hydraulically linked to the AFA. There are no UNESCO World Heritage Sites in the vicinity of, or directly downstream of the AFA. There is also the potential for changing or disrupting land use practices either temporarily or permanently to have social impacts. However with due consideration of the environmental and social factors, land use management can progress through the screening.

The characteristics of the Daingean catchments provide mostly favourable conditions to make land use management an effective method in managing the flood risk. Progressing Land Use Management in a pilot area should not take precedence over other methods which will provide the design SoP. This method should be progressed only if all other methods are found unsuitable.

#### **Graiguenamanagh AFA**

The Graiguenamanagh AFA spans across 4 catchments as shown in Figure 8.1.9. The majority of properties at risk during a 1% AEP fluvial flood event are located in catchments 3 and 4; the areas of these catchments were calculated to be 24.59km<sup>2</sup> and 2873km<sup>2</sup> respectively. The land use was found to be predominantly agricultural, although some significant urban areas were identified in catchments 1 and 3. The Graiguenamanagh catchments are generally steeper in the upper catchments and become flatter in the urbanised areas within the AFA where the at risk properties are located.



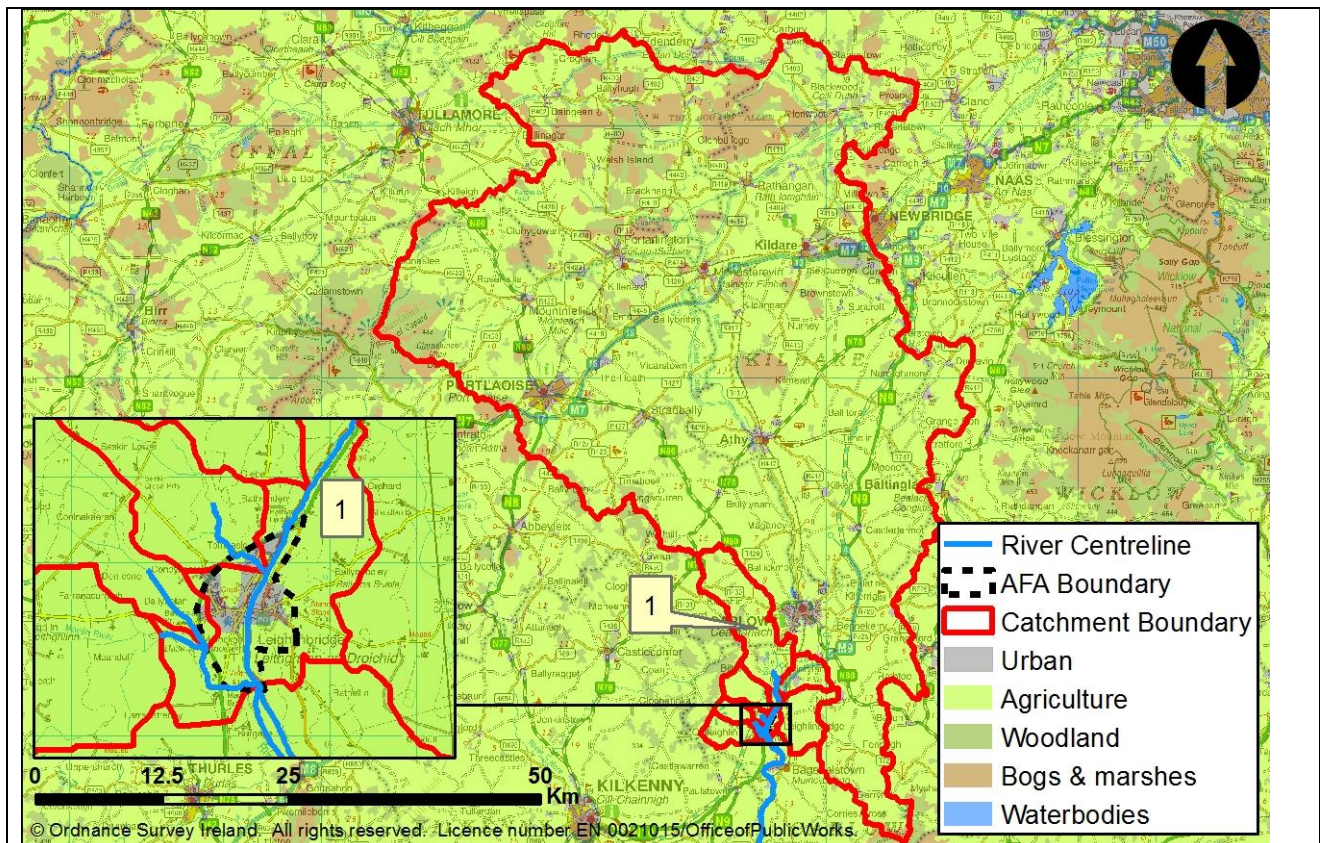
**Figure 8.1.9 Land use of Graiguenamanagh catchments**

The characteristics of the Graiguenamanagh catchments provide favourable conditions to make land use management an effective method in managing the flood risk. The spatial scale of the catchments in Graiguenamanagh would make this method technically complex if it was taken forward as a pilot study as a substantial number of techniques would have to be adopted in order to achieve the required peak flow reduction. The number of stakeholders involved would also be high due to the number of landowners involved. This catchment is not considered suitable and therefore this method was rejected from the screening process.

#### **Leighlinbridge AFA**

The Leighlinbridge AFA spans across 8 catchments as shown in Figure 8.1.10. All the properties at risk during a 1% AEP fluvial flood event are located in catchment 1; the catchment area was calculated to be 65.78km<sup>2</sup>. The land use was found to be predominantly agricultural although some significant urban areas were identified in some catchments, particularly catchment 1. The Leighlinbridge catchments are generally steeper in the upper catchments and become flatter in the urbanised areas within the AFA where the at risk properties are located.





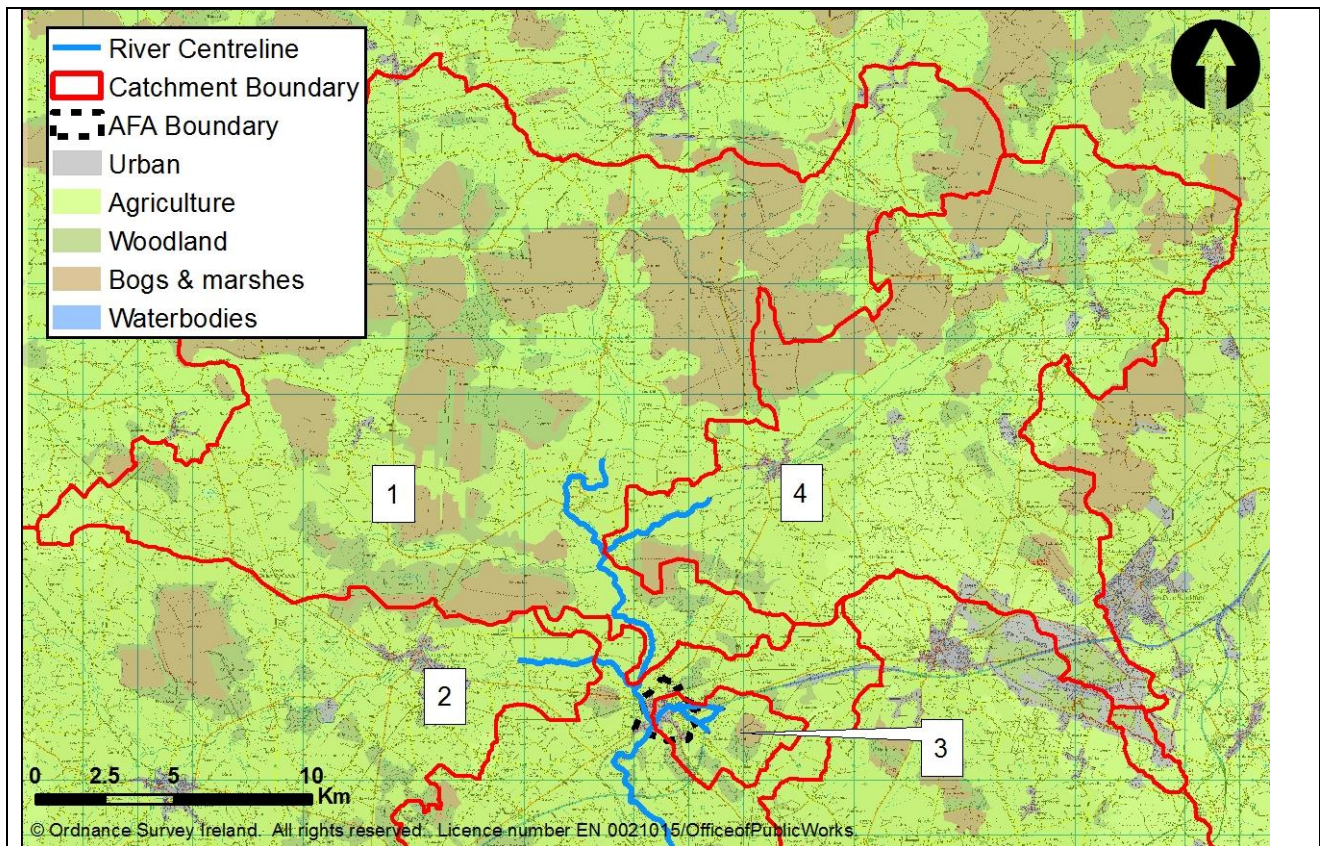
**Figure 8.1.10 Land use of Leighlinbridge catchments**

The characteristics of the Leighlinbridge catchments provide favourable conditions to make land use management an effective method in managing the flood risk. The spatial scale of catchment 1 in Leighlinbridge would make this method technically complex if it was taken forward as a pilot study as a substantial number of techniques would have to be adopted in order to achieve the required peak flow reduction. The number of stakeholders involved would also be high due to the number of landowners involved. This catchment is not considered suitable and therefore method was rejected from the screening process.

### **Monasterevin AFA**

The Monasterevin AFA spans across 4 catchments as shown in Figure 8.1.11. The properties at risk during a 1% AEP fluvial flood event are located in catchments 1 and 3; the areas of these catchments were calculated to be 16.5km<sup>2</sup> and 642.6km<sup>2</sup> respectively. The land use was found to be predominantly bog and agricultural, with some significant urban areas identified in catchment 3. The Monasterevin catchments are relatively flat throughout the catchment which is indicative of a bog land landscape.





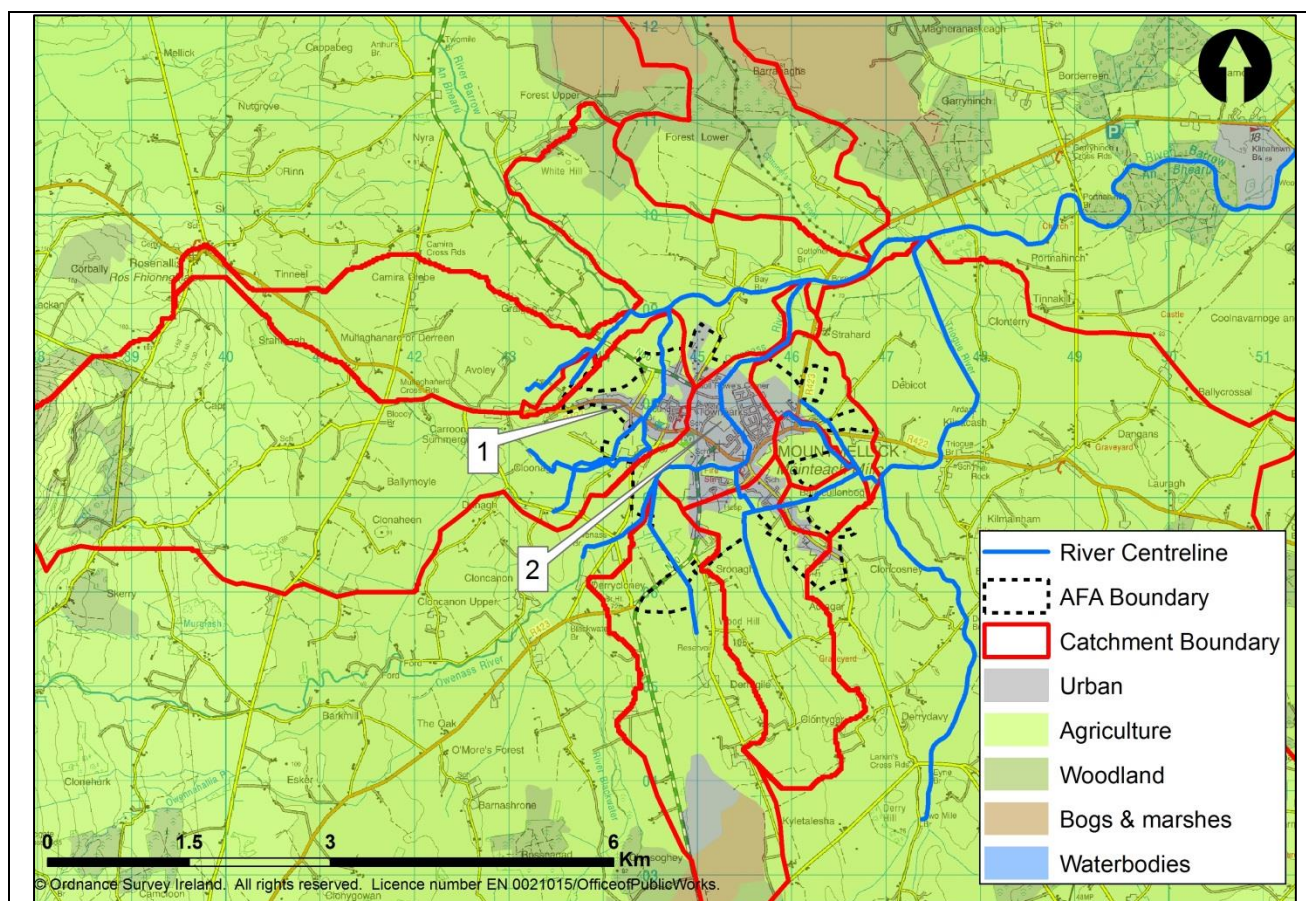
**Figure 8.1.11 Land use of Monasterevin catchments**

The characteristics of the Monasterevin catchments do not provide favourable conditions to make land use management an effective method in managing the flood risk. The spatial scale of catchment 1 would make this method technically complex and the bogs and marsh land are not conducive to employing land use methods for the purposes of flood risk management. Therefore these catchments were not considered suitable and this method was rejected from the screening process.

#### **Mountmellick AFA**

The Mountmellick AFA spans across 9 catchments shown in Figure 8.1.12. All the properties at risk during a 1% AEP fluvial flood event are located in catchments 1 and 2; these catchment areas were calculated to be 14km<sup>2</sup> and 83km<sup>2</sup> respectively. Land-use within catchments 1 and 2 is mainly agricultural, with areas of woodland located to the west of these catchments. The woodland is mainly located on the steep slopes towards the Slieve Bloom Mountains located to the SSW of Mountmellick. Overall, most of the topography associated with Mountmellick AFA and surrounding area is relatively flat and level.





**Figure 8.1.12 Land use of Mountmellick catchments**

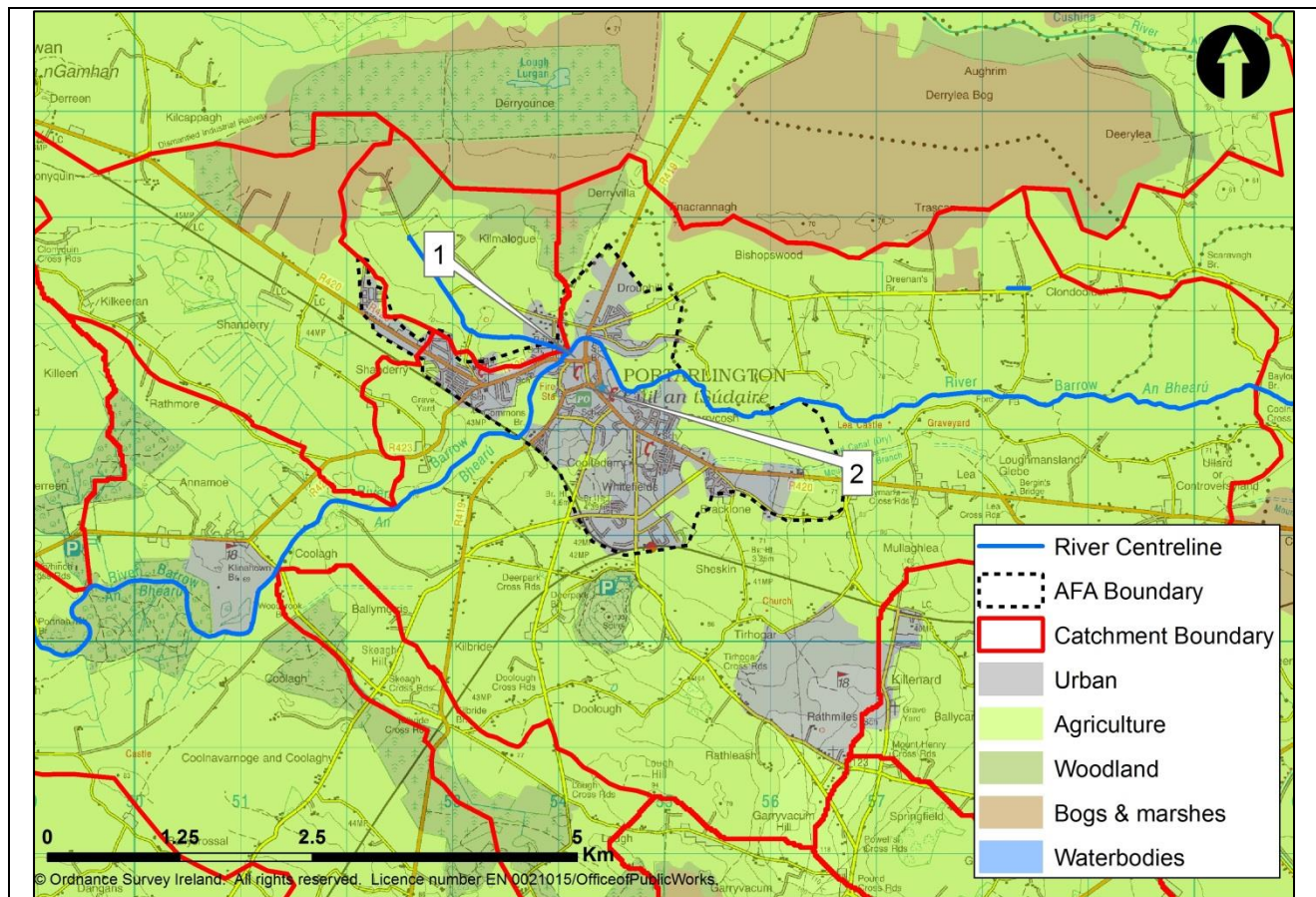
The favourable conditions outlined previously would render the application of land use management practices to Mountmellick catchment 1 as feasible. However, the spatially large-scale ( $>24\text{km}^2$ ) associated with Mountmellick catchment 2 would render this method technically complex, due to the proportional increase in the number of techniques required to achieve the desirable peak flow reduction. Further complications would be associated with the involvement of numerous stakeholders and landowners. Considering that there would be some benefit in the application of land use management in flood risk amelioration, it is recommended that Mountmellick AFA, and in particular the area that encompasses catchment 1 should proceed as a potential pilot study.

#### **New Ross AFA**

The Land Use Management FRM method is not applicable for the New Ross AFA as many of the at risk properties are at risk from coastal mechanism 1 flooding which would not be affected by such methods and a flood defence scheme has been designed to provide flood protection.

#### **Portarlington AFA**

The Portarlington AFA spans across 3 catchments shown in Figure 8.1.13. All the properties at risk during a 1% AEP fluvial flood event are located in catchments 1 and 2; these catchment areas were calculated to be approximately  $60\text{km}^2$  and  $3\text{km}^2$  respectively. Land use within catchments 1 and 2 is mainly agricultural, with an area of woodland and bog located to the north of catchment 1. The topography of both of these catchments is relatively level throughout.



**Figure 8.1.13 Land use of Portarlington catchments**

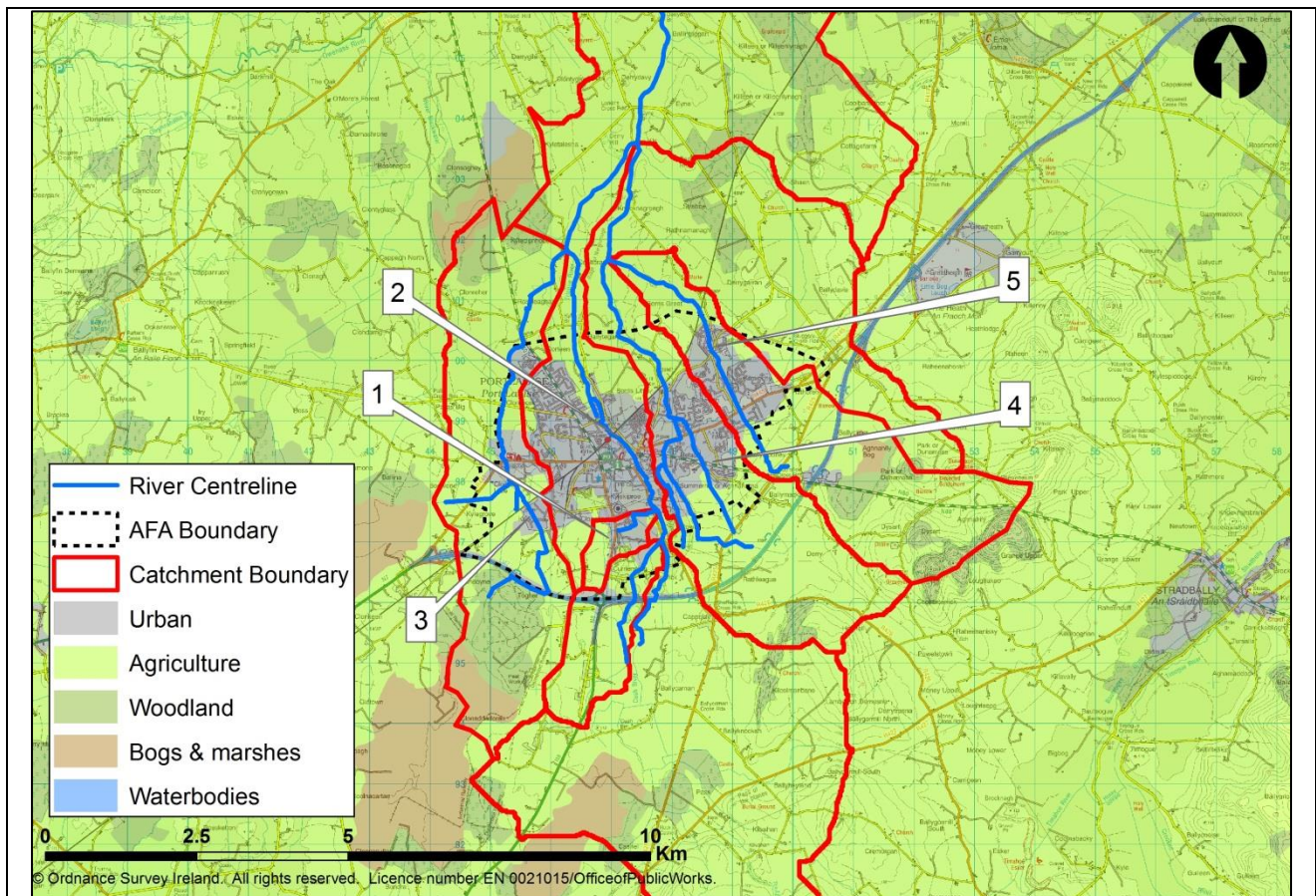
The size of catchment 1 would favour the implementation of land use measures, benefiting some of the properties at risk. Conversely, catchment 2 would be considered as large and consequently less favourable for the implementation of land use management measures, therefore, it is unlikely that land use management would benefit Portarlington AFA. In order for land use management to be of any benefit to Portarlington AFA, the entire Barrow sub-catchment would need to be considered. Since there is unlikely to be any benefit associated with the application of land use management in terms of flood risk amelioration at this scale, the Portarlington AFA was screened out as a potential pilot study.

### Portlaoise AFA

The Portlaoise AFA spans across 8 catchments as shown in Figure 8.1.14. All the properties at risk during a 1% AEP fluvial flood event are located in catchments 1 to 5 inclusive; catchment areas were calculated to be approximately 1km<sup>2</sup>, 117km<sup>2</sup>, 14km<sup>2</sup>, 34km<sup>2</sup> and 11 km<sup>2</sup> respectively.

Land use within all of these catchments is mainly agricultural, with the largest sections of urbanised area associated with catchment 2 and 4. Areas of woodland are mainly located to the north and southern end of catchment 3. Generally, the topography of these catchment areas is relatively flat, with the exception of catchments 4 and 5, which eventually rise up at the SSE corner of the catchment boundaries.





**Figure 8.1.14 Land use of Portlaoise catchments**

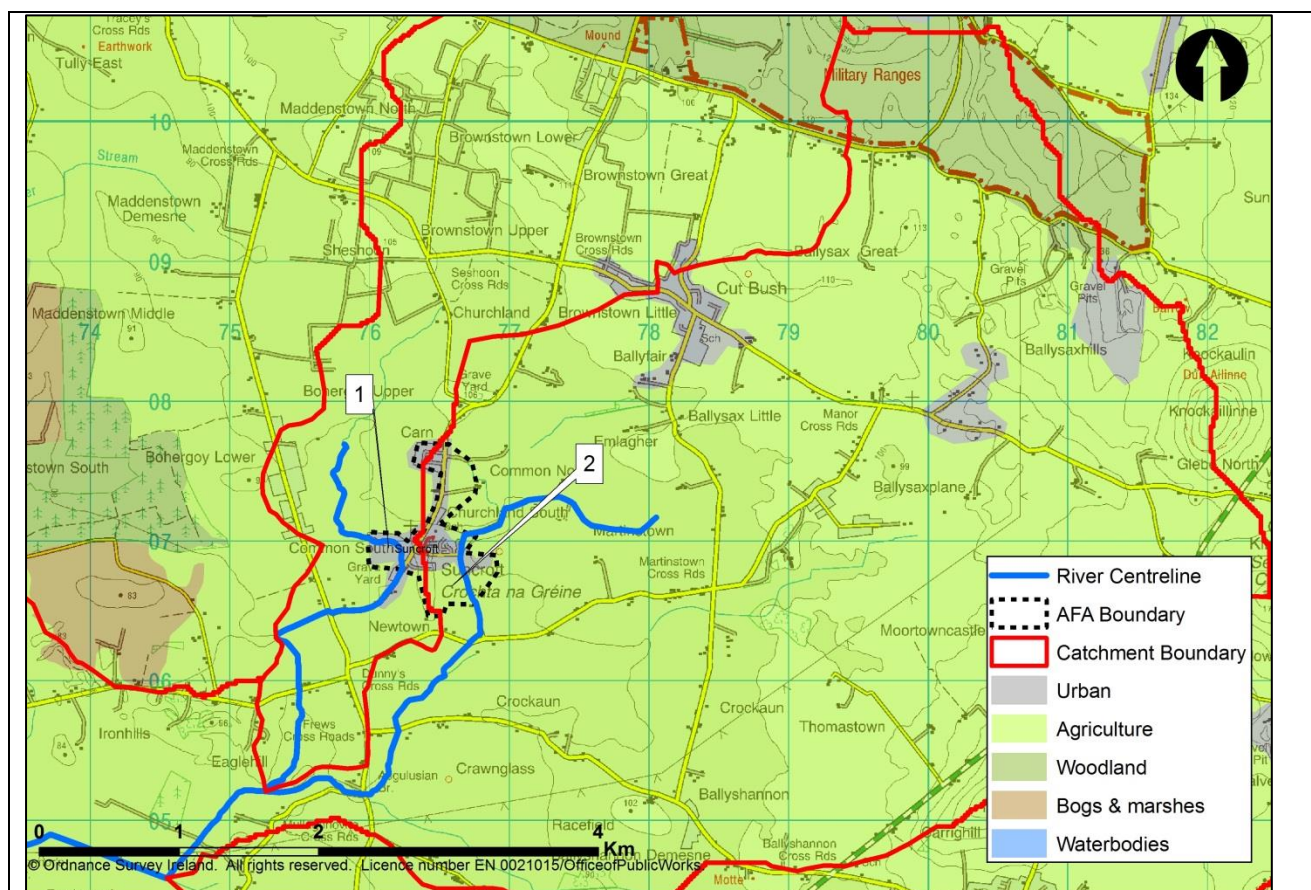
Although catchments 1, 3 and 5 are of a favourable size for applying land use management practices, the presence of large sectors of urbanisation, particularly within catchments 4 and 5 would potentially complicate the application of this FRM. Considering the large percentage of urban coverage associated with the Portlaoise AFA catchments and the likelihood of urban expansion, the Portlaoise AFA was considered unsuitable as a potential pilot study.

#### **Rathangan AFA**

The Land Use Management FRM method is not applicable in Rathangan AFA as no properties are at risk during the 1% AEP event within this AFA.

#### **Suncroft AFA**

The Suncroft AFA spans across 2 catchments as shown in Figure 8.1.15. The properties at risk due to fluvial flooding are located within catchment 1. In assessing the suitability of this catchment for land use management the following criteria was considered; the area of catchment 1 is 11km<sup>2</sup>; the land use for catchment 1 is predominantly agricultural, the topography of this catchment area consists of relatively flat land throughout, including the AFA area and the location of the risk properties.



**Figure 8.1.15 Land use of the Suncroft catchments**

While land use management methods can be applied to any catchment the characteristics of catchment 1 provides favourable conditions to make land use management an effective method in managing flood risk.

Land Use Management may offer some degree of benefit as a FRM method in the Suncroft AFA; therefore Suncroft AFA is recommended as a suitable location to pilot this method.

A summary table of the potential effectiveness of land use management for each AFA is provided in the summary section of this report.

Method	Tech	Econ	Env	Soc
Strategic Development Management	✓	✓	✓	✓
This method manages future flood risk for new development and is applicable throughout UoM14.				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✓	✓	✓	✓
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 the actual effectiveness being dependent on the warning time available. Where the warning period is greater than 12 hrs it is assumed that 10% of the				

flood damage can 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 UoM14. It is assessed in further detail at the AFA scale subject to the measures it is taken in combination with. The operational element cost at UoM scale can be spread across AFAs and the infrastructure may be mutually beneficial.

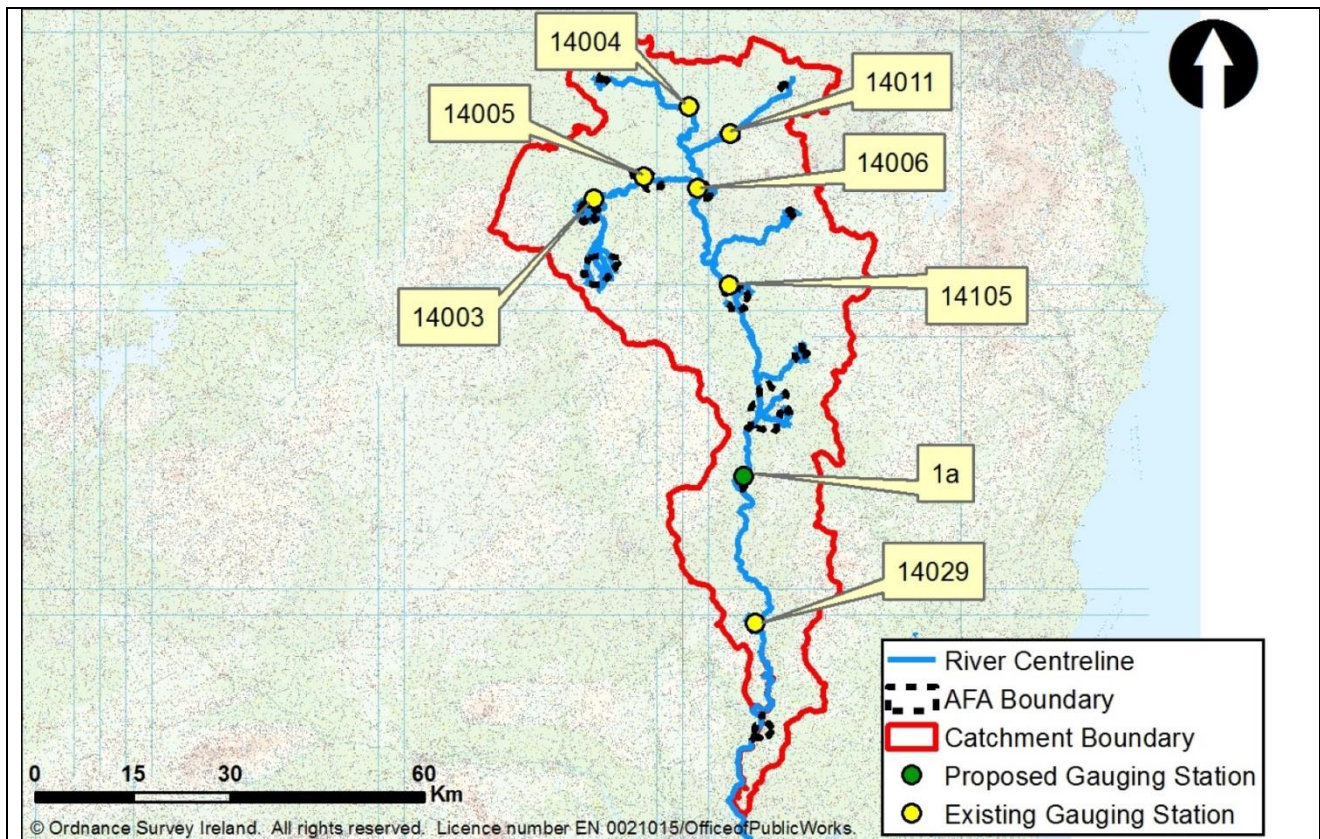
River gauge locations have been identified for each AFA within UoM14 where feasible. Increased forecasting accuracy may also be achieved by locating a series of rainfall gauges within each catchment at a density of approximately 1 per 100km<sup>2</sup>.

### **River Barrow**

A review was carried out as to where river gauges could be placed in UoM14 in order to provide flood warning to properties at risk from the River Barrow. Properties are at risk from the River Barrow in the Portarlinton, Monasterevin, Athy, Leighlinbridge, Graiguenamanagh and New Ross AFAs. The River Barrow becomes tidally influenced at St. Mullin's, downstream of Graiguenamanagh, so a fluvial forecasting system for New Ross would need to be combined with a tidal forecasting system. A decision on tidal forecasting will be taken at national level. Wexford County Council have confirmed there is an existing FRM scheme approved for the New Ross AFA and no optioneering is required.

There are a number of active gauging stations currently located in UoM14 and where possible it is recommended that these stations would be modified to provide real-time data for forecasting. Locating gauges close to the properties at risk increases 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 provides the maximum warning time. Figure 8.1.16 shows the locations of the existing and proposed new river gauges on the River Barrow. This includes a river gauge at the location of the first property at risk on each watercourse within the AFAs as well as gauges upstream of the properties at risk. This will allow for calibration, validation and fine tuning of the forecasting system.





**Figure 8.1.16 Location of proposed gauging stations on the River Barrow**

Gauging station 14005 is located adjacent to the first properties at risk on the River Barrow in the Portarlington AFA. Gauging station 14003 is located 10.5km upstream at Borness as shown in Figure 8.1.16. The Portarlington hydraulic model showed that the average speed of water travel along the River Barrow would be approximately 0.5m/s and therefore the travel time between gauges 14003 and 14005 would be approximately 6 hours.

Station 14006 is located 900m upstream of the first properties at risk on the River Barrow in the Monasterevin AFA, approximately 20.5km downstream of station 14003. The travel time between gauges 14003 and 14006 would therefore be approximately 11.5 hours.

Upstream of Monasterevin the Black River joins the River Barrow. In order to improve forecasting accuracy gauging stations would also be required in this catchment. Gauging station 14004 is located 18km upstream of Monasterevin on the Figile River at Clonbulloge and station 14011 is located 15km upstream of Monasterevin on the Slate River at Rathangan as shown in Figure 8.1.16. The Daingean and Rathangan hydraulic models showed that the average speed of water travel along the Figile and Slate Rivers would be approximately 0.25m/s and 0.3m/s respectively. The estimated travel times from gauges 14004 and 14011 to Monasterevin are therefore approximately 20 hours and 14 hours respectively. The warning time available from the Black River catchment is therefore greater than the warning time available from the River Barrow.

Station 14105 is located 1.7km upstream of the first properties at risk on the River Barrow in the Athy AFA, approximately 20.5km downstream of station 14006 at Monasterevin. The estimated travel time between Monasterevin and Athy is therefore estimated to be approximately 11.5 hours.

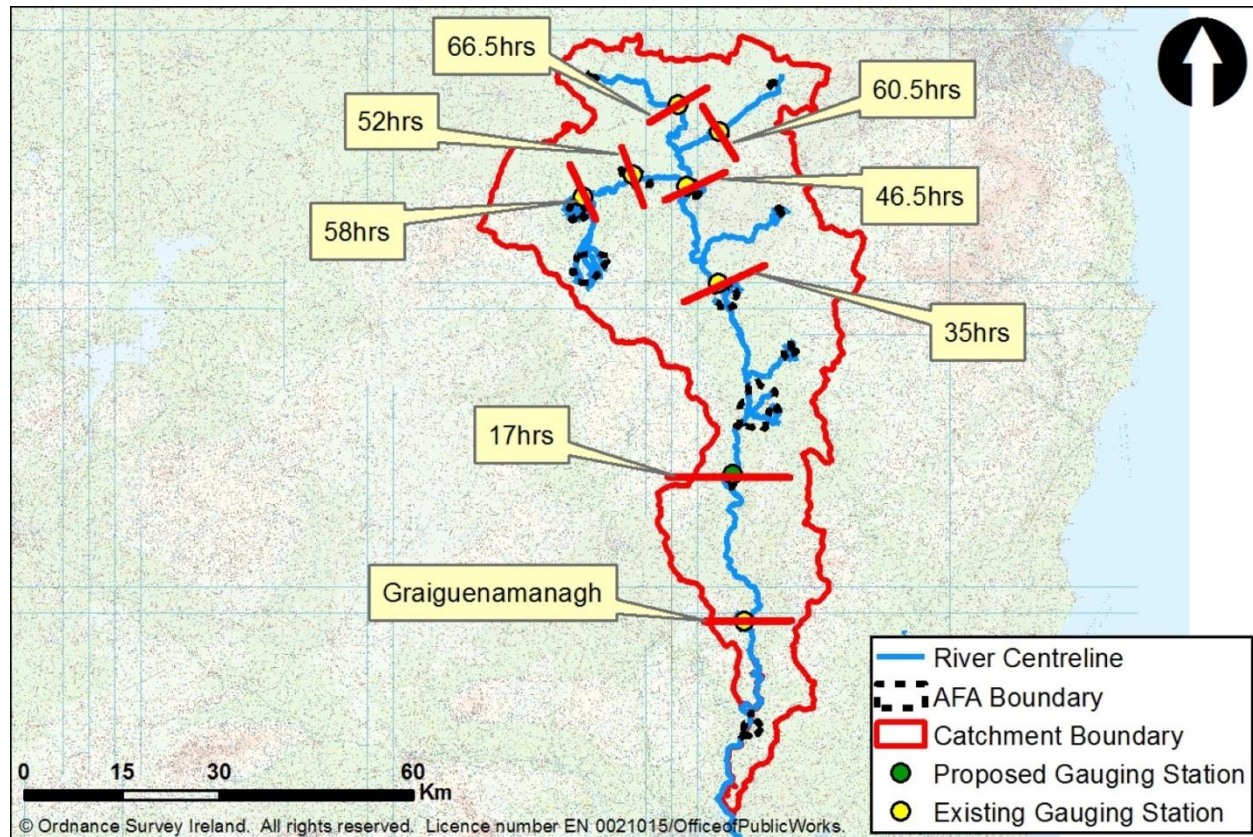
A new gauging station, labelled 1a on Figure 8.1.16, is also proposed on the River Barrow at Leighlinbridge adjacent to the first properties at risk. This proposed station is 32km downstream of station 14105 at Athy, and the estimated travel time between Athy and Leighlinbridge is approximately 18 hours.

Station 14029 is located adjacent to the first properties at risk on the River Barrow in the Graiguenamanagh AFA, approximately 30km downstream of proposed station 1a at Leighlinbridge. The estimated travel time



between Leighlinbridge and Graiguenamanagh is estimated to be approximately 17 hours.

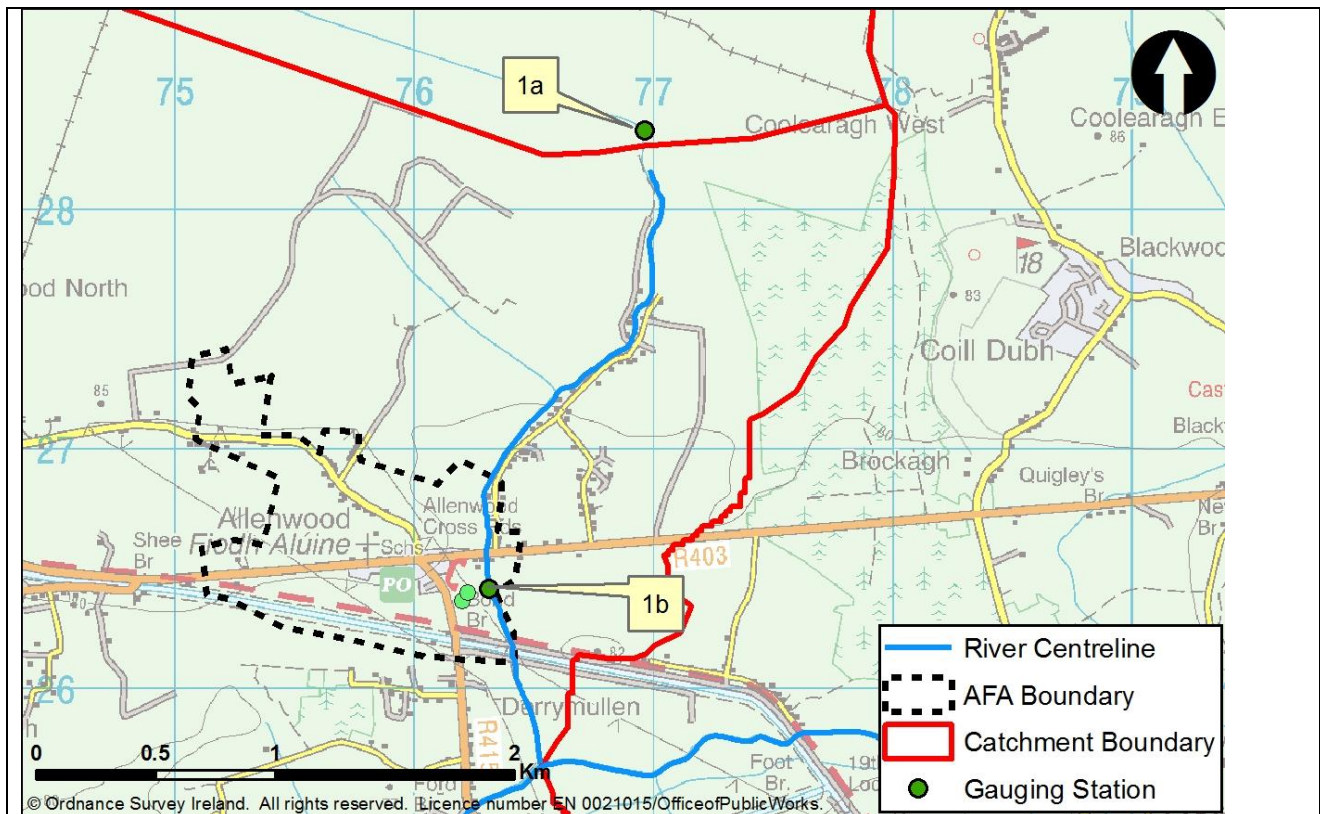
Flood warning/forecasting is therefore technically feasible for properties at risk from the River Barrow, providing between 6-58 hours warning time. Additional gauging stations are currently installed along the River Barrow at various locations and including these stations within a flood warning/forecasting system for the Barrow catchment would allow for additional calibration and improved accuracy. Figure 8.1.17 summarises the estimated warning time available for various locations along the Barrow catchment relative to Graiguenamanagh.



**Figure 8.1.17 Estimated warning time available relative to Graiguenamanagh**

### Allenwood AFA

A review was carried out as to where river gauges could be placed in order to provide flood warning to the properties at risk of fluvial flooding on the Coolearagh River. Figure 8.1.18 shows the location of the proposed new river gauging stations. Proposed gauging stations 1a and 1b are located on the Coolearagh River, approximately 1.4km upstream of the first properties at risk. Proposed gauging station 1b is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. The Allenwood hydraulic model showed that the average speed of water travel along the Coolearagh River would be 0.1m/s. The estimated travel time between proposed gauges 1a/1b and the properties at risk would therefore be approximately 6 hours.



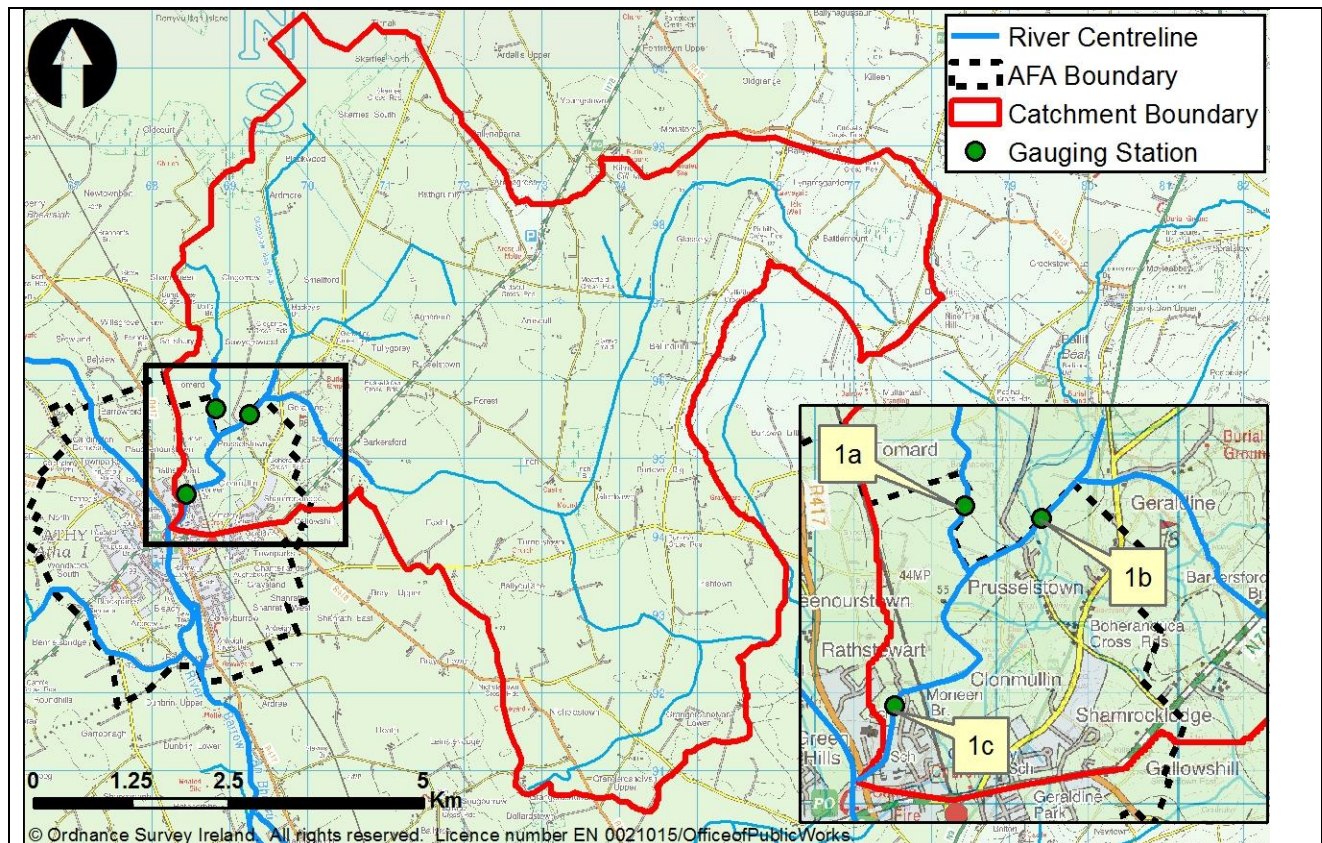
**Figure 8.1.18 Location of proposed gauging stations in Allenwood AFA**

As the available warning time on each of the watercourses upstream of the properties at risk is >2 hours, flood warning/forecasting on this river is considered to be technically feasible.

#### Athy AFA

A review was carried out as to where a river gauge could be placed on the River Moneen in order to provide flood warning to the properties at risk from fluvial flooding. Figure 8.1.19 shows the proposed location of three new river gauging stations, 1a-1c. Proposed gauging stations 1a and 1b are both located approximately 1.5km upstream of the first at risk properties on the River Moneen. Two upstream gauging stations are proposed in order to increase the accuracy of forecasting due to a significant split in the watercourse approximately 1.1km upstream of the first properties at risk. Proposed gauging station 1c is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. An estimate of the time for a 1% AEP flood event to travel from gauges 1a/1b to the properties at risk was calculated. The Athy hydraulic model showed that the average speed of water travel along the River Moneen would be 0.2m/s and therefore the travel time between gauges 1a/1b and the properties at risk would be approximately 2 hours.





**Figure 8.1.19 Location of proposed gauging stations in Athy AFA**

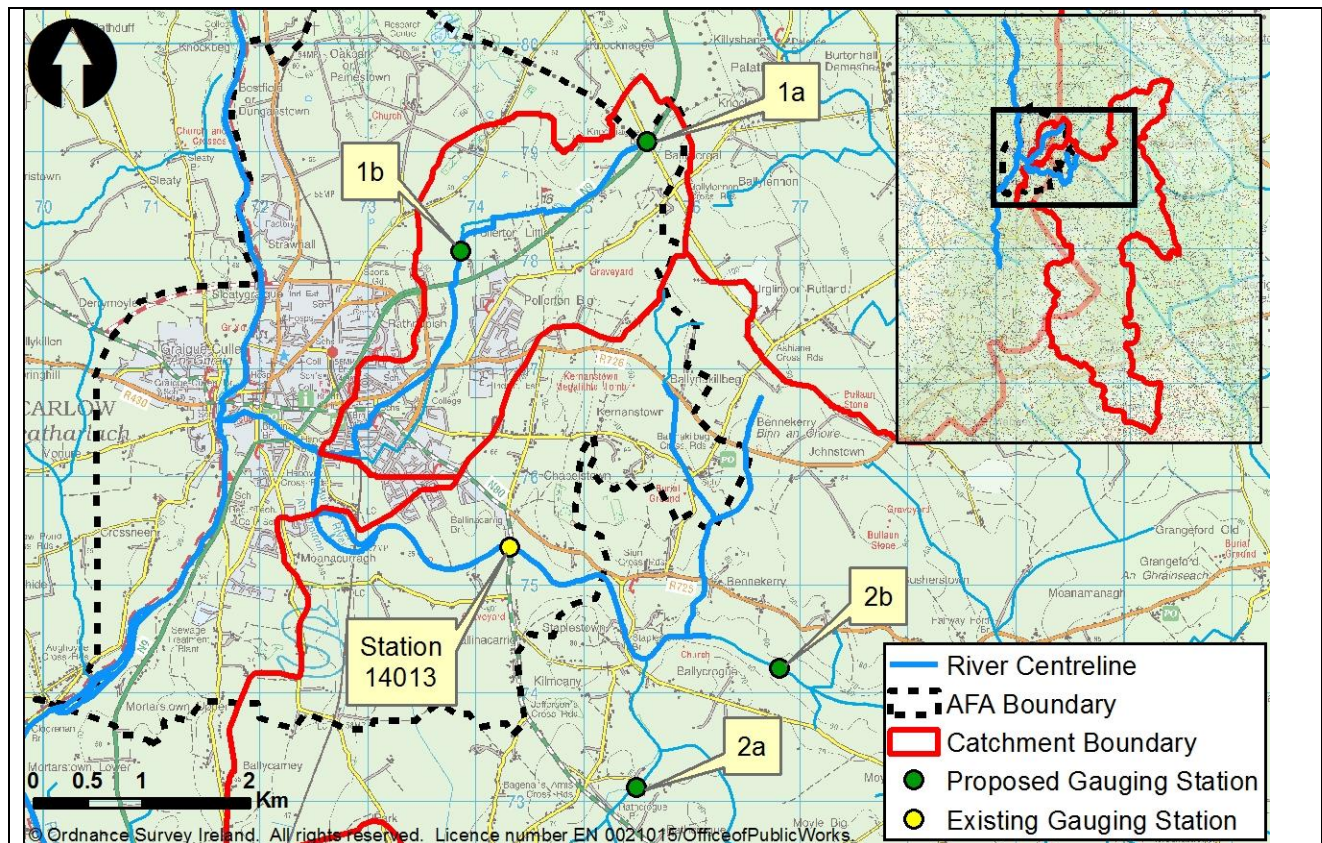
As the available warning time on the River Moneen from the proposed gauging stations 1a/1b is 2 hours, flood warning/forecasting on this river is considered to be technically feasible.

As discussed previously properties are also at risk from the River Barrow in the Athy AFA. Flood warning/forecasting on the River Barrow is also feasible for the Athy AFA, providing approximately 23 hours warning time.

### Carlow AFA

A review was carried out as to where river gauges could be placed on the Burren River and Knocknagee Stream in order to provide flood warning to the properties at risk of fluvial flooding. Figure 8.1.20 shows the location of the proposed new river gauging stations. Proposed gauging station 1a is located approximately 2.2km upstream of the first properties at risk on the Knocknagee Stream and gauging stations 2a and 2b are located approximately 3.3km upstream of the first properties at risk on the Burren River. Two upstream gauging stations are proposed on the Burren River in order to increase the accuracy of forecasting due to a significant split in the watercourse approximately 1.9km upstream of the first properties at risk. Proposed gauging stations 1b and 2c are located adjacent to the first properties at risk on each river and would allow for calibration, fine tuning and validation. The Carlow hydraulic model showed that the average speed of water travel along the Knocknagee Stream and the Burren River would be 0.3m/s and 0.45m/s respectively. The estimated travel time between the proposed upstream gauges and the properties at risk would therefore be approximately 2 hours on both rivers.





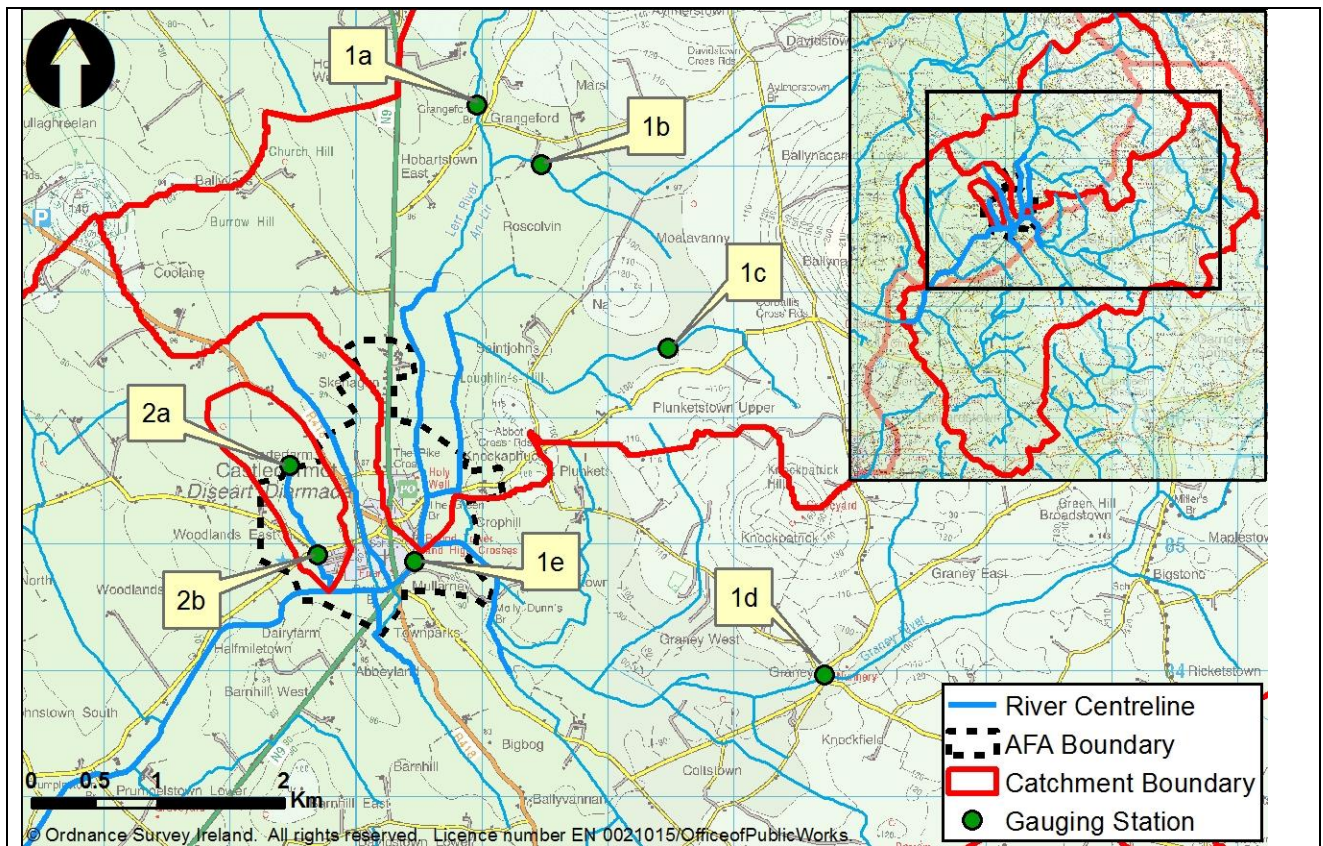
**Figure 8.1.20 Location of proposed gauging stations in Carlow AFA**

As the available warning time on both the Knocknagee Stream and the Burren River from the proposed gauging stations is 2 hours, flood warning/forecasting on these rivers is considered to be technically feasible.

#### Castledermot AFA

A review was carried out as to where river gauges could be placed on the River Lerr and Garterfarm stream in order to provide flood warning to the properties at risk of fluvial flooding. Figure 8.1.21 shows the location of the proposed new river gauging stations. Proposed gauging stations 1a-1d are located approximately 4km upstream of the first properties at risk on the River Lerr and gauging station 2a is located approximately 800m upstream of the first properties at risk on the Garterfarm stream. Four upstream gauging stations are proposed on the River Lerr in order to increase the accuracy of forecasting due to a number of significant splits in the watercourse upstream. Proposed gauging stations 1e and 2b are located adjacent to the first properties at risk on each river and would allow for calibration, fine tuning and validation. The Castledermot hydraulic model showed that the average speed of water travel along the River Lerr and the Garterfarm stream would be 0.55m/s and 0.4m/s respectively. The estimated travel time between the proposed upstream gauges and the properties at risk would therefore be approximately 2 hours on the River Lerr and 35mins on the Garterfarm stream.



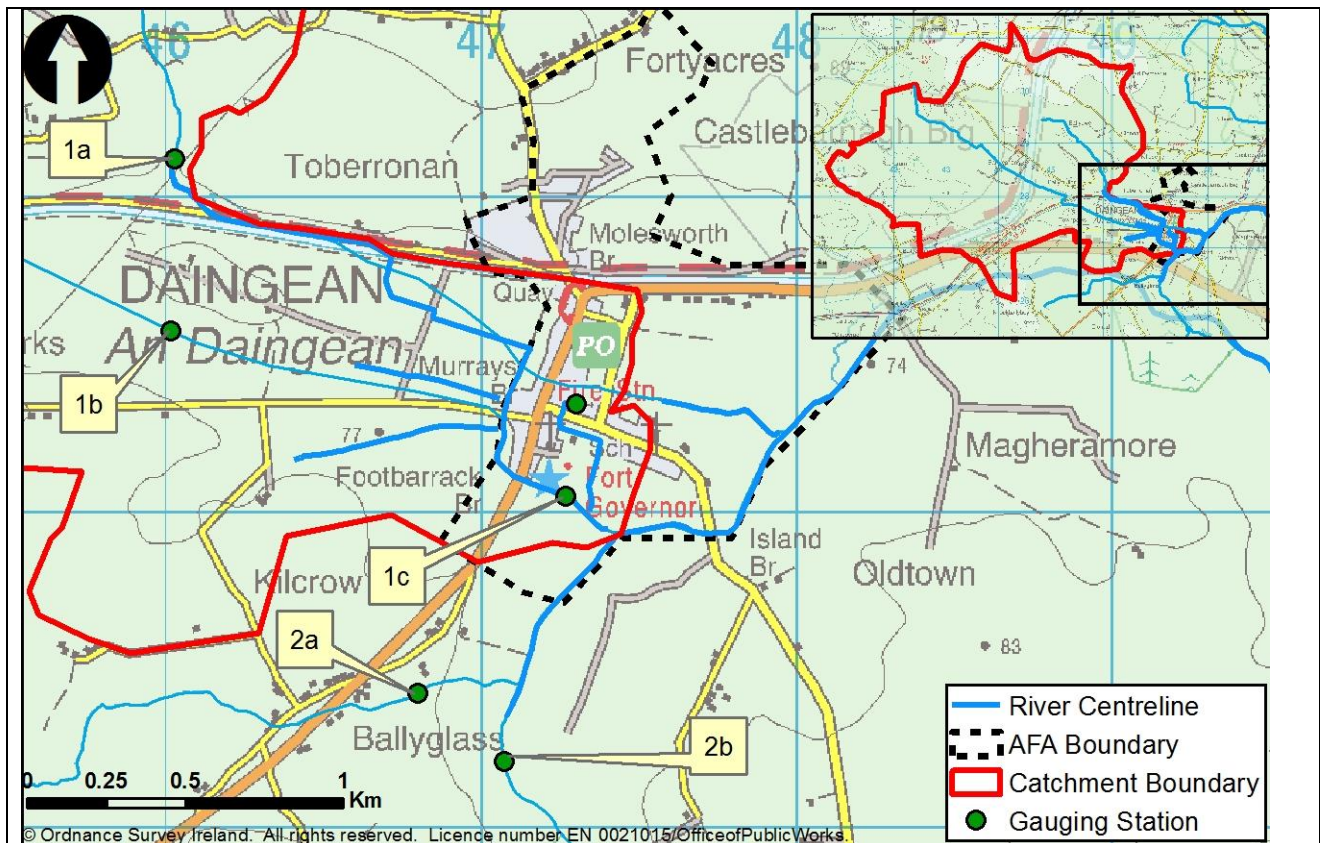


**Figure 8.1.21 Location of proposed gauging stations in Castledermot AFA**

Flood warning/forecasting is considered to be technically feasible on the River Lerr as the available warning time is 2 hours. This FRM method is not technically feasible on the Garterfarm stream however as the warning time available is less than 2 hours.

#### **Daingean AFA**

A review was carried out as to where river gauges could be placed in order to provide flood warning to the properties at risk of fluvial flooding on the Ballyowen River. Figure 8.1.22 shows the location of the proposed new river gauging stations. Proposed gauging stations 1a and 1b are located on the Ballyowen River and Daingean Town Park watercourse respectively, approximately 1.5km upstream of the first properties at risk. Proposed gauging stations 2a and 2b are located on the Philipstown River, approximately 800m upstream. Multiple upstream gauging stations are proposed in order to increase the accuracy of forecasting due to a number of significant splits in the upstream watercourses. Proposed gauging station 1c is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. The Daingean hydraulic model showed that the average speed of water travel along the Ballyowen River and Philipstown River would be 0.2m/s and 0.1m/s respectively. The estimated travel time between the proposed upstream gauges and the properties at risk would therefore be approximately 2 hours on the Ballyowen River, Daingean Town Park watercourse and Philipstown River.



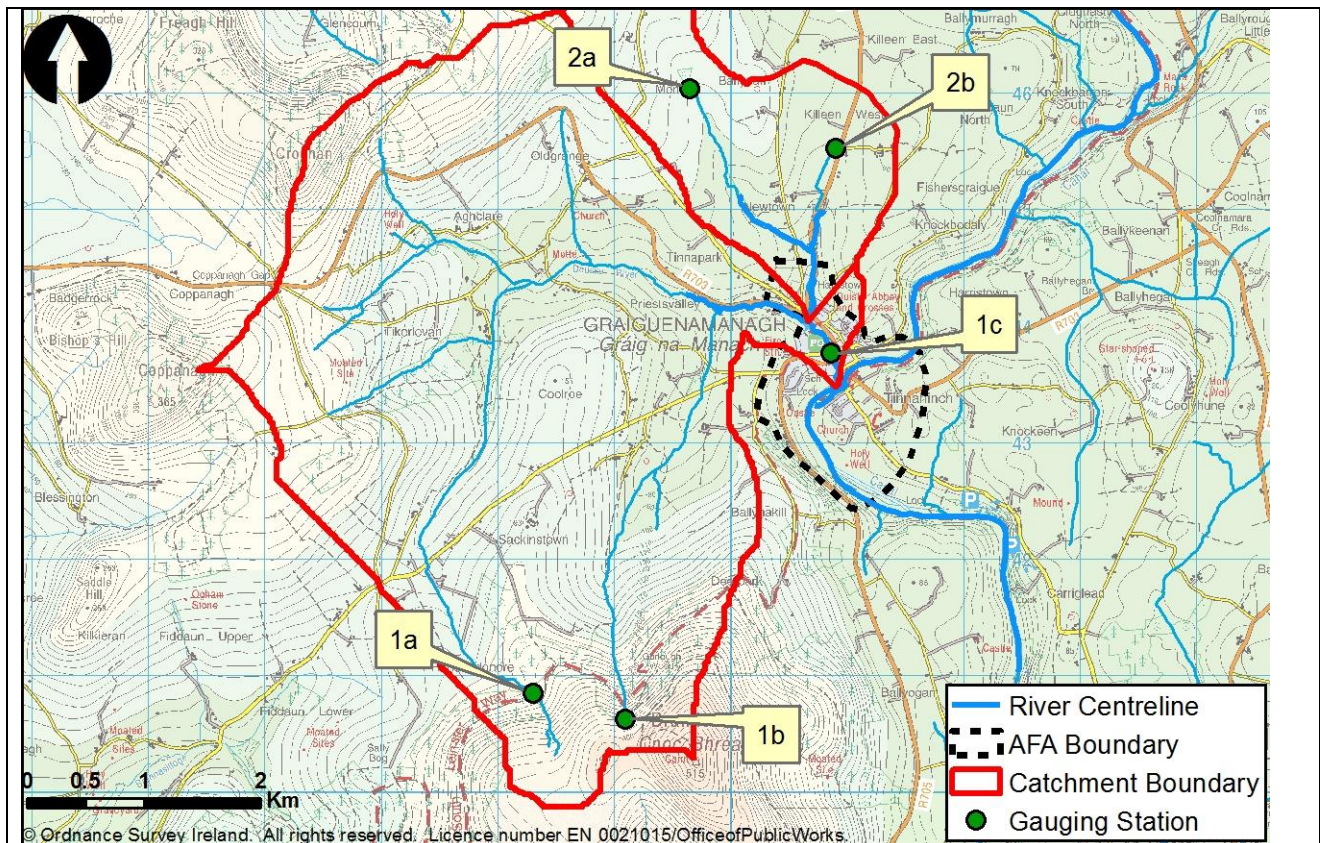
**Figure 8.1.22 Location of proposed gauging stations in Daingean AFA**

As the available warning time on each of the watercourses upstream of the properties at risk is 2 hours, flood warning/forecasting on these rivers is considered to be technically feasible.

#### **Graiguenamanagh AFA**

A review was carried out as to where river gauges could be placed in order to provide flood warning to the properties at risk of fluvial flooding on the Duiske West River. Figure 8.1.23 shows the location of the proposed new river gauging stations. Proposed gauging stations 1a and 1b are located on the Duiske West catchment, approximately 7.2km and 5.0km upstream of the first properties at risk. Proposed gauging stations 2a and 2b are located on the Killen River catchment, approximately 2.8km and 2.0km upstream of the properties at risk and as far up the catchment as possible. Multiple upstream gauging stations are proposed in order to increase the accuracy of forecasting due to a number of significant splits in the upstream watercourses. Proposed gauging station 1c is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. The Graiguenamagh hydraulic model showed that the average speed of water travel along the Duiske West River and Killen River would be 1.0m/s and 0.55m/s respectively. The estimated travel time between proposed gauge 1a and the properties at risk would therefore be approximately 2 hours. The estimated travel times for all other proposed gauge locations is less than 2 hours, ranging between 60-85mins.





**Figure 8.1.23 Location of proposed gauging stations in Graiguenamanagh AFA**

As the available warning time for the majority of the catchment upstream of the properties at risk on the Duiske West River is less than 2 hours, flood warning/forecasting is not considered to be technically feasible for this watercourse.

As discussed previously properties are also at risk from the River Barrow in the Graiguenamanagh AFA. Flood warning/forecasting on the River Barrow is feasible for the Graiguenamanagh AFA, providing up to approximately 58 hours warning time.

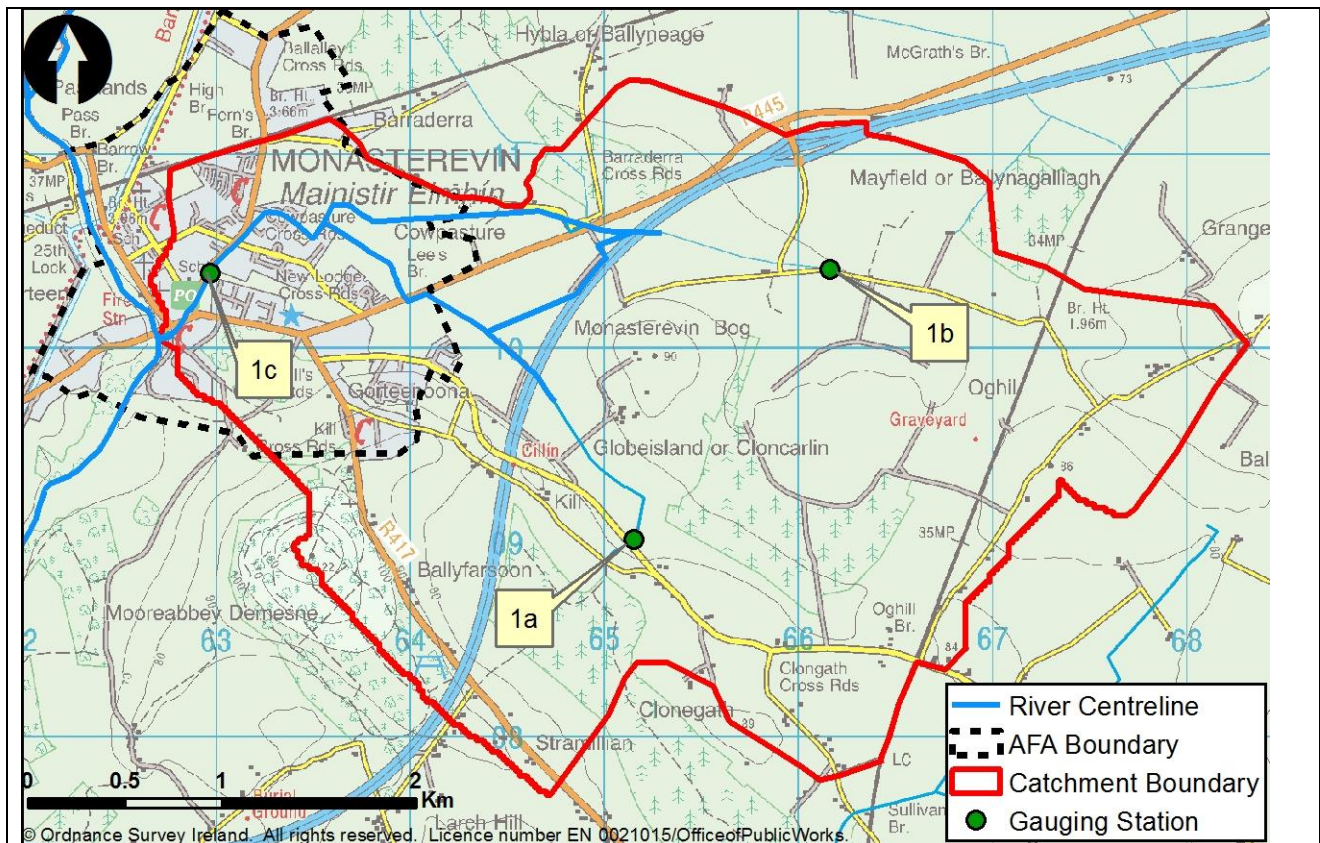
#### **Leighlinbridge AFA**

All properties at risk in the Leighlinbridge AFA are subject to flooding from the River Barrow. As discussed previously flood warning/forecasting on the River Barrow is feasible for the Leighlinbridge AFA, providing up to approximately 41 hours warning time.

#### **Monasterevin AFA**

A review was carried out as to where river gauges could be placed in order to provide flood warning to the properties at risk of fluvial flooding on the Cassidy Stream. Figure 8.1.24 shows the location of the proposed new river gauging stations. Proposed gauging stations 1a and 1b are located on the Cassidy Stream and Barraderra watercourse respectively, approximately 3.3km and 3.5km upstream of the first properties at risk. Proposed gauging station 1c is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. The Monasterevin hydraulic model showed that the average speed of water travel along the Cassidy Stream and Barraderra watercourse would be 0.2m/s and 0.6m/s respectively. The estimated travel time between proposed gauge 1a and the properties at risk would therefore be approximately 4.5 hours. The estimated travel time between gauge 1b and the properties at risk is approximately 1 hour 40mins.





**Figure 8.1.24 Location of proposed gauging stations in Monasterevin AFA**

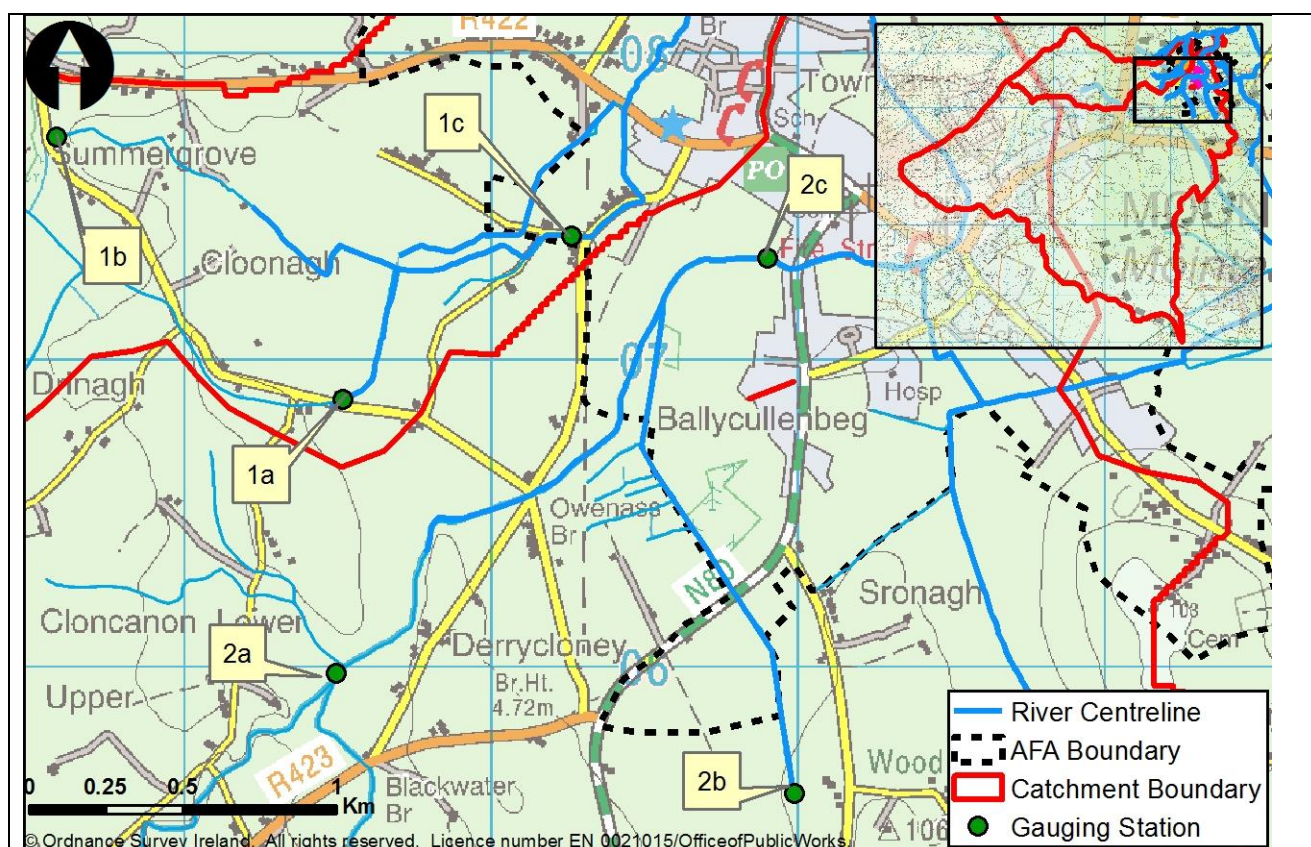
As the available warning time for a significant proportion of the upstream catchment is less than 2 hours, flood warning/forecasting is therefore considered not to be technically feasible for the properties at risk on the Cassidy Stream.

As discussed previously properties are also at risk from the River Barrow in the Monasterevin AFA. Flood warning/forecasting on the River Barrow is feasible for the Monasterevin AFA, providing up to approximately 11.5 hours warning time.

### Mountmellick AFA

A review was carried out as to where river gauges could be placed in order to provide flood warning to the properties at risk of fluvial flooding on the Pound River and the Owenass River. Figure 8.1.25 shows the location of the proposed new river gauging stations. Proposed gauging stations 1a and 1b are located on the Carroon and Avoley Rivers respectively, approximately 1.1km and 1.4km upstream of the first properties at risk. Proposed gauging station 1c is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. The Mountmellick hydraulic model showed that the average speed of water travel along the Carroon and Avoley Rivers would be 0.15m/s and 0.2m/s respectively. The estimated travel time between proposed gauges 1a/1b and the properties at risk would therefore be approximately 2 hours.

Proposed gauging stations 2a and 2b are located on the Owenass and Wood Rivers respectively, approximately 2.2km upstream of the first properties at risk. Proposed gauging station 2c is located adjacent to the first properties at risk. The Mountmellick hydraulic model showed that the average speed of water travel along the Owenass and Wood Rivers would be 0.3m/s. The estimated travel time between proposed gauges 2a/2b and the properties at risk would therefore be approximately 2 hours.



**Figure 8.1.25 Location of proposed gauging stations in Mountmellick AFA**

As the available warning time on each of the watercourses upstream of the properties at risk is 2 hours, flood warning/forecasting on these rivers is considered to be technically feasible.

#### **New Ross AFA**

The River Barrow becomes tidally influenced downstream of Graiguenamagh so a fluvial forecasting system for New Ross would need to be combined with a tidal forecasting system. A decision on tidal forecasting will be taken at national level. Wexford County Council have confirmed there is an existing FRM scheme approved for the New Ross AFA and no optioneering is required.

#### **Portarlinton AFA**

All properties at risk in the Portarlinton AFA are subject to flooding from the River Barrow. As discussed previously flood warning/forecasting on the River Barrow is feasible for the Portarlinton AFA, providing up to approximately 6 hours warning time.

#### **Portlaoise AFA**

A review was carried out as to where river gauges could be placed in order to provide flood warning to the properties at risk of fluvial flooding in the Portlaoise AFA. Figure 8.1.26 shows the location of the proposed new river gauging stations. Proposed gauging station 1a is located on the Togher watercourse, approximately 2.5km upstream of the first properties at risk. Proposed gauging station 1b is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. The Portlaoise hydraulic model showed that the average speed of water travel during a 1% AEP event along the Togher watercourse would be 0.25m/s. The estimated travel time between proposed gauge 1a and the properties at risk would therefore be approximately 3 hours.

Proposed gauging station 2a is located on the Clonminam watercourse, approximately 400m upstream of the first properties at risk. Proposed gauging station 2b is located adjacent to the first properties at risk. The Portlaoise hydraulic model showed that the average speed of water travel along the Clonminam watercourse

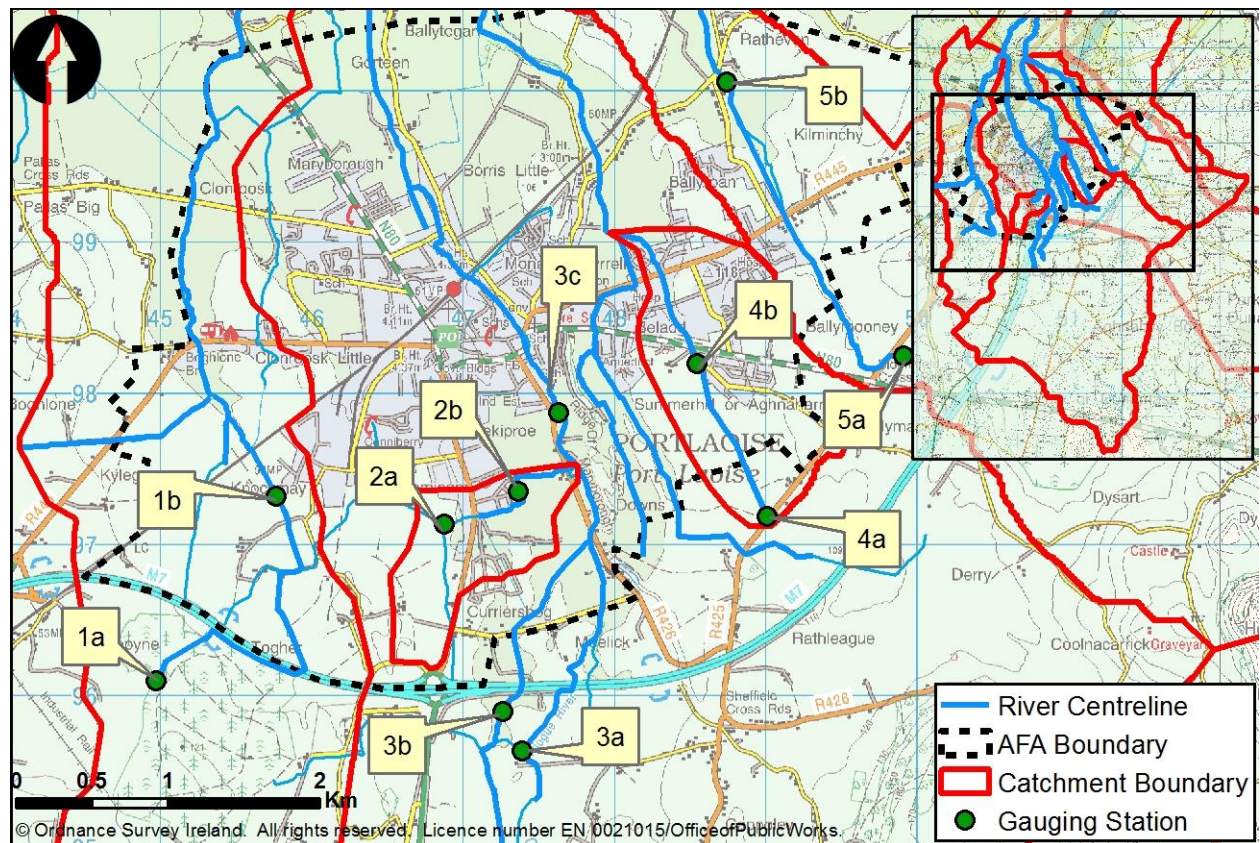


would be 0.3m/s. The estimated travel time between proposed gauge 2a and the properties at risk would therefore be approximately 20mins.

Proposed gauging stations 3a and 3b are located on the Triogue River and Peat Works watercourse respectively, approximately 2.7km and 2.3km upstream of the first properties at risk. Proposed gauging station 3c is located adjacent to the first properties at risk. The Portlaoise hydraulic model showed that the average speed of water travel along the Triogue River would be 0.3m/s. The estimated travel time between proposed gauges 3a/3b and the properties at risk would therefore be approximately 2.5 hours and 2 hours respectively.

Proposed gauging station 4a is located on the River Borris, approximately 1.1km upstream of the first properties at risk. Proposed gauging station 4b is located adjacent to the first properties at risk. The Portlaoise hydraulic model showed that the average speed of water travel along the River Borris would be 0.1m/s. The estimated travel time between proposed gauge 4a and the properties at risk would therefore be approximately 3 hours.

Proposed gauging station 5a is located on the Bloomfield Stream, approximately 2.4km upstream of the first properties at risk. Proposed gauging station 5b is located adjacent to the first properties at risk. The Portlaoise hydraulic model showed that the average speed of water travel along the Bloomfield Stream would be 0.7m/s. The estimated travel time between proposed gauge 5a and the properties at risk would therefore be approximately 1 hour.



**Figure 8.1.26 Location of proposed gauging stations in Portlaoise AFA**

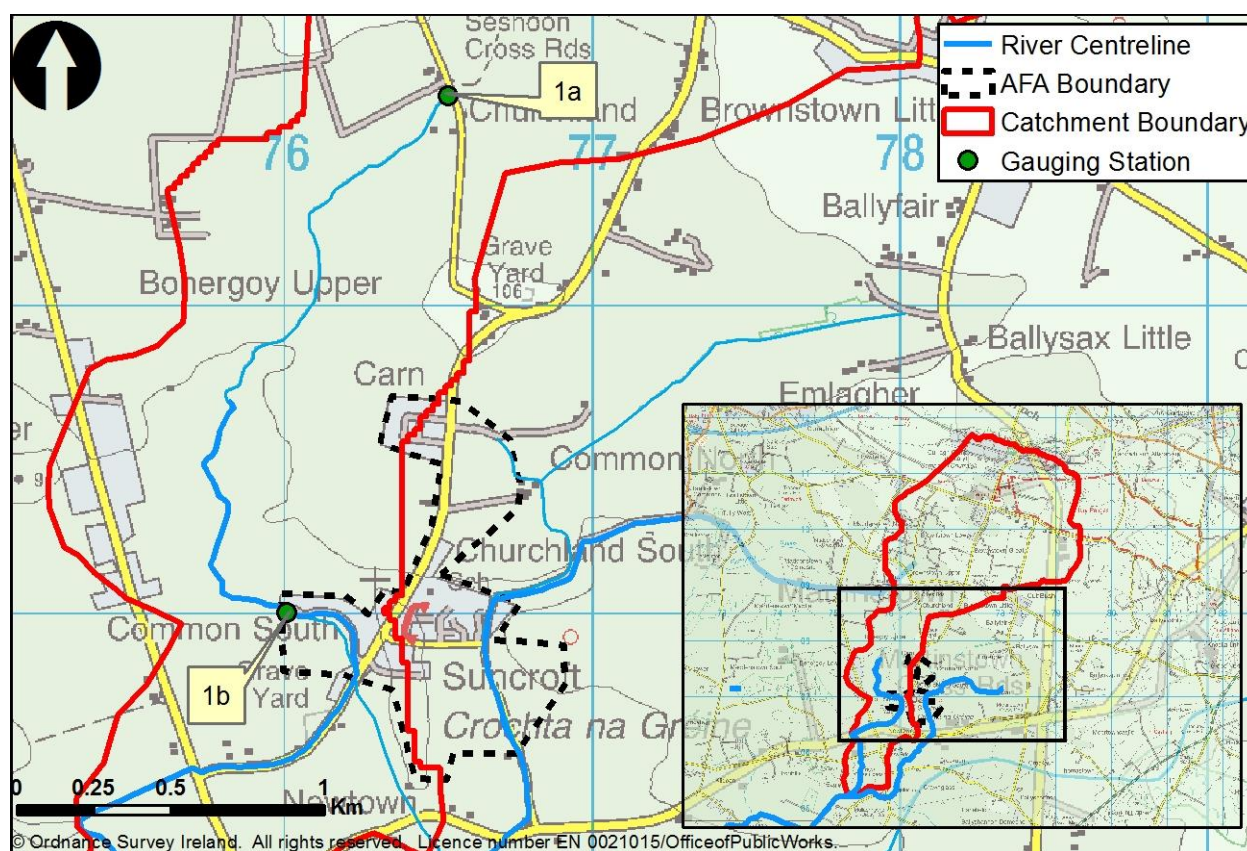
Flood warning/forecasting is considered to be technically feasible on the Togher watercourse, Triogue River and River Borris as the available warning time is 2 hours or greater. This FRM method is not technically feasible on the Clonminam watercourse or Bloomfield Stream however as the warning time available is less than 2 hours.

**Rathangan AFA**

The Flood Warning/Forecasting FRM method is not applicable in Rathangan AFA as no properties are at risk during the 1% AEP event within this AFA.

**Suncroft AFA**

A review was carried out as to where river gauges could be placed in order to provide flood warning to the properties at risk of fluvial flooding on the Common North River. Figure 8.1.27 shows the location of the proposed new river gauging stations. Proposed gauging station 1a is located approximately 2.3km upstream of the first properties at risk, as far up the catchment as possible. Proposed gauging station 1b is located adjacent to the first properties at risk and would allow for calibration, fine tuning and validation. The Suncroft hydraulic model showed that the average speed of water travel along the Common North River would be 0.5m/s. The estimated travel time between proposed gauge 1a and the properties at risk would therefore be approximately 1 hour 15mins.



**Figure 8.1.27 Location of proposed gauging stations in Suncroft AFA**

As the available warning time on the Common North River is less than 2 hours, flood warning/forecasting is not considered to be technically feasible for this watercourse.

**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 time from principle river	Warning times from tributaries of the principle river
Allenwood AFA	6hrs	-



Athy AFA	23hrs	2hrs		
Carlow AFA	-	2hrs		
Castledermot AFA	2hrs	35mins		
Daingean AFA	2hrs	2hrs		
Graiguenamanagh AFA	Up to 58hrs	60-85mins		
Leighlinbridge AFA	Up to 41hrs	-		
Monasterevin AFA	11 ½ hrs	1hr 40min		
Mountmellick AFA	2 hrs	2 hrs		
New Ross AFA	No fluvial risk	No fluvial risk		
Portarlinton AFA	6 hrs	-		
Portlaoise AFA	2-3hrs	20min-1hr		
Rathangan AFA				
Suncroft AFA	<2hrs	-		
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 UoM14.				
Summary				
<p>The following measures are appropriate throughout the UoM:</p> <ul style="list-style-type: none"> <li>• Planning and Development Control</li> <li>• Building Regulations</li> <li>• Sub-catchment Wide SuDs</li> <li>• Strategic Development Management</li> <li>• Public Awareness Campaign</li> </ul> <p>Flood warning/forecasting was also assessed for the River Barrow watercourse as a whole and it was found to be technically feasible. Flood forecasting would provide between 8-17 hours warning time for the Athy, Graiguenamanagh, Leighlinbridge, Monasterevin and Portarlinton AFAs as well as providing warning for the New Ross AFA. However as the New Ross AFA would also be affected by a 0.5% AEP coastal flood event they should be combined with a tidal forecasting system. A decision on tidal forecasting will be taken at national level.</p> <p>A summary of the potential effectiveness of land use management for each AFA and of flood warning and forecasting systems for properties at risk in each AFA is as follows:</p>				



	Land Use Management	Flood Warning/Forecasting
Allenwood AFA	✗	✓
Athy AFA	✗	✓
Carlow AFA	✗	✓
Castledermot AFA	✗	✗
Daingean AFA	✓	✓
Graiguenamanagh AFA	✗	✓
Leighlinbridge AFA	✗	✓
Monasterevin AFA	✗	✗
Mountmellick AFA	✗	✗
New Ross AFA	No fluvial risk	No fluvial risk
Portarlinton AFA	✗	✓
Portlaoise AFA	✗	✗
Rathangan AFA	No fluvial risk	No fluvial risk
Suncroft AFA	✓	✗

## 8. OPTIONEERING OF SSA'S

### 8.2 Barrow Sub Catchment Optioneering of FRM Options

Name	Local Authority	SSA	Status	Date
Barrow Sub Catchment	Kildare, Laois, Carlow, Kilkenny, Wexford <u>Barrow - Reach 1</u> <ul style="list-style-type: none"> <li>Allenwood AFA</li> <li>Rathangan AFA</li> <li>Daingean AFA</li> <li>Portlaoise AFA</li> <li>Mountmellick AFA</li> <li>Portarlinton AFA</li> <li>Monasterevin AFA</li> </ul> <u>Barrow – Reaches 2 - 4</u> <ul style="list-style-type: none"> <li>Athy AFA</li> <li>Castledermot AFA</li> <li>Carlow AFA</li> <li>Leighlinbridge AFA</li> <li>Graiguenamanagh AFA</li> </ul> <u>Barrow - Reach 5</u> <ul style="list-style-type: none"> <li>New Ross AFA</li> </ul>	Sub Catchment	Final	16/06/2016

#### 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

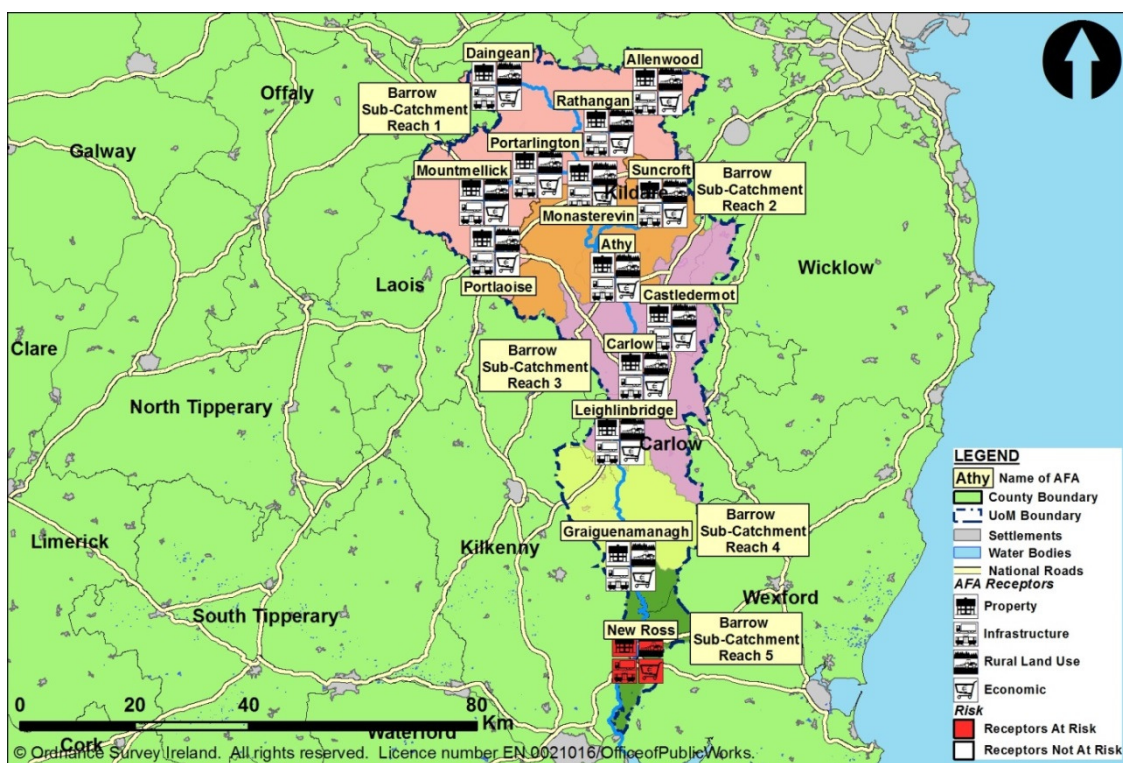
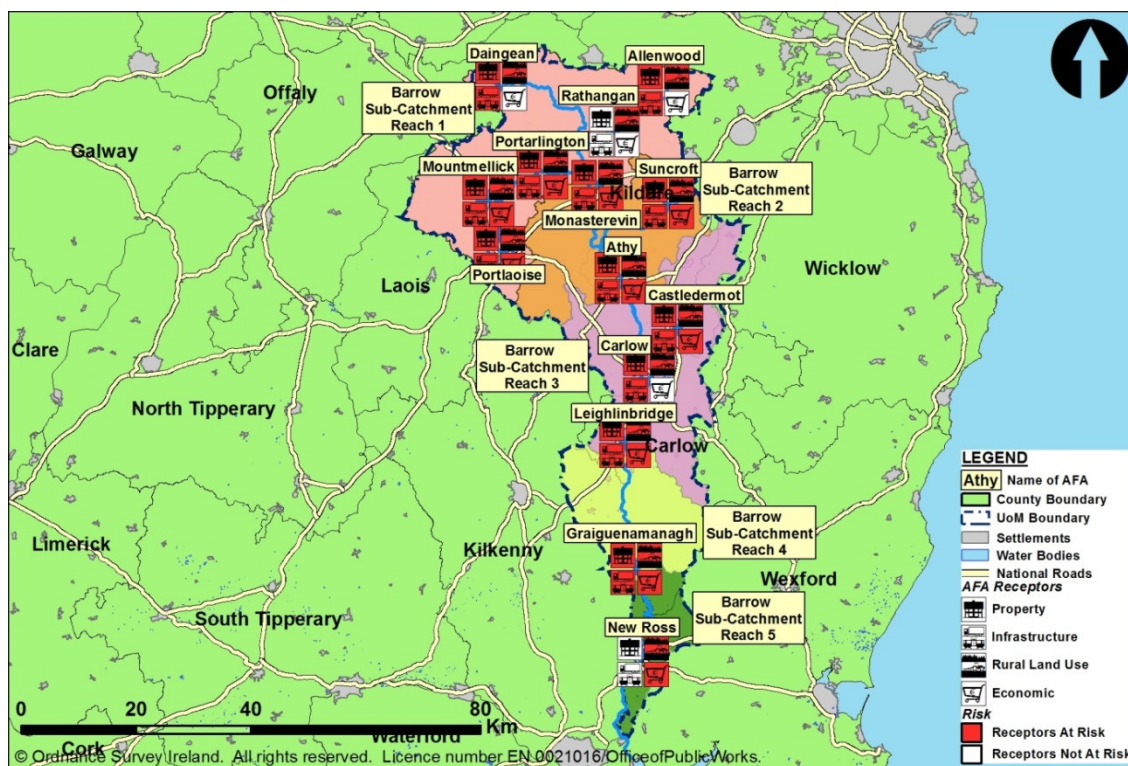


Figure 8.2.1 summarises the flood risk on the main economic activities within the Barrow Sub Catchment. During a 1% AEP fluvial flood event properties, infrastructure and rural land is affected within all ten AFAs, and economic (commercial) properties are affected within Portlaoise, Mountmellick, Portarlinton, Monasterevin, Athy, Castledermot, Leighlinbridge and Graiguenamanagh AFAs.

In Graiguenamanagh, Leighlinbridge, Portarlinton, New Ross and Suncroft AFAs the onset of non-residential property damage occurs in the 50% AEP event and in Castledermot AFA damage commences in the 10% AEP event, in Athy, Monasterevin and Mountmellick AFAs damage first occurs in the 2% AEP event and in Portlaoise AFA damage first occurs in the 1% AEP event.

In Athy, Graiguenamanagh, Portarlinton and Suncroft AFAs the onset of residential property damage occurs in the 50% AEP event and in Castledermot and New Ross AFAs damage commences in the 10% AEP event, in Daingean and Monasterevin AFAs damage first occurs in the 5% AEP event, in Leighlinbridge and Portlaoise AFAs damage first occurs in the 2% AEP even and in Allenwood, Carlow and Mountmellick AFAs damage first occurs in the 1% AEP event.

There is no damage to properties in Rathangan AFA during a 1% AEP event.

### 8.1.3 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 at UoM SSA - Reject	✗
Building Regulations	Consider at UoM SSA - Reject	✗
Sub-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 at AFA SSA - Reject	✓
Diversion of Flow	Consider at AFA SSA - Reject	✗
Flood Warning/Forecasting	Consider Further	✗
Public Awareness Campaign	Consider at UoM SSA - Reject	✓
Individual Property Protection	Consider at AFA SSA - Reject	✗
Other Works	Consider at AFA SSA - Reject	✗

**8.1.3.1 Feasibility Review Summary**

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	Social Screening
Land Use Management	x			
Storage	x	✓		
Improvement of Channel Conveyance	x			
Hard Defences	x	✓		
Flood Warning/Forecasting	x			
x - Reject    x - Progress    ? - Progress, potential impacts identified    ! - Progress, potential for significant impacts identified				

**8.1.3.2 Justification for Rejection/Retention**

Method	Tech	Econ	Env	Soc
Land Use Management	✓			
Land Use Management was assessed in Section 8.1 and it was concluded that the method was not suitable at UoM or Sub-catchment SSA. Further analysis is undertaken at individual AFA SSA where potential was identified by the UoM SSA analysis.				
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 Sub Catchment and reducing 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.

**Barrow Sub Catchment Reach 1**

Barrow Sub Catchment Reach 1 includes Allenwood, Daingean, Portlaoise, Mountmellick, Portarlinton, Monasterevin and Rathangan AFAs. Sub Catchment Storage on the Barrow and its tributaries has been reviewed within HA14 in relation to these AFAs. However at the Mountmellick and Portlaoise AFAs the flood risk emanates from the tributaries of the Barrow and potential storage areas identified upstream would have a negligible benefit in terms reduced flows in the River Barrow itself and were therefore not considered at this SSA. At the Portarlinton AFA potential storage identified upstream did not provide sufficient attenuation such that properties would benefit in the AFA but providing this storage was found to make a contribution to the cumulative benefit downstream. As such this storage was retained within the analysis although no benefit at the Portarlinton AFA could be included.

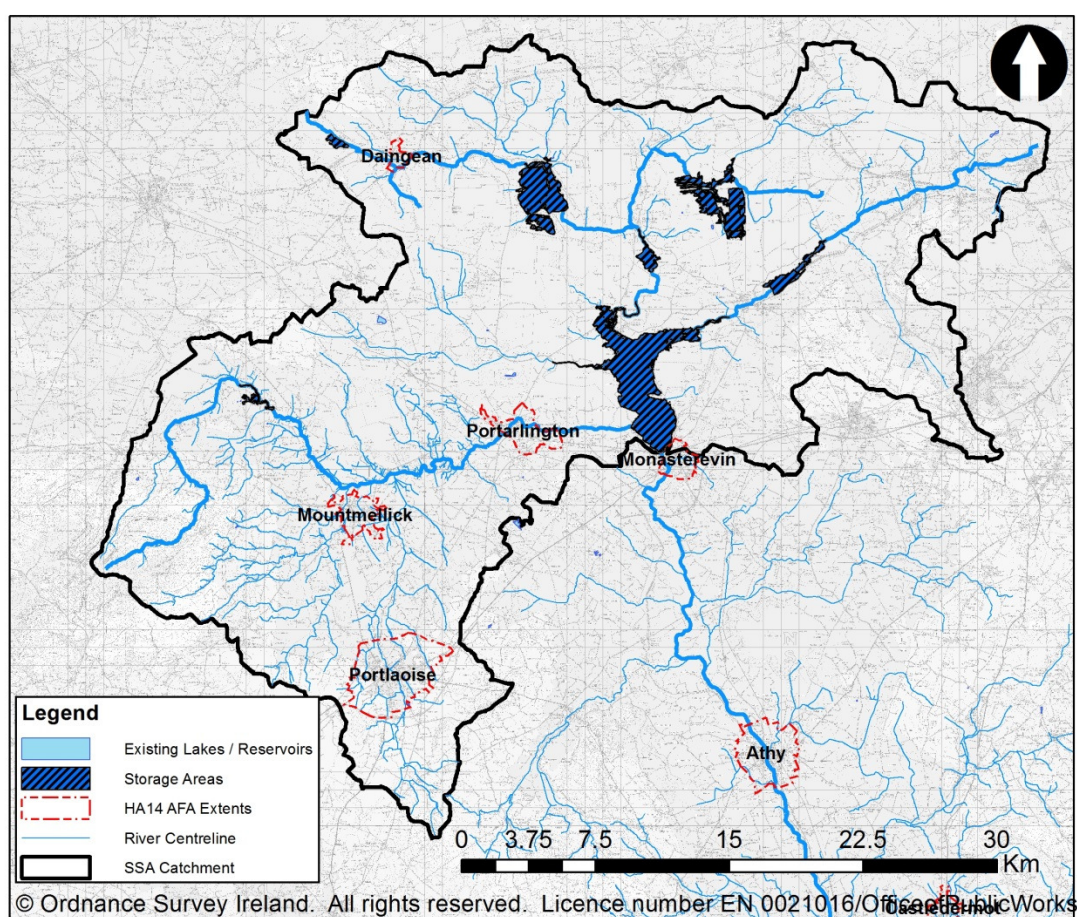
The assessment of the Storage method at this SSA requires that the Barrow catchment upstream of Monasterevin is considered in relation to potential storage areas. The first step in this assessment was to identify any existing depressions within the topography that are on-line or adjacent to a watercourse



representing at least 5% of the total catchment. It was considered that providing storage on watercourses representing less than this threshold area would be of negligible benefit given that the effectiveness of storage is dependent on the proportion of the catchment which is served by the storage area. The second step in this assessment was to identify any pinch points within the catchment which could be used to create a significant storage area through construction of a controlling weir and embankment structure across the floodplain. Areas were then checked to ensure they did not impinge on existing properties. Following this analysis a total of seven areas were identified at which significant storage could be provided leading to attenuation of peak flows. The areas which were identified are as follows:

- 0.43 km<sup>2</sup> area upstream of Daingean on the Philipstown River
- 6.47 km<sup>2</sup> area on the lower reaches of the Philipstown River approximately 4km west of Clonbullogue
- 5.40 km<sup>2</sup> area on the Figile River approximately 4km east of Clonbullogue
- 0.94 km<sup>2</sup> area on the Figile River just downstream of Clonbullogue
- 1.64 km<sup>2</sup> area on the Slate River just upstream of Rathangan
- 0.43 km<sup>2</sup> area on the River Barrow approximately 6km upstream of Mountmellick
- 17.7km<sup>2</sup> area on the River Barrow just upstream of Monasterevin taking in the confluences with the Figile, Slate and Cushina Rivers. Some bunding of this area is required to protect properties and roads.

The potential storage areas considered are shown in Figure 8.1.3.2.1.1.1.1.1.



**Figure 8.1.3.2.1.1.1.1.1 Potential Storage Areas Identified Upstream of Monasterevin**

Following the identification of storage areas an assessment of their effectiveness was undertaken to ascertain what reduction in peak flows would be achieved. The basis for this assessment was a re-calculation of the catchment FARL value at the relevant AFA and then application of this value to ascertain the effect on peak flow values. Given that the upper Barrow has a very active floodplain, much of which

covers the identified potential storage areas at present, it was considered that the effectiveness of these areas could be overestimated through this analysis method. To counteract this, the area considered effective for the purposes of recalculation of FARL was reduced by the area of 1% AEP floodplain contained within the potential storage area.

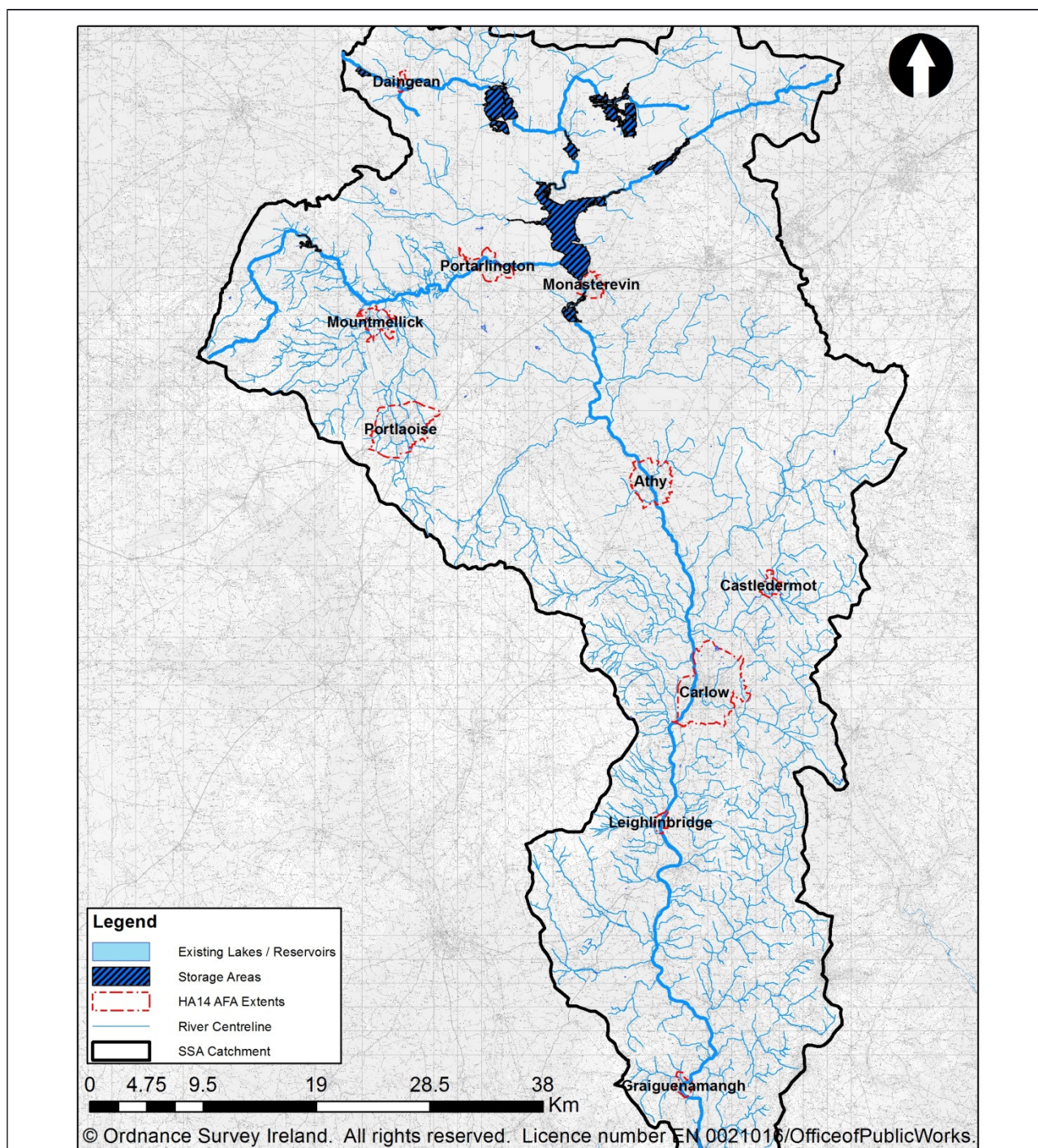
The assessment found that with the seven storage areas in place the FARL was reduced from 1 to 0.93 and 0.91 at the Daingean and Monasterevin AFAs respectively. This had the effect of reducing the peak flow in the 1% AEP event to that in the 2% AEP event at Daingean and to that in the 5% AEP event at Monasterevin. At the reduced peak flows, properties are still affected at Daingean and Monasterevin and as such the method does not provide the full standard of protection. However this method will protect a small number of properties at both AFAs and as such is considered technically feasible.

The total cost of providing the seven storage areas including for seven new weirs, 137m of low flow culvert structures and 4.5km of embankment/bund to impound flood flows is estimated at €13.10M. This is many multiples of the total capped benefit available at the Daingean and Monasterevin AFAs (the only AFAs benefitting) and the method is therefore rejected at this Sub Catchment SSA as not being economically viable.

#### **Barrow Sub Catchment Reaches 2, 3 and 4**

Only one additional storage area was identified within the Barrow catchment downstream of Monasterevin that could potentially benefit multiple AFAs. This storage area is approximately 1.46km<sup>2</sup> in area and is located just downstream of Monasterevin as shown in Figure 8.1.3.2.1.1.1.2.





**Figure 8.1.3.2.1.1.1.2 Potential Storage Areas Identified in Barrow Catchment**

At the Castledermot AFA the flood risk emanates from tributaries of the Barrow and potential storage areas identified upstream would have a negligible benefit in terms of reduced flood flows in the Barrow hence these were not considered at this SSA. Consequently none of the eight areas identified at the sub-catchment scale could have any effect on flooding at Castledermot or at Carlow where there is no risk identified from the River Barrow in the 1% AEP event. As such it is not considered appropriate to consider potential benefit from these AFAs as there is none provided by this method.

Given that all of the potential storage identified is upstream of the Athy, Carlow, Leighlinbridge and Graiguenamanagh AFAs and that no further storage locations were identified downstream of Athy the cost of providing the storage is the same at each SSA and the method can therefore be screened together for

all three Barrow SSAs (Sub-Catchments 2, 3 and 4).

The assessment of the effectiveness of this method found that with the eight storage areas in place the FARL was reduced from 1 to 0.93, 0.95 and 0.96 at the Athy, Leighlinbridge and Graiguenamanagh AFAs respectively. This would have the effect of reducing the peak flow in the 1% AEP event to that in the 2% AEP event at the Athy and Leighlinbridge AFAs but would have a less significant effect further downstream and therefore would not provide meaningful protection to properties at the Graiguenamanagh AFA. However this method will protect properties at the Daingean, Monasterevin, Athy and Leighlinbridge AFAs and as such is technically feasible as a flood management method.

The total cost of providing the eight storage areas including eight new weirs, 158m of low flow culvert structures and 5.4km of embankment/bund to impound flood flows is estimated at €15.90M. This is within the total capped benefit available at the Daingean, Monasterevin, Athy and Leighlinbridge AFAs (the benefitting AFAs) however it does not provide the full standard of protection. To provide the full standard of protection with the storage method used in combination with other methods is likely to cost in excess of the €17.77M of capped benefit available at all four of the AFAs at which the storage method could provide some degree of benefit. There are alternative methods available at each of these AFAs which would provide the full standard of protection at a total cost of €7.91M and as such the storage method for these three reaches of the Barrow Sub Catchment SSAs cannot be considered economically viable unless the available methods which do provide the full standard of protection are found not to be viable for any reason.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x			

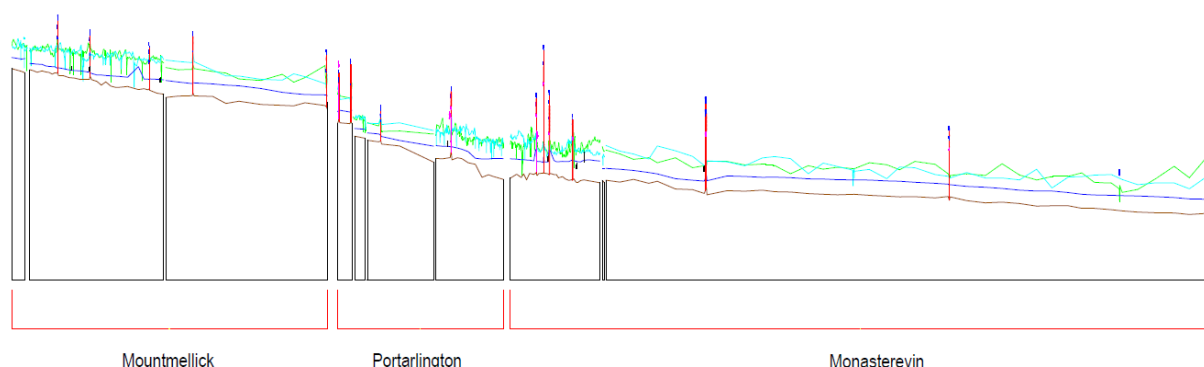
This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. At Sub Catchment SSA, whereby flood risk management in multiple AFAs is under consideration, this can be achieved by lowering bed levels, widening/reshaping channels and/or removing channel/structure constrictions.

### Barrow Sub Catchment Reach 1

Barrow Sub Catchment Reach 1 includes Allenwood, Rathangan, Daingean, Portlaoise, Mountmellick, Portarlinton and Monasterevin AFAs. Sub Catchment conveyance improvement on the Barrow River has been reviewed for this reach of UoM14.

The properties at risk in Allenwood, Daingean, Portlaoise and Mountmellick are not impacted by water levels within the Barrow River. The properties are located in discrete locations on tributaries flowing into the Barrow; therefore improving the channel conveyance of the Barrow watercourse will not benefit properties within these AFAs. Methods for improving channel conveyance are further assessed at the AFA SSA level for Allenwood, Daingean, Portlaoise and Mountmellick to determine their application for the individual AFAs within this reach of the Sub Catchment.

The implementation of conveyance measures along the Barrow River was reviewed to benefit the remaining AFAs (Portarlinton and Monasterevin) which have properties at risk during the 1% AEP fluvial event. Figure 8.1.3.2.1.1.1.3 shows the longitudinal section of the River Barrow for Reach 1.



**Figure 8.1.3.2.1.1.1.3 Longitudinal Section of River Barrow Mountmellick to Monasterevin**

The water levels affecting properties are controlled by the capacity of the River Barrow itself along this reach therefore the impact of increasing channel conveyance from Portarlinton to Monasterevin could be assessed.

To benefit the 148 properties flooding via the River Barrow (out of a total of 158 properties at risk of fluvial flooding) within the AFAs the following works would be required:

- Removal and disposal of 336,600m<sup>3</sup> of bed/bank material
- Upgrading of 7 river crossings

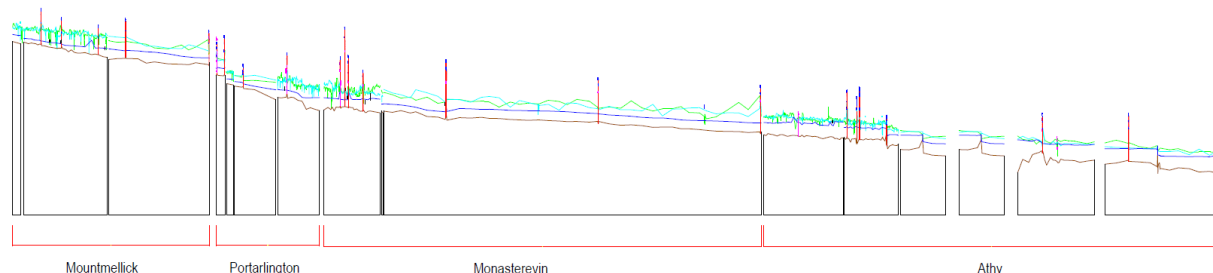
The cost of these works is estimated to be in the order of €31.7m (assuming no excavation of rock or provision of bank scour protection). This measure would need to be undertaken in conjunction with additional FRM methods to protect the 10 remaining at risk properties in Portarlinton to Monasterevin AFAs and also those which are located on tributaries of the Barrow River within the Daingean, Portlaoise and Mountmellick AFAs.

The combined benefits for all AFAs are limited to circa €22m and as the estimated costs of channel conveyance works in Portarlinton and Monasterevin alone is €31.7m an overall scheme is very unlikely to be viable. In addition there are environmental considerations and social issues. Conveyance improvements in these upstream AFAs could also exacerbate flooding in downstream AFAs. This method was therefore rejected as it would not be technically effective on reach 1 of the Sub Catchment SSA.

## **Barrow Sub Catchment Reach 2**

Barrow Sub Catchment Reach 2 includes the Athy AFA, in addition to the upstream Reach 1 AFAs (Allenwood, Rathangan, Daingean, Portlaoise, Mountmellick, Portarlinton, Monasterevin). Sub Catchment conveyance improvement on the River Barrow has been reviewed within this reach of UoM14. As discussed above off-Barrow properties at risk in Allenwood, Daingean, Portlaoise and Mountmellick AFAs will not benefit from this measure.

The implementation of conveyance measures along the River Barrow to benefit the remaining AFAs which have properties at risk during the 1% AEP fluvial event, Portarlinton, Monasterevin and Athy was reviewed. Figure 8.1.3.2.1.1.1.4 shows the longitudinal section of the River Barrow for Reach 2.





**Figure 8.1.3.2.1.1.1.4 Longitudinal Section of River Barrow Mountmellick to Athy**

The water levels affecting properties are controlled by the capacity of the River Barrow itself along this reach therefore the impact of increasing channel conveyance from Monasterevin to Athy could be assessed.

To benefit the 247 properties flooding via the River Barrow (out of a total of 257 properties at risk of fluvial flooding) within the Portarlinton, Monasterevin and Athy AFAs the following works would be required:

- Removal and disposal of 501,000m<sup>3</sup> of bed/bank material
- Upgrading of 11 river crossings

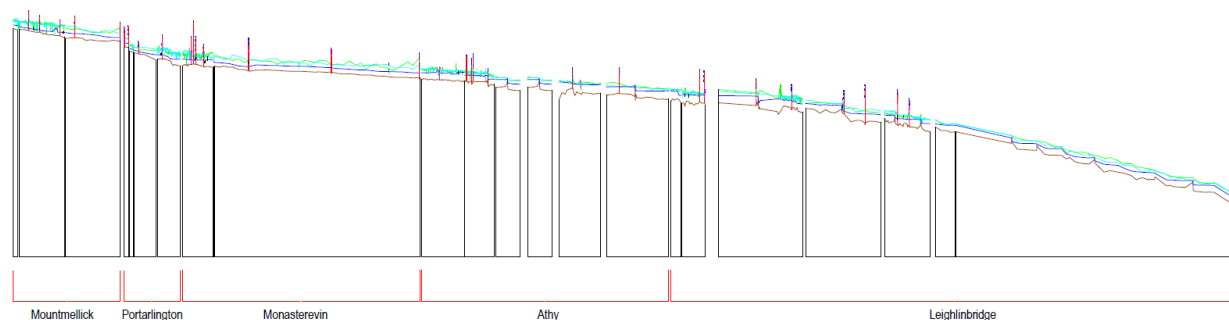
The cost of these works is estimated to be in the order of €49.1m (assuming no excavation of rock or provision of bank scour protection). This measure would need to be undertaken in conjunction with additional FRM methods to protect the remainder of the properties and those located on tributaries of the Barrow River within the Allenwood, Daingean, Portlaoise and Mountmellick AFAs.

The combined benefits for all AFAs are limited to circa €35.6m and as the estimated costs of channel conveyance works in Portarlinton, Monasterevin and Athy alone is €49.1m an overall scheme is very unlikely to be viable. In addition there are environmental considerations and social issues. Conveyance improvements in these upstream AFAs could also exacerbate flooding in downstream AFAs. This method was therefore rejected as it would not be technically effective on reach 2 of the Sub Catchment SSA.

### Barrow Sub Catchment Reach 3

Barrow Sub Catchment Reach 3 encompasses the Reach 2 AFAs (Allenwood, Rathangan, Daingean, Portlaoise, Mountmellick, Portarlinton, Monasterevin and Athy) and includes Castledermot, Carlow and Leighlinbridge AFAs. Sub Catchment conveyance improvement on the Barrow River has been reviewed within this reach of UoM14. As discussed above properties at risk in Allenwood, Daingean, Portlaoise, Mountmellick and, for the same reasons, those within Castledermot and Carlow AFAs are not impacted by water levels within the Barrow River.

The implementation of conveyance measures along the Barrow River was reviewed to benefit the remaining AFAs which have properties at risk during the 1% AEP fluvial event, Portarlinton, Monasterevin, Athy and Leighlinbridge. Figure 8.1.3.2.1.1.1.5 shows the longitudinal section of the River Barrow for Reach 3.

**Figure 8.1.3.2.1.1.1.5 Longitudinal Section of River Barrow Mountmellick to Leighlinbridge**

The water levels affecting properties are controlled by the capacity of the River Barrow itself along this reach therefore the impact of increasing channel conveyance from Athy to Leighlinbridge could be assessed.

To benefit the 304 properties flooding via the River Barrow (out of a total of 314 properties at risk of fluvial flooding) within the Portarlinton, Monasterevin, Athy and Leighlinbridge AFAs the following works would be required:

- Removal and disposal of 725,000m<sup>3</sup> of bed/bank material
- Upgrading of 13 river crossings
- Removal of 3 weirs

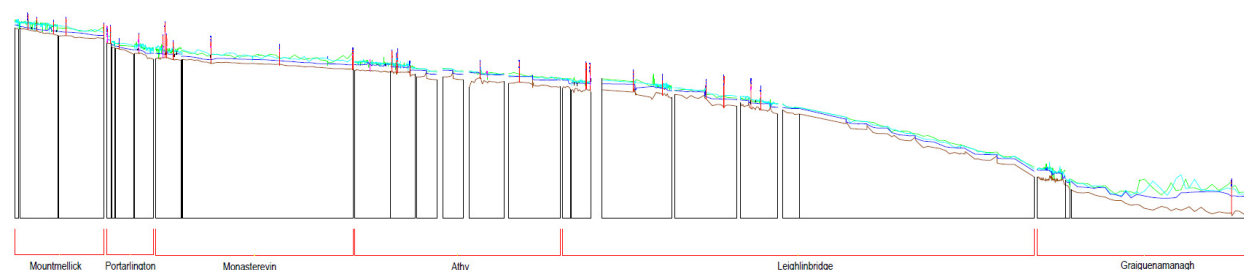
The cost of these works is estimated to be in the order of €79m (assuming no excavation of rock or provision of bank scour protection). This measure would need to be undertaken in conjunction with additional FRM methods to protect the remaining properties and those which are located on tributaries of the Barrow River within the Allenwood, Daingean, Portlaoise, Mountmellick, Castledermot and Carlow AFAs.

The combined benefits for all AFAs are limited to circa €41.5m and as the estimated costs of channel conveyance works in Portarlinton, Monasterevin, Athy and Leighlinbridge alone is €79m an overall scheme is very unlikely to be viable. In addition there are environmental considerations and social issues. Conveyance improvements in these upstream AFAs could also exacerbate flooding in downstream AFAs. This method was therefore rejected as it would not be technically effective on reach 3 of the Sub Catchment SSA.

#### Barrow Sub Catchment Reach 4

Barrow Sub Catchment Reach 4 includes Graiguenamanagh AFA in addition to those in Reach 3. Sub Catchment conveyance improvement on the Barrow River has been reviewed within this reach of UoM14. As discussed above properties at risk in Allenwood, Daingean, Portlaoise, Mountmellick, Castledermot and Carlow AFAs are not impacted by water levels within the Barrow River.

The implementation of conveyance measures along the Barrow River to benefit the remaining AFAs which have properties at risk during the 1% AEP fluvial event, Portarlinton, Monasterevin, Athy, Leighlinbridge and Graiguenamanagh were reviewed. Figure 8.1.3.2.1.1.1.6 shows the longitudinal section of the River Barrow for Reach 4.



**Figure 8.1.3.2.1.1.1.6 Longitudinal Section of River Barrow Mountmellick to Graiguenamanagh**

The water levels affecting properties are controlled by the capacity of the River Barrow itself along this reach therefore the impact of increasing channel conveyance from Leighlinbridge to Graiguenamanagh could be assessed.

To benefit the 368 properties flooding via the River Barrow (out of a total of 378 properties at risk of fluvial flooding) within the Portarlinton, Monasterevin, Athy, Leighlinbridge and Graiguenamanagh AFAs the following works would be required:

- Removal and disposal of 871,000m<sup>3</sup> of bed/bank material
- Upgrading of 21 river crossings
- Removal of 5 weirs

The cost of these works is estimated to be in the order of €95.7m (assuming no excavation of rock or provision of bank scour protection). This measure would need to be undertaken in conjunction with additional FRM methods to protect the remainder of the properties which are located on tributaries of the Barrow River within the Allenwood, Daingean, Portlaoise, Mountmellick, Castledermot and Carlow AFAs.



The combined benefits for all ten AFAs are limited to circa €51.7m and as the estimated costs of channel conveyance works in Portarlinton, Monasterevin, Athy, Leighlinbridge and Graiguenamanagh alone is €95.7m an overall scheme is very unlikely to be viable. In addition there are environmental considerations and social issues. Conveyance improvements in these upstream AFAs could also exacerbate flooding in downstream AFAs. This method was therefore rejected as it would not be technically effective on reach 4 of the Sub Catchment SSA.

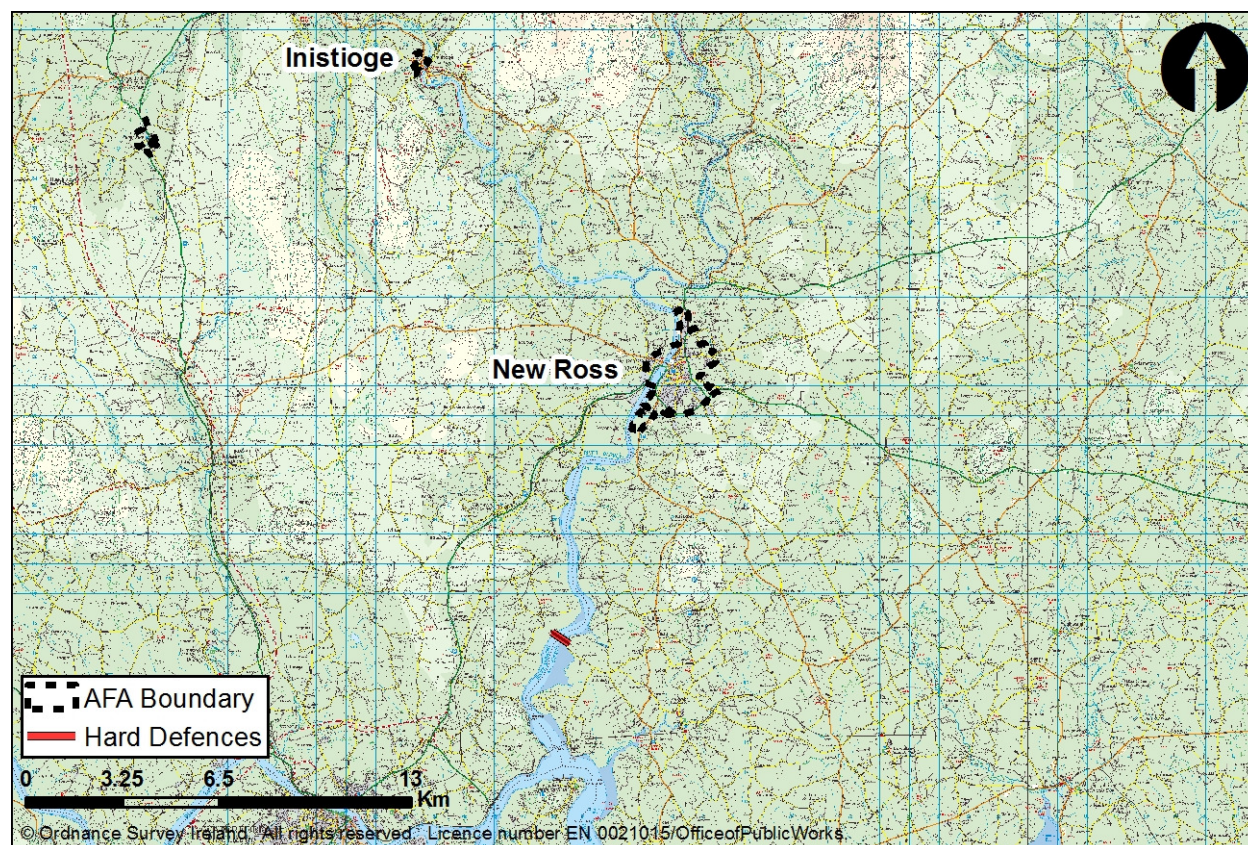
Methods for improving channel conveyance are further assessed at AFA SSA level to determine their application to the individual AFAs within this Sub Catchment.

Method	Tech	Econ	Env	Soc
Hard Defences	x	✓		

This method involves the construction of a tidal barrier across a coastal lough, bay or estuary that would shut its flood gates when triggered by water levels predicted by a tidal surge forecast. Adoption of this method would cause significant changes to the hydrodynamics experienced in the proposed coastal cell (Reach 5). This would 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.

#### Barrow Sub Catchment Reach 5

A review was carried out as to where a tidal barrier could be placed across Waterford Estuary benefitting tidally influenced AFAs in UoM14, and also in UoM15, in order to protect the existing properties at risk. One area was identified where the proposed barrier would provide protection for more than one AFA, New Ross AFA and Inistioge AFA, and where there's a relatively narrow estuary crossing downstream of New Ross AFA, see Figure 8.1.3.2.1.1.1.7. Therefore the tidal barrier is technically feasible.



**Figure 8.1.3.2.1.1.1.7 Tidal Barrier to provide flood protection to New Ross AFA and Inistioge AFA**

The estimated cost of this tidal barrier is in the order of €60m, therefore this method is economically unfeasible as it significantly exceeds the €7m combined benefit for these two AFAs, and it should be rejected from the screening process.

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			

Flood Warning/Forecasting was assessed in Section 8.1. The AFAs included within the Barrow Sub-catchment therefore have already been assessed at UoM SSA and no further method can be identified by Sub-catchment SSA analysis. Further analysis is undertaken at individual AFA SSA where potential was identified by the UoM SSA analysis.

### Summary of Feasibility Review

Land Use Management and Flood Warning/Forecasting methods at Sub-catchment SSA are not technically feasible within the Barrow Sub-catchment.

Storage measures may offer a partially effective technical solution at Sub Catchment SSA but are not economically justified within the Barrow Sub Catchment as measures at AFA SSA are more economically advantageous.

Channel conveyance improvements at Sub Catchment SSA are not technically feasible within the Barrow Sub Catchment.

Hard defences in the form of a tidal barrier to protect coastal flood risk across multiple AFAs at the Sub-catchment SSA were assessed and found to not be economically viable within the Barrow Sub-catchment.

The applicability of these measures, alongside alternative measures, is further assessed at AFA SSA level.

## 8. OPTIONEERING OF SSA'S

### 8.3 Allenwood optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Allenwood	Kildare	140147	AFA	Final	15/06/2016

#### 8.3.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.3.2 Flood Cells



**Figure 8.3.1 Allenwood AFA Flood Cells within a 1% AEP Fluvial Flood Extent**

#### Summary of Flood Cells:

Out of bank flooding occurs from the Coolearagh River during a 1% AEP flood event due to insufficient channel capacity inundating the floodplain. Five properties are located within this floodplain however only 2 properties would incur a monetary damage by flooding during a 1% AEP flood event due to low FFLs as highlighted in Figure 8.3.1. The optioneering process therefore aims to address the risk to these 2 properties. As there is a single flood mechanism and relatively low risk this flood cell is considered to be a local cell.



### 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 Coolearagh River that flows through Allenwood AFA is located within the Barrow and Rathangan Drainage District. Further details of operations in this district are presented in section 6.3

### 8.3.4 Summary of Flood Risk within SSA boundary



**Figure 8.3.2 Flood risk in Allenwood AFA within a 1% AEP Fluvial Flood Extent**

In Allenwood AFA the onset of residential property damage occurs in the 1% AEP event. There are no non-residential properties at risk in this area.

### 8.3.6 Monetary Damage and Benefit

	Total in AFA
Annual Average Damage (AAD)	€1,622
Present Value Damage (pvD)	€34,849
Standard of Protection (SoP)	1%AEP
Number of Properties Benefiting from Design SoP	2
Minimum Present Value Benefit	€2,735
Capped Minimum Present Value Benefit	€2,735

\*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.



**8.3.8 Short Listing FRM Methods – Local Cell**

Method	Review Comment	Continue Screening
		Flood Cell 1
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	✓

### 8.3.8.1 Feasibility Review Summary for Local Cell (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				

### 8.3.8.2 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 the 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 can include clearance of channels and is also 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 are no obvious locations where the do minimum method would greatly reduce flood risk. Additional channel clearance would have minimal impact on flood risk due to the flood mechanism in this flood cell. This is an unacceptable outcome in terms of contributing to achieving a 1% AEP standard of protection and this method was therefore 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 situated within a catchment which is not considered suitable as a pilot area and therefore should not be progressed any further in the screening process.

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 reducing 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.

No suitable storage areas were identified, this method is therefore considered technically unfeasible.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✓	✗		

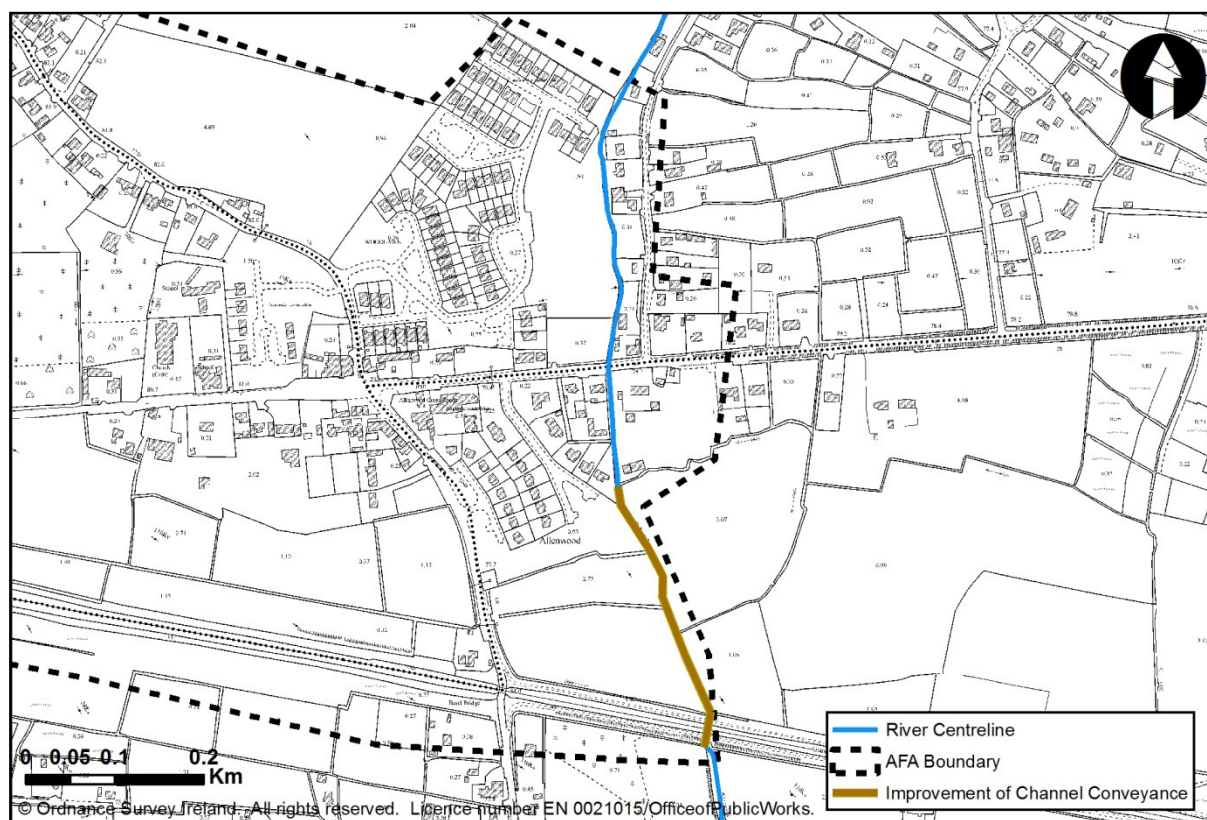
This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed level, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse and reducing roughness of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

Flood cell 1 is located beside the Coolearagh River where out of bank flooding is caused by inadequate channel capacity and insufficient capacity of the culvert under the Grand Canal.

It would be technically feasible to lower the bed level along the reach of the Coolearagh River where the flood risk originates and upgrade the culvert, as shown in Figure 8.3.3.

An economic review estimated the cost of improved channel conveyance to be €626,285 which is not

economically viable.

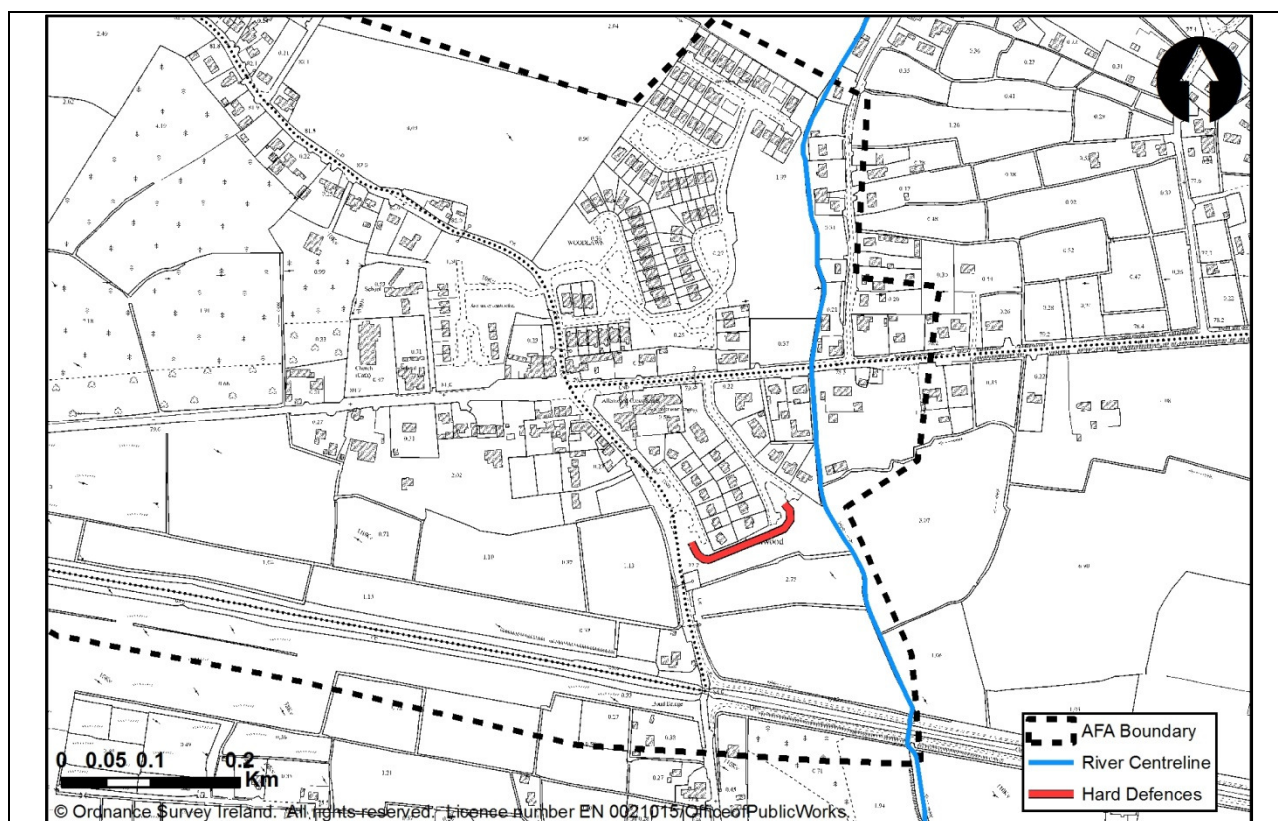


**Figure 8.3.3 Location of Channel Improvement**

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 8.3.4 shows the location of the Hard Defences required to protect properties during the 1% AEP event.



**Figure 8.3.4 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 1.3m and a total length of approximately 153m. An economic review estimated the cost of the hard defences to be €276,545 making this method economically unviable.

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 clusters of properties are located.

The 2 properties in flood cell 1 may be suitable for relocation however the cost to relocate these properties, based on the market value, is €514,924. This method is therefore not economically viable.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			

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.

A review was carried to identify locations where a Flow Diversion route could be constructed in the vicinity of flood cell 1. No suitable flow diversion routes were identified.



Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✓	✗		
<p>The application of flood warning / forecasting was tested at UoM scale. A suitable location far enough upstream of flood cell 1 is available to provide sufficient warning. This method is therefore technically feasible. An economic review estimated the cost of a flood forecasting and warning system to be €53,735 making this method economically unviable.</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 required SoP. For this reason this method should only be considered should no other method be found suitable. The estimated cost to provide protection to these properties is €22,806 this method is therefore considered economically unviable.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✗			
No other works were identified for these flood cells				
Summary of Feasibility Review – Flood Cell 1				
<p>As no feasible FRM options have been identified which offer the full or partial SoP, and there are properties currently at risk of flooding it is recommended that the existing regime is maintained to prevent a deterioration in the SoP at Allenwood.</p>				

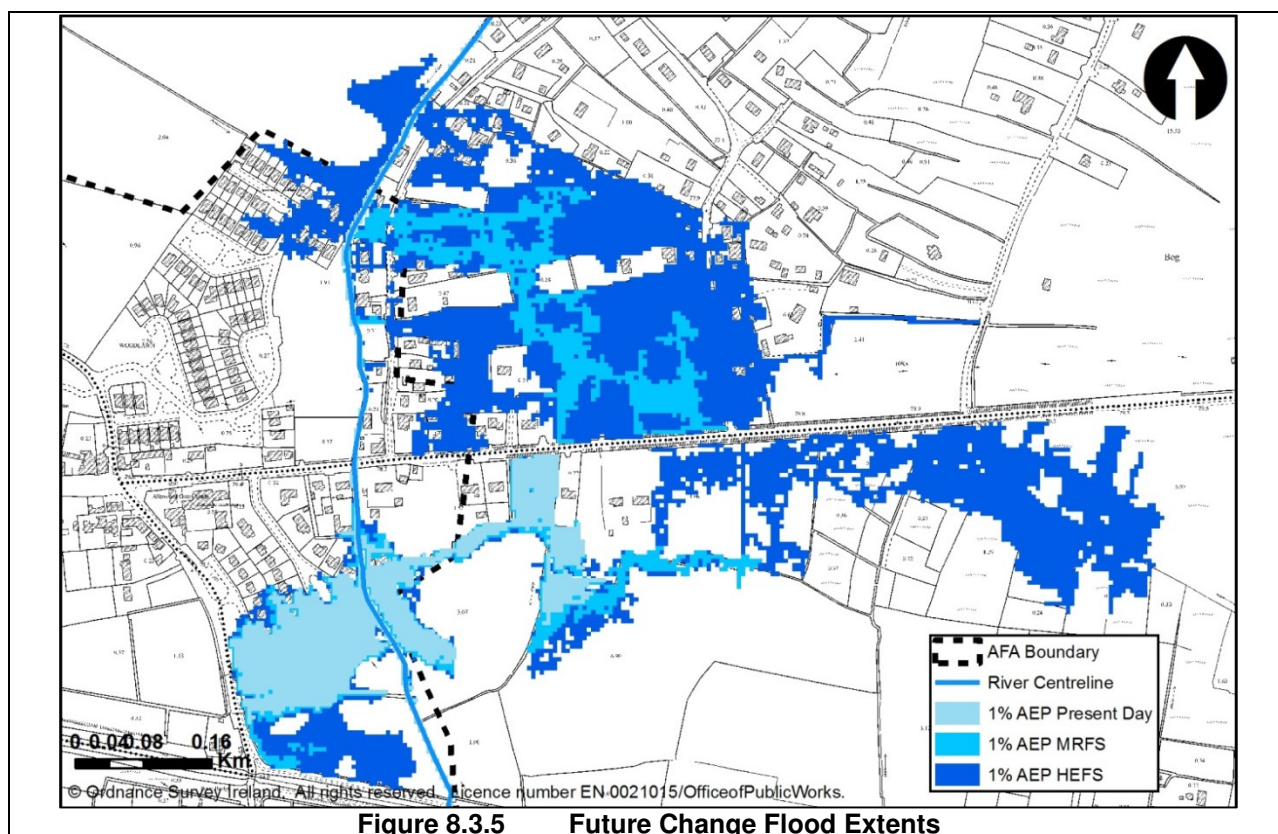
### 8.3.9 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Maintain Existing Regime	✓				
Maintain Existing Regime is the only option available for the Allenwood AFA as no feasible options which provide either the full or even a partial improved SoP to all properties have been identified.					
8.3.9.1 Option 1 Details – Maintain Existing Regime					
As no FRM options have been identified which offer the full SoP to all properties, Maintain Existing Regime it is recommended for the Allenwood AFA.					
In addition to this method the following was also identified at UoM level (see section 8.1) to be included in any potential option identified:					
<ul style="list-style-type: none"><li>• Planning and Development Control</li><li>• Building Regulations</li><li>• Sub-catchment Wide SuDs</li><li>• Strategic Development Management</li><li>• Public Awareness Campaign</li></ul>					
Total MCA-Benefit Score	Option Cost (€millions)		MCA-Benefit Score / Cost Ratio		
-	-		-		
Economic Appraisal (Cost-Benefit Analysis) Outcomes					
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio		
€34,849	-	€2,735	-		

### 8.3.9.2 AFA Sensitivity to Future Change

During a MRFS 1% AEP flood event the increase in flood extent is significant due to the topography of the Allenwood area. This would result in an additional 4 properties being at risk bringing the property count from 2 in the present day 1% AEP event to 6. The AAD would increase from €1,622 to €12,640. As a result Allenwood AFA would be considered to be at moderate vulnerability from the MRFS.

During the HEFS 1% AEP flood event the increase in flood extent is much more substantial. This would result in an additional 48 properties being at risk bringing the property count from 2 in the present day 1% AEP event to 50. The AAD would increase from €1,622 to €88,711. As a result Allenwood AFA would be considered to be at significant moderate vulnerability from the HEFS.



**Figure 8.3.5 Future Change Flood Extents**

### 8.3.9.3 Future Changes Adaptability

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

1. **Does the option reduce vulnerability?** Land Use Management and the sustainable planning and development management methods aimed at reducing future flood risk as discussed in section 8.1 at UoM scale. These methods will reduce the vulnerability of potential future receptors. Given that there is an increase in the number of properties affected in the MRFS and HEFS and a large proportion of the AFA with the potential for development there is a need to ensure that future receptors at risk are prepared.
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. Land Use Management has the ability to achieve these criteria well.
3. **Does the option deliver co-benefits?** No co-benefits were identified. However Land Use Management does have the ability to provide benefits to the environment and to agriculture.
4. **Does the option provide flexibility?** It is unlikely that Land Use Management features can be adapted to account for future flows however there may be scope to add additional features which collectively accommodate future flows. Alternative FRM methods could be added to provide an increased SoP. Hard defences could be used, making the option more flexible.
5. **Does the option allow for deferring/removing or abandoning?** Given the present day risk there is no allowance for options to be deferred however depending on the features used there might be scope to for removal in the future.

An objective for the 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 changes adaptability assessment the following summarises how well the option achieves this objective.

#### 8.3.9.4 Local Authority Comments

Kildare County Council initially reviewed the optioneering for Allenwood AFA in December 2015, the risk was reassessed and an updated analysis was reviewed in May 2016.

#### 8.3.9.5 Summary

There is good data available for Allenwood AFA with which to verify the model hydrology and hydraulics.

No options were found suitable in Allenwood AFA; therefore the existing regime should continue in order to maintain the current SoP. The existing and future flood extents should be considered for any proposed planning and development.

Methods also were identified at UoM level (see section 8.1) that are applicable to Allenwood 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 critical environmental, cultural heritage or social issues have been identified.

It should be noted that this area is moderately sensitive to climate change

Very low risk was identified in Allenwood AFA and no option was identified therefore the existing regime should be maintained to maintain the current SoP.

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 Athy Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Athy	Kildare	140150	AFA	Final	15/06/2016

#### 8.2.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.2.2 Flood Cells

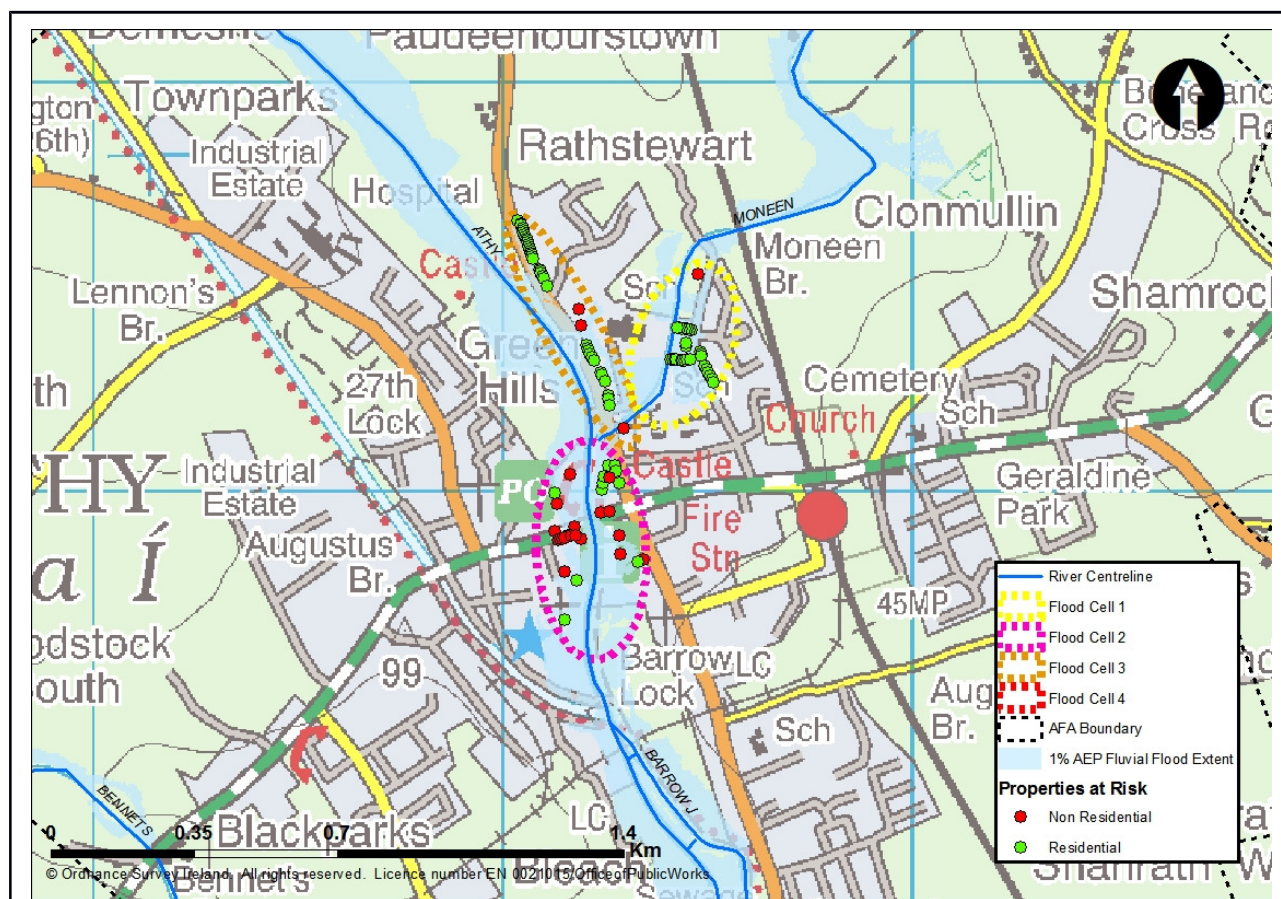


Figure 8.2.2.1.1.1.1.1

**Athy AFA Flood Cells within a 1% AEP Fluvial Flood Extent**

#### Flood Cell 1:

Flood cell 1 is located on the Moneen River, approximately 130m upstream of where it joins with the River Barrow. Model simulations show that during the 1% AEP fluvial event, flow is restricted by a culvert (14MONE0060D); once flood waters rise out of bank upstream of this surcharged culvert they follow an overland flow path down Moneen Lane. Further 'out of bank' flooding on the Moneen River occurs between chainage 2220 and 2384m. 28 properties along Convent View are affected; the majority (27) are



residential and the other is a school. Considering that this flood cell is influenced by the behaviour of a number of watercourses (Doll, Foxhill and Clogorrow) this flood cell is considered as complex.

#### **Flood Cell 2:**

Flood cell 2 encompasses the town centre of Athy. It is located on the River Barrow, downstream of the River Moneen inflow. The flooding mechanism associated with flood cell 2 is 'out of bank' flooding originating from the River Barrow which impacts on a total of 30 properties during a 1% AEP fluvial event. The majority of these affected properties are non-residential properties (19). This flood cell is considered as complex since the flooding mechanism is dependent upon the behaviour of both the River Barrow and the Moneen River.

#### **Flood Cell 3:**

Flood cell 3 is located upstream of flood cell 1 and 2. Within this flood cell, an overland flood flow path originating from the Moneen River merges with out of bank flooding from the River Barrow. A total of 40 properties are affected by a 1% AEP fluvial flooding event, the majority of these affected properties are residential (37); located along upper and lower St Joseph's Street (R417). This flood cell is also considered as complex, since flooding mechanisms are associated with the behaviour of both the Moneen and Barrow Rivers.

#### **Flood Cell 4:**

Flood cell 4 is situated close to the southern extent of the Athy AFA boundary; one non-residential property (warehouse); is affected by the occurrence of a 1% AEP fluvial flood event. This property is located at Ardleigh Lock, and is affected by overland flooding originating from the River Barrow. It is justified to consider this flood cell as local since only 1 property is affected.

#### **Summary of Flood Cells:**

As shown in Figure 8.4.1 the main flood risk associated with the Athy AFA (flood cells 1, 2 & 3) originates from the Moneen and Barrow Rivers. 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 (see Section 8.2.5).

Flood cell 4 is a discrete area with 1 property at risk and a single flood mechanism to consider. It is therefore appropriate to screen this flood cell as a standalone area to assess the options applicable as localised works (see Section 8.2.6).

On completion of the optioneering screening assessment measures for all flood cells will be combined to form complete options for the Athy AFA as detailed in Section 8.2.7.

### **8.2.1 Existing Regime**

The 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 with Athy AFA including the River Barrow and Moneen are part of the Barrow Drainage District. Further details of operations in this district are presented in section 6.3

### 8.2.3 Summary of Flood Risk within SSA boundary

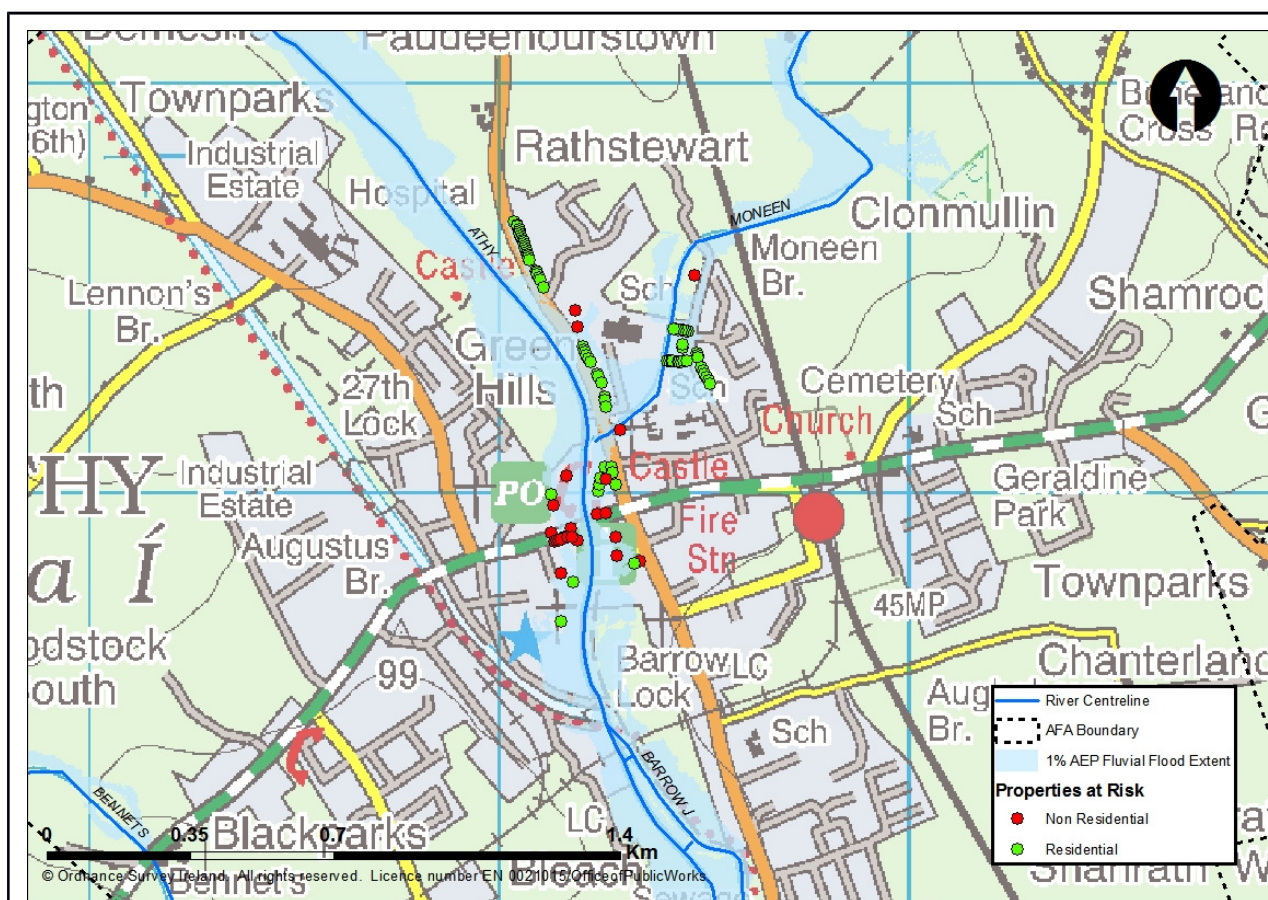


Figure 8.2.3.1.1.1.1.1.1 Flood risk in Athy AFA within a 1% Fluvial Flood Extent

In Athy AFA the onset of residential property damage occurs in the 50% AEP event in flood cells 1, 2 and 3. Non-residential properties are impacted in the 50% AEP event within flood cells 1, 2 and 3; and the 2% AEP event in flood cell 4. There are no residential properties at risk in flood cell 4.

### 8.2.4 Monetary Damage and Benefit

	Flood Cell 1, 2 & 3	Flood Cell 4	Total in AFA
Annual Average Damage (AAD)	€1,390,242	€188	€ 1,409,463
Present Value Damage (pvD)	€ 29,865,170	€4,046	€ 30,278,083
Preferred Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	98	1	99
Minimum Present Value Benefit	€28,030,819	€1,107	€28,031,926
Capped Minimum Present Value Benefit	€13,543,453	€1,107	€13,544,560

\*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.

**8.2.5 Short Listing FRM Methods – Complex Cells**

Method	Review Comment	Continue Screening
		Flood Cell 1, 2 & 3
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 at UoM SSA - Reject	✗
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	✓

8.2.5.1 Feasibility Review Summary for Complex Cell (flood cell 1, 2 & 3)				
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	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				
8.2.5.2 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 therefore was rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional Maintenance	✗			
This method considers the existing maintenance regime 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 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	x			

Do Minimum, applies to the FRM that may include clearance of channels and is also 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 cells 1, 2 & 3 there is little opportunity to improve the conditions in the Moneen and Barrow watercourses that would subsequently result in a reduction of the overall flood risk. Consequently, this FRM has been rejected from the screening process.

	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in the catchments / the large size of the catchments this method is considered unsuitable to benefit flood cells 1, 2 and 3. This method is therefore technically unfeasible.

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 reducing 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 technical review established that the volume of water required to be stored upstream of the flood cell 1 (Moneen River), is circa 611,713m<sup>3</sup>. This far exceeds the only available storage of 37,280 m<sup>3</sup>. None of this storage is available beyond the current 1%AEP event floodplain without affecting additional properties. The volume of water required to be stored upstream of flood cells 2 & 3 has been estimated to be 18,926,782 m<sup>3</sup>. This volume renders upstream storage as an unsuitable FRM to alleviate flooding within Athy during the occurrence of a 1% AEP fluvial event. In summary, Upstream Storage as a FRM can be considered as technically unfeasible.



Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

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

A technical review of the channel long-sections and critical structures within the vicinity of flood cells 1, 2 and 3 was conducted in order to identify sections of the Barrow and Moneen Rivers; where Improved Channel Conveyance could be applied, as shown in Figure 8.2.5.2.1.1.1.1.1.

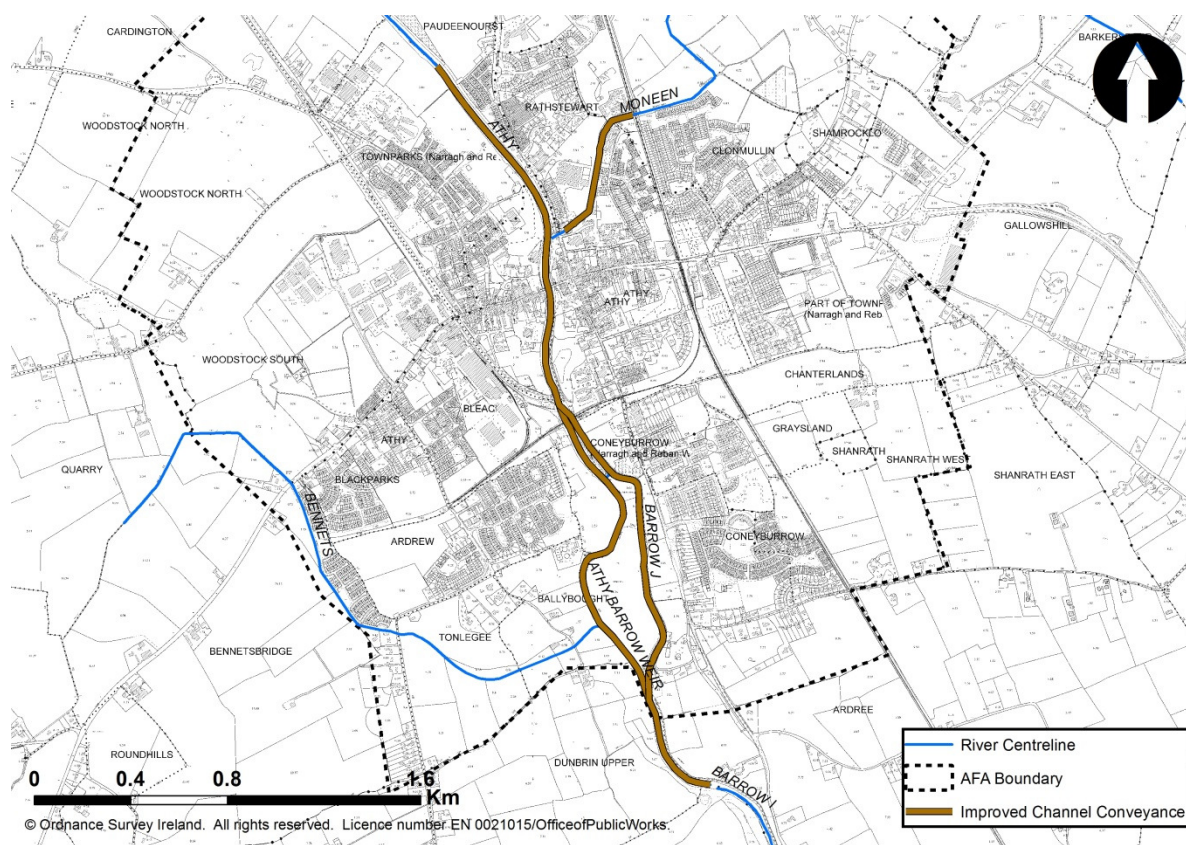


Figure 8.2.5.2.1.1.1.1.1 Location of Channel Improvement in Flood Cell 1, 2 & 3

In flood cell 1, the properties located adjacent to the Moneen River are at risk of flooding during the occurrence of a 1% AEP event. This is primarily due to insufficient channel capacity and the presence of the structure 14MONE00060D. Model simulations show that during a 1% AEP fluvial event, water spills out of the channel downstream of Moneen Bridge, forming a flow path situated on the left bank (SE). At this point, flooding could be prevented by dredging the channel and upgrading the structure 14MONE00060D to convey the 1% flow of approximately  $6.52\text{m}^3/\text{s}$ . It is technically feasible to lower the bed level along the Moneen River to improve channel conveyance although this would involve underpinning 1 bridge as shown in Figure 8.2.5.2.1.1.1.1.2 and dredging  $0.565\text{km}$  of the river. However, applying this FRM in isolation along the Moneen River would not significantly alleviate flooding within flood cells 2 and 3.

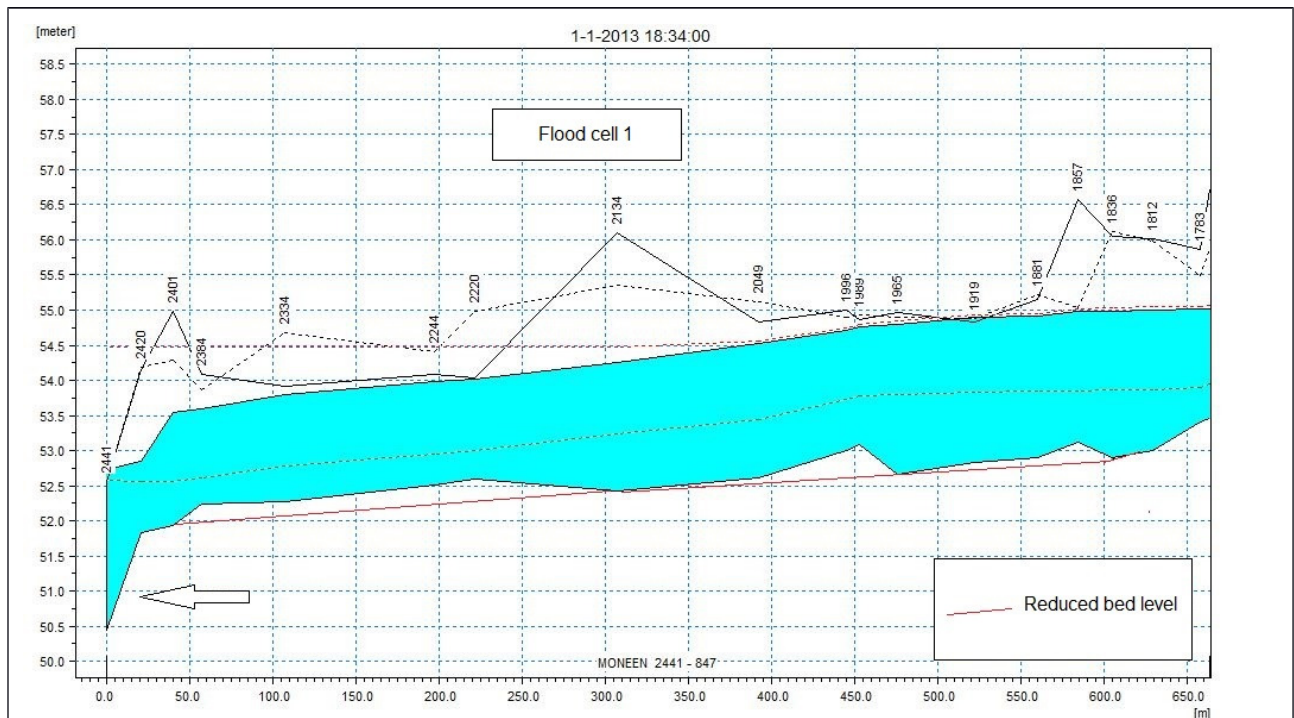


Figure 8.2.5.2.1.1.1.2 Potential Area of Improved Conveyance (Moneen River)

In order for improvement of channel conveyance to be effective within Athy, the application of this methodology needs to be extended to flood cell 2 and flood cell 3. In flood cells 2 and 3 it is technically feasible to lower the bed level along the River Barrow, as shown in Figure 8.2.5.2.1.1.1.3.

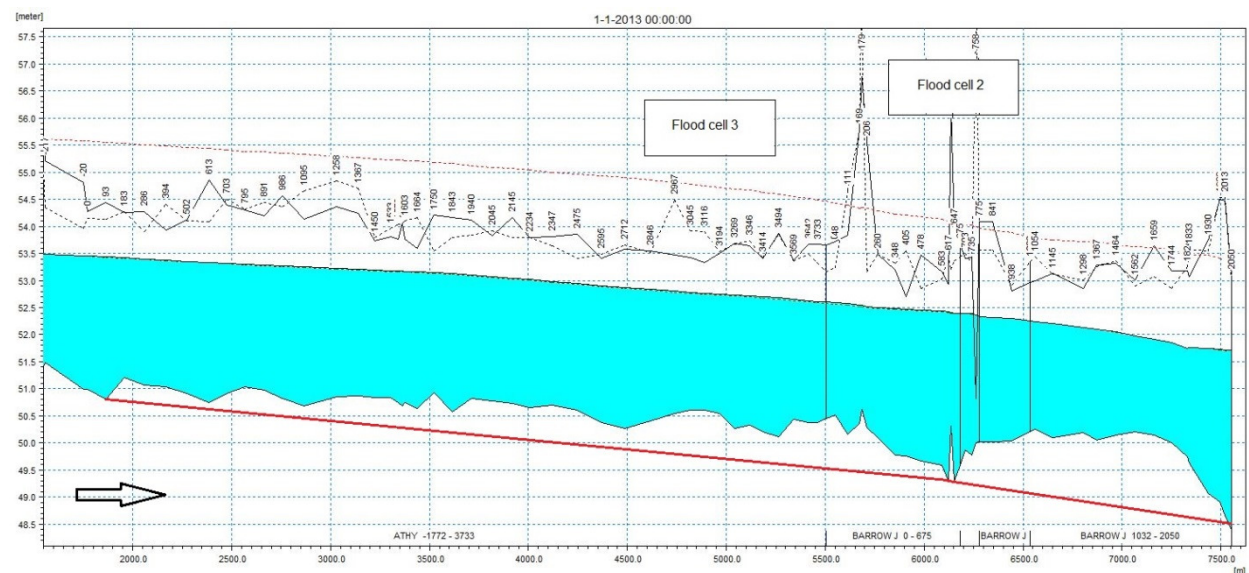


Figure 8.2.5.2.1.1.1.3 Potential Area of Improved Conveyance (River Barrow)

In total it is estimated that improved channel conveyance along the Barrow and Moneen Rivers involves dredging a total river length of 4.3km, excavating some 164,565m<sup>3</sup> of material and underpinning 4 bridges. It is noted that this scheme would also alleviate flooding in flood cell 4. However, it is estimated that this method would cost approximately €15,836,993 making this method economically unviable.



Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	!	✓

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.

For Athy, a technical review was conducted to ascertain the locations where Hard Defences should be positioned, to protect at risk properties. Figure 8.2.5.2.1.1.1.4 shows the locations of Hard Defences with a SoP of 1% AEP.

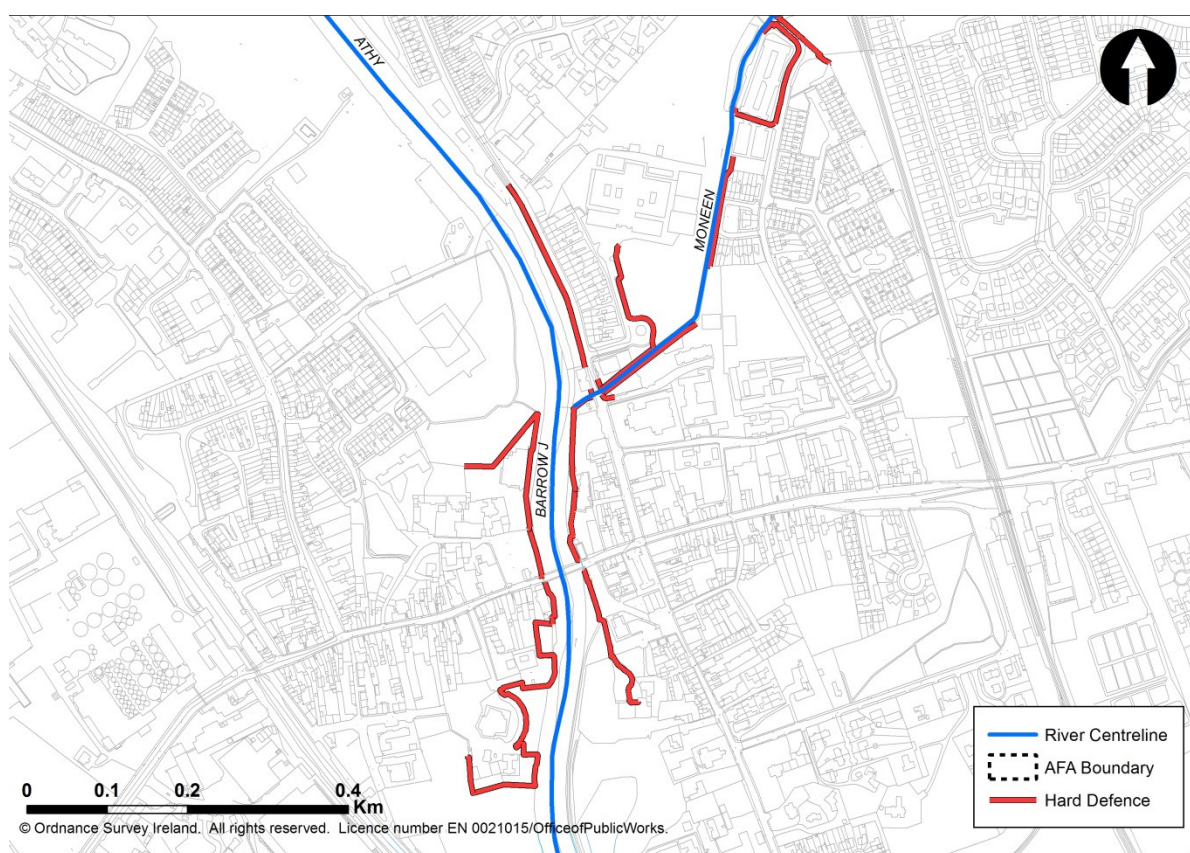


Figure 8.2.5.2.1.1.1.4 Location of Potential Hard Defences within Athy

The hard defences required in flood cell 1 to protect the properties during the 1% AEP event are a combination of walls and embankments. A series of flood walls and embankments would be placed along the Moneen River to protect properties located along Moneen Lane and Convent Lane.

In flood cell 2, a series of walls and embankments are required to be emplaced along St Joseph's Terrace and Stanhope Street to provide the required SoP from the River Barrow. A series of walls and embankments would be emplaced on the right bank (to the west) to protect commercial properties located upstream of where the N78 crosses over the River Barrow. This series of walls and embankments continue downstream on both banks of the River Barrow, protecting properties located along Offaly Street and Convent Lane.

In order to ascertain the effect 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 1.3m and a total length of 2.4 km. An economic review estimated the cost of the hard defences to be approximately €4,020,751 making this method economically viable.

The Athy AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Grand Canal pNHA travels through Athy. Derryvullagh Island is over 4km up-catchment of Athy. Stradbally Hill pNHA is over 5km upcatchment of the AFA. The Derries Wood pNHA is over 12km upstream of Athy. IWeBS key sites in the vicinity.

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✓	✓	✓	✓

The application of flood warning / forecasting was tested at UoM scale. A suitable location far enough upstream of flood cells 1, 2 and 3 is available to provide sufficient warning. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.

An economic review estimated that the cost of providing one hydrometric gauging station with simple forecasting systems would be approximately €47,492. This method is therefore economically viable.

The proposed gauging station is not within any environmental designations and it is unlikely that flood forecasting would have any impact to designated sites in the vicinity of Athy 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 clusters of properties are located.

An assessment of the distribution of properties within flood cells 1, 2 & 3 was carried out. No discrete clusters of properties were found. This method was therefore considered technically unfeasible.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			

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.

A technical review was conducted to identify possible flow diversion routes. For flow diversion to work it involves diverting flow from upstream of the risk area and discharging it back into the River downstream. No possible flow diversion routes have been identified where the Moneen and Barrow Rivers can by-pass at risk locations within Athy. The Moneen River and River Barrow already occupy the lowest topographic route and Athy's urban centre has developed within this flood plain area. Since no alternative diversion routes can be identified this method is therefore technically unfeasible.

Method	Tech	Econ	Env	Soc
--------	------	------	-----	-----

Individual Property Protection	x	✓	✓	✓
<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 required SoP within flood cells 1, 2 and 3, and would therefore not be technically the best method to use. For these reasons this method should only be considered should no other method be found suitable.</p> <p>The estimated cost to provide protection measures for these properties is €1,441,343 making it economically viable.</p> <p>The Athy AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Grand Canal pNHA travels through Athy. Derryvullagh Island is over 4km up-catchment of Athy. Stradbally Hill pNHA is over 5km upcatchment of the AFA. The Derries Wood pNHA is over 12km upstream of Athy. IWeBS key sites in the vicinity.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for this flood cell.				
<b>8.2.5.3 Summary of Feasibility Review – Flood Cells 1, 2 &amp; 3</b>				
<p>The following FRM has been carried forward to address the flood risk arising from flood cells 1, 2 and 3;</p> <ul style="list-style-type: none"> <li>• Hard Defences</li> </ul> <p>Hard Defences as a standalone method has passed through the screening process, since this method can provide the full protection to all properties during the occurrence of a 1% AEP fluvial flood event.</p>				



**8.2.6 Short Listing FRM Methods – Local Cell (Flood cell 4)**

Method	Review Comment	Continue Screening
		Flood Cell 4
Do Nothing	Consider Further	x
Additional Maintenance	Consider Further	✓
Do Minimum	Consider Further	✓
Planning and Development Control	Consider at UoM SSA - Reject	✓
Building Regulations	Consider at UoM SSA - Reject	x
Catchment Wide SuDs	Consider at UoM SSA - Reject	x
Land Use Management	Consider Further	x
Strategic Development Management	Consider at UoM and Sub-Catchment SSA - Reject	✓
Storage	Consider Further	x
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 and Sub-Catchment SSA - Reject	✓
Individual Property Protection	Consider Further	x
Other Works	Consider Further	✓

8.2.6.1 Feasibility Review Summary of FRM Methods for flood cell 4				
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	Social Screening
Do Nothing	✓			
Additional Maintenance	✗			
Do Minimum	✗			
Land Use Management	✗			
Storage	✗			
Improvement of Channel Conveyance	✗	✓		
Hard Defences	✗	✓	!	✓
Flood Warning/Forecasting	✓	✓	✓	✓
Relocation of properties	✓	✓	✓	?
Diversion of Flow	✓			
Individual Property Protection	✗	✓	✓	✓
Other Works	✓			
✗ - Reject    ✗ - Progress    ? - Progress, potential for impacts identified    ! - Progress, potential for significant impacts identified				
8.2.6.2 Justification for Rejection/Retention				
Method	Tech	Econ	Env	Soc
Do nothing	✓			
The do nothing FRM method for flood cell 4 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	✗			
As the degree of flood risk stays as present within flood cell 4, the resulting SoP is considered unacceptable and increasing maintenance will not be pursued under the CFRAM Study.				
Method	Tech	Econ	Env	Soc
Do Minimum	✗			

Flooding within cell 4 occurs as the result out of bank flooding upstream from this point. The relatively low bank levels allow flood waters to spill out of bank during a 1% AEP fluvial flood event. Within flood cell 4 there is little opportunity to improve conditions close to the River Barrow. Consequently, there is little scope to reduce the overall flood risk within this flood cell. 'Do Minimum' is an unacceptable outcome in terms of contributing to achieving a design SoP and was therefore rejected from the screening process.

Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to large size of the catchment the method is considered unsuitable to benefit flood cell 4. This method is technically unfeasible.

Method	Tech	Econ	Env	Soc
Storage	x			

The volume of water required to be stored on the Barrow River before reaching flood cell 4 has been estimated to be approximately 18,926,782m<sup>3</sup>. A review of the surrounding land was carried out but no suitable location was found to accommodate this volume of water. This method is therefore considered technically unfeasible.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

In flood cell 4, flooding during a 1% AEP fluvial event is the result of insufficient channel capacity and an overland flow paths that pass through flood cell 4.

A technical review of the River Barrow channel long section where 'Improved Channel Conveyance' would benefit flood cell 4 was progressed from the review conducted for flood cells 1, 2 and 3 upstream of this location (refer to Figure 8.2.5.2.1.1.1.1.1). Figure 8.2.6.2.1.1.1.1.1 shows a long section highlighting the areas and depth to which the bed level should be deepened, that would particularly benefit flood cell 4 as well as the other flood cells (1 to 3) that are located upstream of this location.

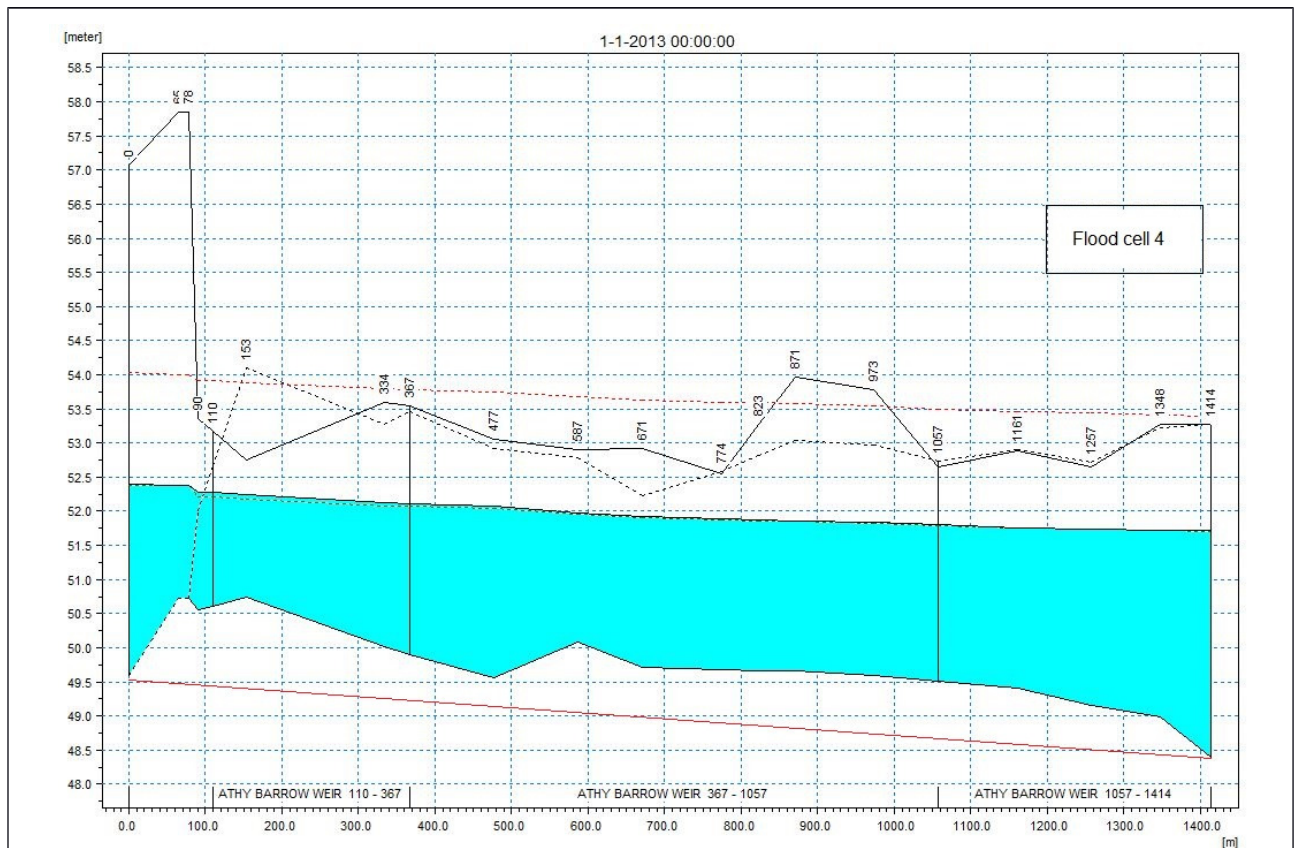


Figure 8.2.6.2.1.1.1.1.1 Potential Area of Improved Conveyance (River Barrow)

Although, the Improvement of Channel Conveyance as a FRM would be technically viable, when considered along with dredging the River Channel upstream of flood cell 4, the total estimated cost of these works is approximately €17,366,082 making this method potentially economically unviable.

Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	!	✓

A review was carried out to ascertain where Hard Defences would be required to protect existing property within flood cell 4. Figure 8.2.6.1.1.1.1.8 shows the location of the Hard Defences required to protect the single commercial property in flood cell 4 during the 1% AEP event.

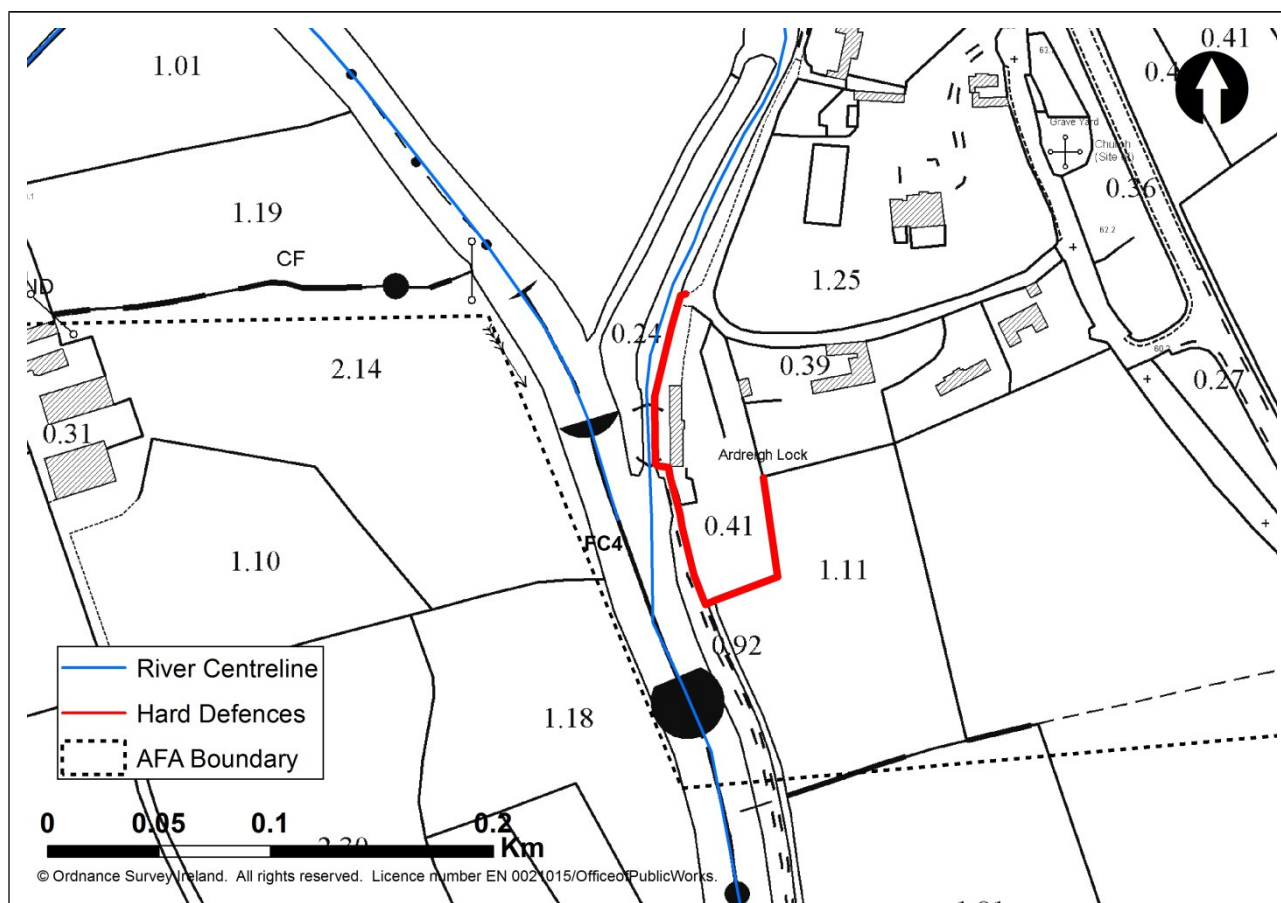


Figure 8.2.6.1.1.1.1.8 Location of Hard Defence in Flood Cell 4

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 1.1m and a total length of 230m. An economic review estimated the cost of the hard defences is approximately €127,227 making this FRM economically feasible for flood cell 4.

The Athy AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Grand Canal pNHA travels through Athy. Derryvullagh Island is over 4km upcatchment of Athy. Stradbally Hill pNHA is over 5km upcatchment of the AFA. The Derries Wood pNHA is over 12km upstream of Athy. IWeBS key sites in the vicinity.

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✓	✓	✓	✓

The application of flood warning / forecasting was tested at UoM scale. Several locations along the River Barrow have been identified upstream of Athy and flood cell 4 to provide sufficient warning. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.

There are a number of active gauging stations currently located in UoM14 and where possible it is recommended that these stations be modified to provide real-time data for forecasting. An economic review estimated that the cost of providing one hydrometric gauging station with simple forecasting systems would be approximately €47,492. This method is therefore economically viable. However, this basic cost is expected to rise with the addition and upgrade of other gauges along the River Barrow.



It is unlikely that flood forecasting would have any impact to designated sites in the vicinity of the Athy AFA.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✓			

A technical review was carried out to assess the suitability of a flow diversion that would alleviate flooding within flood cell 4. Since the flooding that affects flood cell 4 is influenced by flood flow paths that have originated upstream and given the relatively level topography associated with the Ardreigh, no suitable diversion route has been identified.

Method	Tech	Econ	Env	Soc
Relocation of properties	x	✓	✓	?

The property at risk during the design event within flood cell 4 is a warehouse (including store). In principle this commercial property could be moved elsewhere and the €93,136 market value associated with this property justifies this method as economically feasible.

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

While this method would not provide the required design 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 the pass through the screening process. It is estimated that 'Individual Property Protection' of this property would cost €258,472; therefore this method is economically feasible.

Method	Tech	Econ	Env	Soc
Other Works	✓			

No other works were identified for this flood cell.

#### 8.2.6.3 Summary of Feasibility Review – Flood Cell 4

The following FRM has been carried forward to address the flood risk arising from flood cell 4

- Hard Defences
- Relocation of properties

Hard Defences as a standalone method has passed through the screening process, since this method can provide the full protection to all properties during the occurrence of a 1% AEP fluvial flood event. The Relocation of properties has also passed through the screening process, where this single commercial property would be relocated to an area of lesser flood risk. Individual Property Protection can only provide partial protection. Individual Property Protection should only be used should Hard Defences be deemed unsuitable later in the optioneering process.

## 8.2.7 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Hard Defences	x	✓			
Relocation of Properties (Flood cell 4)	✓	x			

Flood cell 1, 2 and 3 - Hard Defences option is carried forward relating to these complex flood cells. Hard Defences or Relocation of Properties (flood cell 4) has also been carried forward for this local flood cell.

### 8.6.7.1 Option 1 Details - Hard Defences (Flood cells 1, 2, 3 & 4)

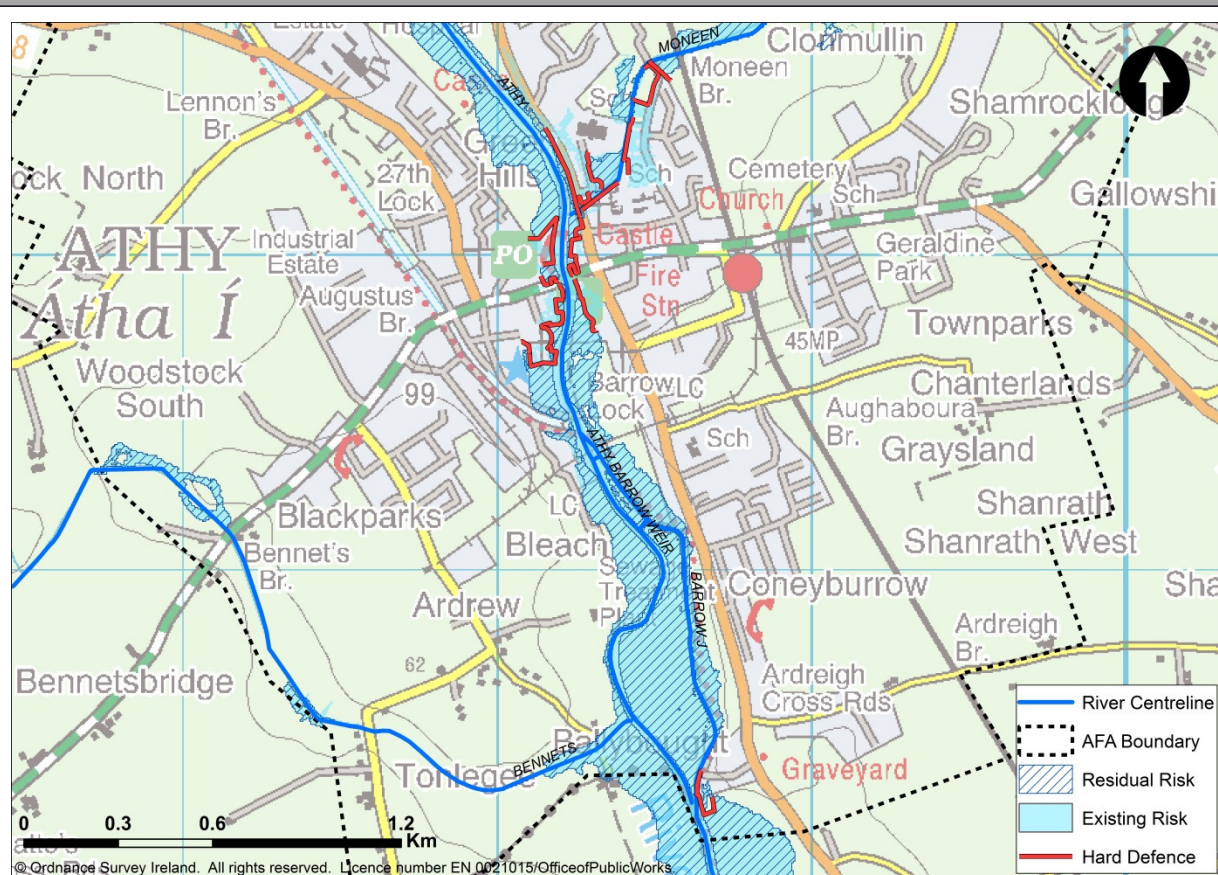


Figure 8.2.7.1.1.1.1.1

Athy AFA Option 1

At risk properties would be protected by a series of 'Hard Defences' consisting of flood embankments and walls as shown in Figure 8.2.8. These hard defences would protect to the 1% AEP fluvial flood event with an average height of 1.2km and a total length of 2.5km.

Figure 8.2.7.1.1.1.1.1.1 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 Hard Defence, 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Urban Wall	608m length, 1.29m high (average)	€1,193,005	
Embankment	1.9km length, 1.33m high (average)	€528,549	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
1642	4.11	399.45	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€30,278,083	€4,112,090	€13,544,560	3.29

#### 8.2.7.2 Option 2 Details - Hard Defences and Relocation of Properties (Flood Cell 4)

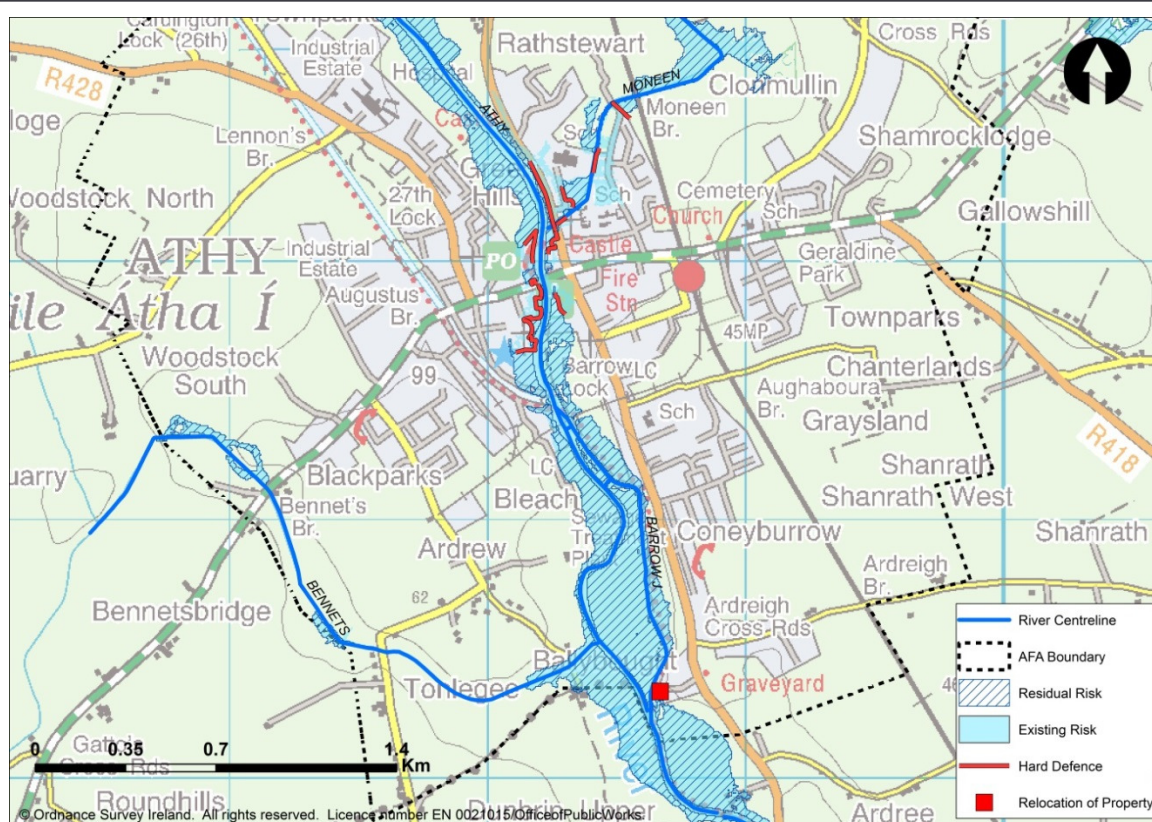


Figure 8.2.10 Athy AFA Option 2

At risk properties will be protected with a series of Hard Defences, particularly within flood cells 1, 2

and 3. The isolated commercial property located downstream within flood cell 4 would be relocated elsewhere, to an alternative area of lesser flood risk.

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).

The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Urban Wall	608m length, 1.29m high (average)	€1,193,005	
Embankment	1.7km length, 1.33m high (average)	€484,499	
Individual Property Protection	1 Commerical Property (FC4)	€93,136	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
1642	4.06	404.89	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€30,278,083	€4,056,410	€13,544,560	3.34



### 8.2.7.3 AFA Sensitivity to Future Changes

During a MRFS 1% AEP flood event the increase in flood extent is controlled by the fluvial basin terrain associated with the Barrow River. The main area of additional flood risk is associated with the Rathstewart area of Athy.

During a MRFS 1% AEP event an additional 109 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €1.4million to €1.43million. As a result Athy AFA would be considered to be at high vulnerability from the MRFS.

During a HEFS 1% AEP flood event there would be a significant increase in flood extent. This would result in an additional 322 properties being at risk bringing the property count from 99 in the present day 1% AEP event to 421. The AAD would increase from €1.4million to €11.03 million. As a result Athy AFA would be considered to be at high vulnerability from the HEFS.

The addition of further properties affected by future changes indicates a proportional increase of the annual average damage associated with the Athy AFA. Therefore, Athy would be considered to be at high vulnerability. Options were therefore assessed for their adaptability to future change.

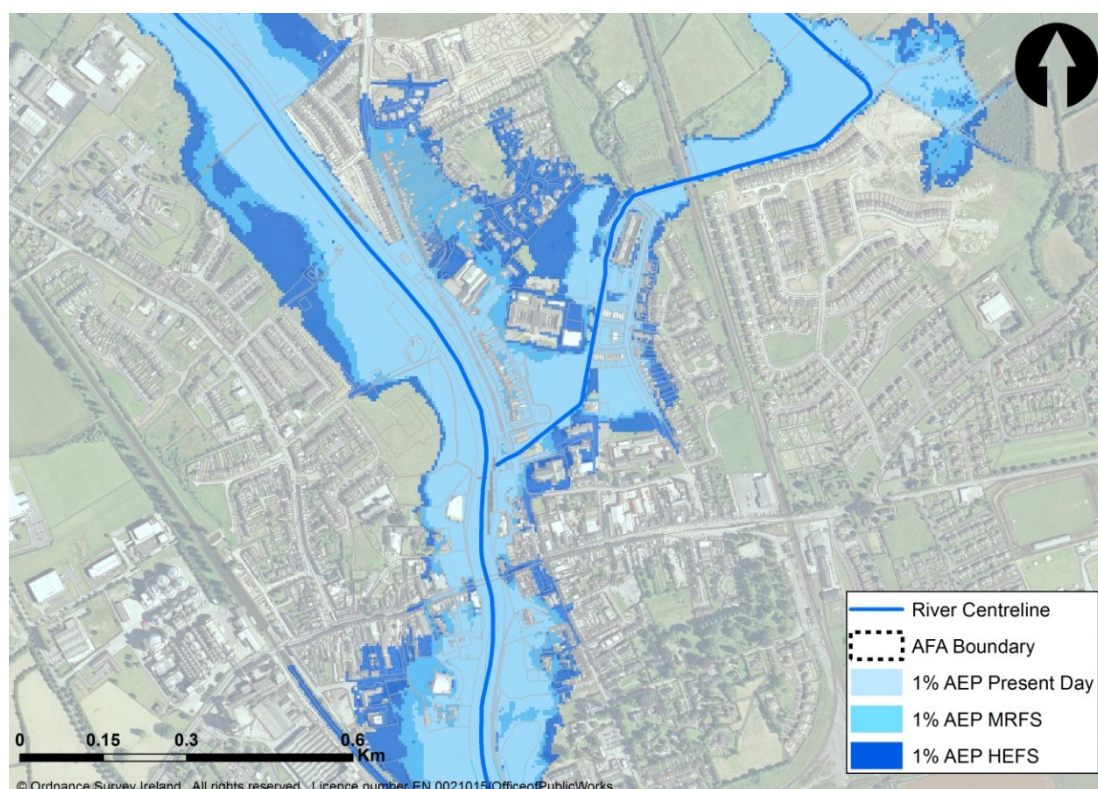
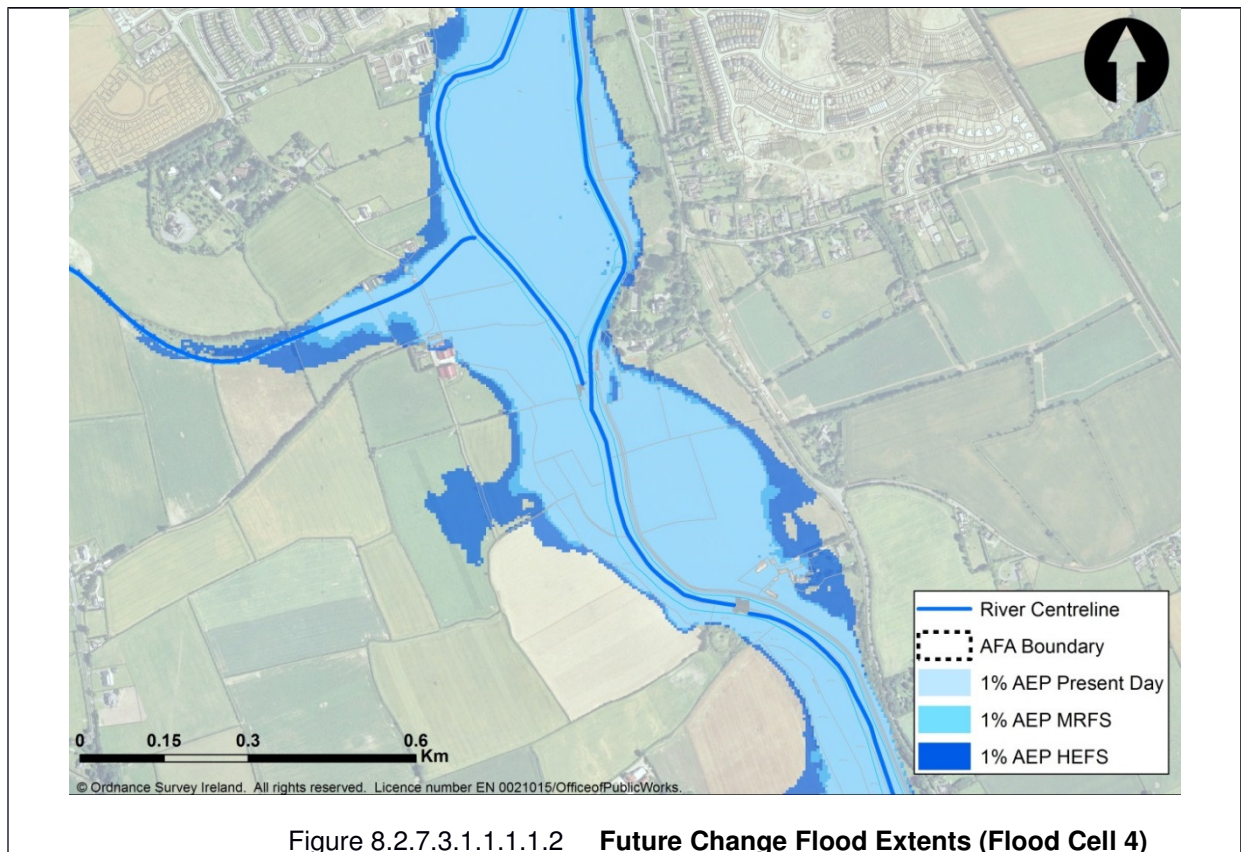


Figure 8.2.7.3.1.1.1.1.1 Future Change Flood Extents (Flood Cell 1, 2 & 3)





#### 8.2.7.4 Future Change Adaptability

The following discusses the adaptability of the potential FRM methods proposed within Athy AFA:

**Hard Defence Flood Cell 1** - This method could be adapted by increasing the height of the wall and extending its length. A review of the effect of the MRFS and the HEFS showed that the walls might need to be increased from a 1.49m average to 1.93m and 2.01m average, for the MRFS and HEFS respectively. This additional wall height could be accommodated. The review also showed that the additional length of wall required would be minimal. To ensure that this wall would be adaptable the design would need to account for the potential increase on wall height. This method is considered to have a **moderate to poor** adaptability.

**Hard Defence Flood Cell 2** - This method could be adapted by increasing the height of the wall and extending its length. A review of the effect of the MRFS and the HEFS showed that the walls might need to be increased from a 1.3m average to 1.7m and 2.0m average, for the MRFS and HEFS respectively. This additional wall height could be accommodated. The review also showed that the additional length of wall required would be minimal. To ensure that this wall would be adaptable the design would need to account for the potential increase on wall height. This method is considered to have a **moderate to poor** adaptability.

**Hard Defence Flood Cell 3** - This method could be adapted by increasing the height of the wall and extending its length. A review of the effect of the MRFS and the HEFS showed that the walls might need to be increased from a 1.3m average to 1.6m and 2.0m average, for the MRFS and HEFS respectively. This additional wall height could be accommodated. The review also showed that the additional length of wall required would be approximately 0.70m. To ensure that this wall would be adaptable the design would need to account for the potential increase on wall height. This method is considered to have a **moderate to poor** adaptability.

**Hard Defence Flood Cell 4** - This method could be adapted by increasing the height of the wall and extending its length. A review of the effect of the MRFS and the HEFS showed that the walls might need to be increased from a 1.1m average to 1.3m and 1.8m average, for the MRFS and HEFS respectively. This additional wall height could be accommodated. The review also showed that the additional length of wall required would be approximately 0.40m. To ensure that this wall would be adaptable the design would need to account for the potential increase on wall height. This method is considered to have a **moderate to poor** adaptability.

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 Athy is currently urbanised there would be some scope for these methods to impact upon the area being assessed. Since there is a significant increase in the number of properties affected in the MRFS and HEFS there is still a need to ensure that the owners and users future receptors at risk are prepared through methods such as public awareness campaign.
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 the future. Options which include hard defences restrict the water making water levels more sensitive to increased flow. Options 1 and 2 would create this situation, however, where possible flood defences have been set as far back from the river's edge to allow the flood plain to function as much as is possible. This also minimises the visual impact of hard defences upon the green spaces associated with Athy riverside location.
3. **Does the option deliver co-benefits?** No direct co-benefits have been identified. However, option 1 and 2 and the emplacement of the hard defences located close to the river's edge may also act as a public safety feature, ensuring the safety of the public walking close to the rivers edge.
4. **Does the option provide flexibility?** The potential options proposed for Athy both include Hard Defences. A review has shown that this FRM is the most adaptable to the MRFS and

HEFS.

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, it is not impossible to remove the emplaced Hard Defence; however this is not recommended considering the high degree of vulnerability associated with Athy.

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 the table below summarises how well each option achieves this objective.

Summary of Option Adaptability		
Option	Description	Score
Option 1 - Hard Defences (FC1, 2, 3 & 4)	Option is adaptable at moderate cost, difficulty and impact	3
Option 2- Hard Defence (FC1, 2, 3) and Relocation of Properties (FC4)	Option is adaptable at moderate cost, difficulty and impact	3

### 8.2.7.5 Local Authority Comments

Local Authority representatives reviewed the options in December 2015 and provided commentary as follows

- It was empathised that Athy is an important location for archaeology and that this should be reflected when assessing the local weightings.
- It was also commented that the proposed option relating to 'Hard Defence' appeared to be a pragmatic solution.

### 8.2.7.6 Summary

There is good confidence in both the hydrology and hydraulics of the Athy AFA due to the presence of a gauging station and flood extent verification events.

The following potential options, with a BCR  $\geq 0.5$  have been identified:

- Option 1 – Hard Defence (FC 1, 2, 3 & 4)
- Option 2 – Hard Defence (FC1, 2 & 3) and Relocation (FC4)

Alongside any potential option the existing regime should continue with maintenance being carried out ad hoc when resources allow. Once the potential Hard Defences are established, Maintenance of these structures should also form part of the ongoing regime.

Methods also were identified at UoM level (see section 8.1) that are applicable to Athy 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 AFAs are located upstream or downstream that would be affected by any of the potential options identified. However there are a number of rural locations downstream of the Athy AFA. The flow at the downstream model boundary was reviewed for the 1% AEP current scenario versus the 1% AEP with the option in place scenario. There was a negligible flow difference between the hydraulic model simulations.

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.

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

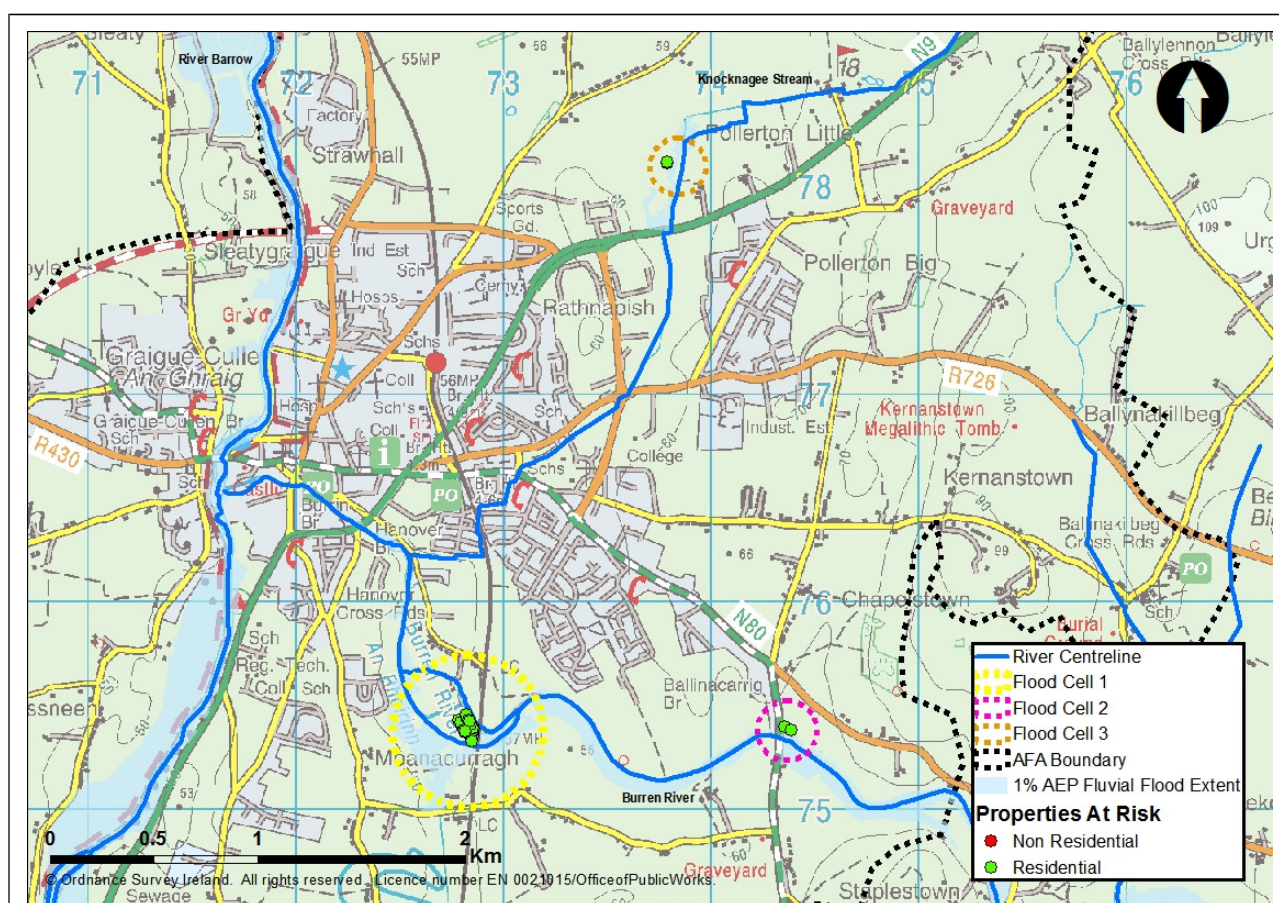
### 8.5 Carlow Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Carlow	Carlow	140155	AFA	Final	15/06/2016

#### 8.3.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.3.2 Flood Cells



**Figure 8.3.2.1.1.1.1.1 Carlow AFA Flood Cells within a 1% AEP Fluvial Flood Extent**

#### Flood Cell 1:

Flooding within flood cell 1 during a 1% AEP fluvial event, is a consequence of insufficient channel capacity, causing flood water to spill out of the Millrace and the Burren River. As a consequence, 31 properties on Burrin Road are flooded. This flood risk is caused by a single flood mechanism and flood cell 1 is therefore considered as local.



**Flood Cell 2:**

Flood cell 2 is located on the Burren River and approximately 1km upstream of flood cell 1. This flood cell includes the critical structure, Ballinacarrig Bridge (14BURN00400E). The presence of this critical structure restricts flood flow during a 1% AEP fluvial event, leading to the flooding two residential properties located on the right bank (north). This flood cell has been defined as local since flooding is caused by a single flood mechanism and affects a discrete area with two properties at risk.

**Flood Cell 3:**

Flood cell 3 is located on the right bank of the Knocknagee Stream. During a 1% fluvial event, the presence of the critical structure (14KNOK00183I) restricts flow. As a consequence, two residential properties located at Lakeside are flooded. This flood cell has been defined as local since flooding is caused by a single flood mechanism.

**Summary of Flood Cell:**

The Carlow Flood Defence Scheme was completed in 2013. Flood defences (retaining walls) were constructed along the River Barrow and Burren River. Prior to the completion of this flood defence scheme the extent of flooding within Carlow AFA was significantly greater.

As shown in Figure 8.3.2.1.1.1.1.1 three flood cells have been identified within Carlow AFA. Flood Cell 1 is a discrete area with a large number of properties at risk. It is justified to screen this flood cell as a standalone area, assessing options as applicable localised works.

Flood cells 2 & 3 are also discrete but separate areas with few properties at risk and single separate flood mechanisms to consider. It is therefore appropriate to screen these flood cells separately as standalone areas assessing options as applicable localised works.

On completion of the optioneering screening assessment, measures for all flood cells will be combined to form complete options for the Carlow AFA as detailed in Section 8.3.2.

**8.3.3 Existing Regime**

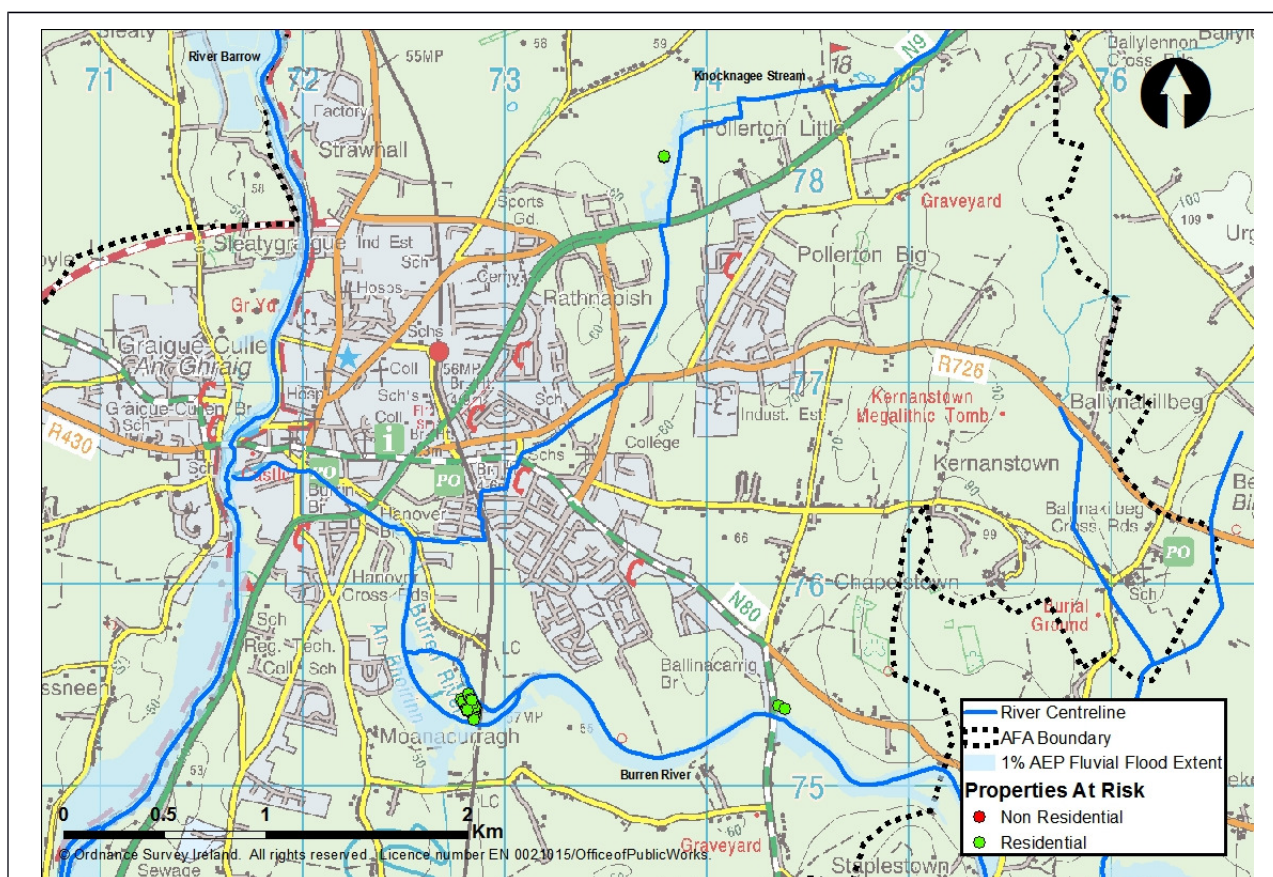
The existing regime considers all activities currently carried out which impact on the management of flood risk. The level and frequency of maintenance is considered, along with inspection, and any other specific activity (for example the operation of locks, barrages, sluice gates and valves).

The rivers within Carlow are maintained by Carlow County Council who carry out routine inspections and maintenance as and when resources are available. The Carlow Flood Defence Scheme was completed in 2013. Flood defences (retaining walls) were constructed along the River Barrow and Burren River. Prior to the completion of this flood defence scheme the extent of flooding within Carlow AFA was greater. More recently (November 2015), the council have been involved in a local scheme (Paupish Lane flood prevention works); this has been implemented to alleviate flooding within flood cell 1.

Regardless, of the flood remedial works, some properties are still being frequently flooded; therefore an extension to the existing regime is required to achieve a standard of protection throughout Carlow AFA. This report details the assessment of a range of flood risk management measures with the aim of identifying alternative and additional options.

Several watercourses that flow through Carlow, particularly the Burren River and downstream extent of the Knocknagee Stream are located within the Burren and the Barrow Drainage District. Further details of operations in these districts are presented in section 6.3

### 8.3.4 Summary of Flood Risk within SSA boundary



**Figure 8.3.4.1.1.1.1.1 Flood Risk in Carlow AFA 1% AEP**

In Carlow AFA the onset of residential property damage occurs in the 1% AEP event in flood cell 1 and the 10% AEP in flood cells 2 and 3. There are no non-residential properties at risk in any of the flood cells within Carlow AFA.

### 8.3.5 Monetary Damage and Benefit

	Flood Cell 1	Flood Cell 2	Flood Cell 3	Total in AFA
Annual Average Damage (AAD)	€71,333	€7,870	€15,199	€394,872
Present Value Damage (pvD)	€ 1,532,383	€169,067	€326,507	€8,482,650
Preferred Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	31	2	2	35
Minimum Present Value Benefit	€434,110	€116,168	€296,246	€1,446,270
Capped Minimum Present Value Benefit	€434,110	€116,168	€296,246	€846,524

\*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.

**8.3.6 Short Listing FRM Methods – Local Cells (Cells 1, 2 & 3)**

Method	Review Comment	Continue Screening		
		Flood Cell 1	Flood Cell 2	Flood Cell 3
Do Nothing	Consider Further		✓	✓
Additional Maintenance	Consider Further	✓	✓	✓
Do Minimum	Consider Further	✓	✓	✓
Land Use Management	Consider at UoM SSA - Reject	✓	✓	✓
Storage	Consider Further	✓	✓	✓
Improvement of Channel Conveyance	Consider Further	✓	✓	✓
Hard Defences	Consider Further	x	✓	✓
Relocation of Properties	Consider Further	✓	✓	✓
Diversion of Flow	Consider Further	✓	✓	✓
Flood Warning/Forecasting	Consider at UoM SSA - Reject	✓	✓	✓
Individual Property Protection	Consider Further	✓	✓	✓
Other Works	Consider Further	✓	✓	✓

## 8.3.5.1 Feasibility Review Summary for flood cell 1

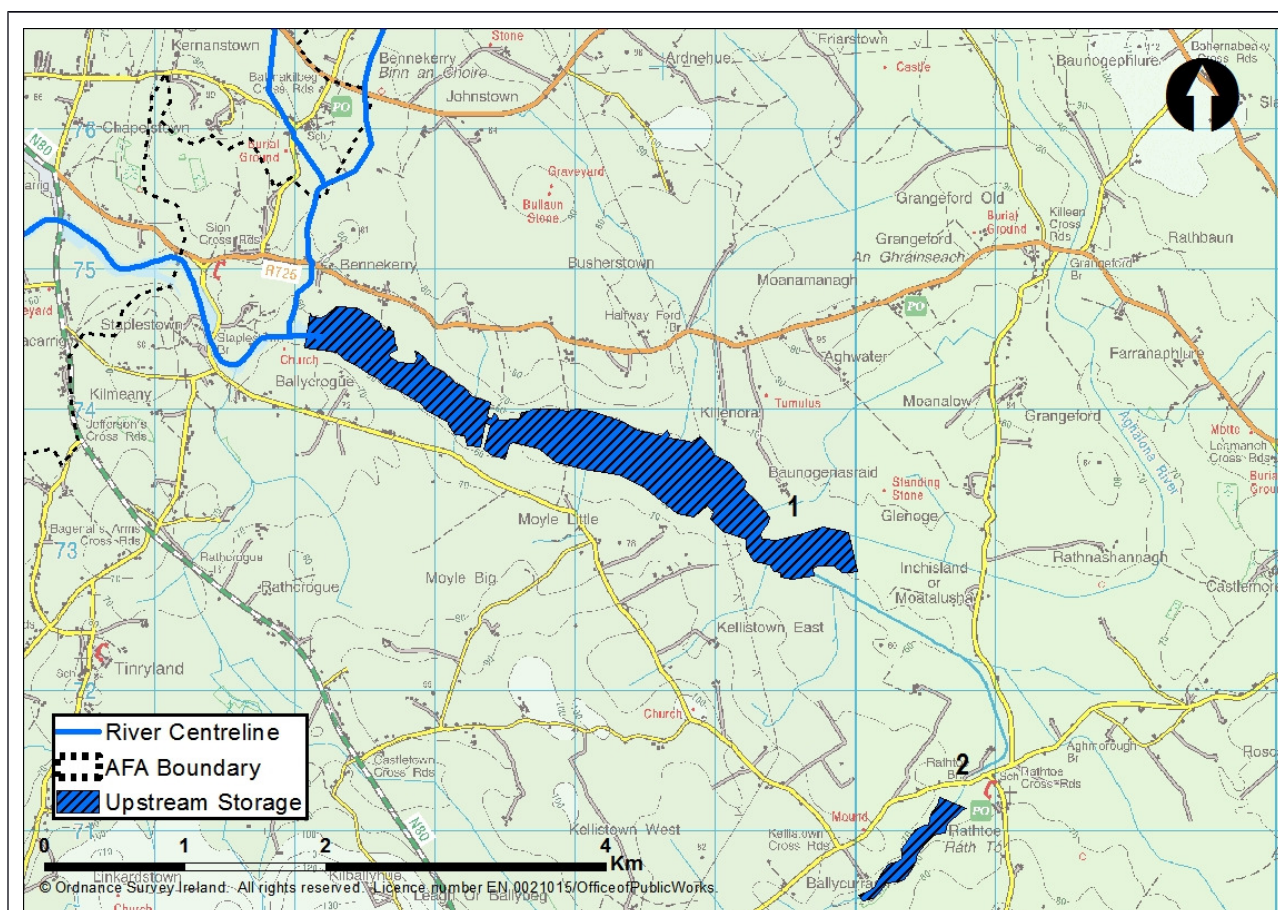
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	Social Screening
Do nothing	✓			
Additional Maintenance	✗			
Do Minimum	✗			
Land Use Management	✗			
Storage	✗	✓		
Improvement of Channel Conveyance	✗			
Hard Defences	✗	✓	?	?
Relocation of properties	✓	✓		
Diversion of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

## 8.3.5.2 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 therefore was rejected from the screening process.				

Method	Tech	Econ	Env	Soc
Additional Maintenance	x			
<p>This method considers whether improvements can be made to augment the 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.</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	x			
<p>Within flood cell 1 there is little opportunity to improve the conditions in the Millrace and therefore little scope to reduce the overall flood risk. The Millrace splits off from the Burren River upstream of flood cell 1 an example of 'Do Minimum' would be to block off or reduce the flow into the Millrace in an effort to alleviate flooding within flood cell 1. Model simulations have shown that the blocking of the Millrace is technically unfeasible, however the erection of a barrier to prevent or reduce flow down the Millrace does little to prevent 'out of bank' flooding occurring on the right bank of the Burren River. During a 1% AEP fluvial event, flood cell 1 is flooded as the consequence of River Burren's insufficient channel capacity and well as out of bank flooding from the Millrace. Consequently, 'Do Minimum' has been rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	x			
<p>The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in the catchment/large size of the catchment this method is considered unsuitable to benefit flood cell 1. This method is technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Storage	x	✓		
<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 reducing 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> <p>A review of the surrounding topography was carried out to locate possible storage areas. Two potential storage areas were identified upstream of flood cell 1 as shown in Figure 8.3.6.1.1.1.1.1.</p>				





**Figure 8.3.6.1.1.1.1.1 Potential storage areas 1 & 2 (Flood Cells 1 & 2)**

For flood cell 1 the technical review identified that if the upstream storage areas 1 and 2 are used simultaneously this can reduce 1% AEP fluvial flow to a 50% AEP fluvial flow. Consequently, all the properties at risk within flood cell 1 would be protected. Construction of these storage areas would require a series of embankments with an average height of 4m and total length of approximately 460m. In addition, one culvert is required per storage area to act as a flow control device and convey flow through the embankment. An economic review estimated the cost of constructing these 2 storage areas to be approximately €1,092,787 rendering this method economically unviable.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x			

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.

Flooding within flood cell 1 is the result of insufficient channel capacity of the Burren River and the Millrace to convey high flows during a 1% AEP fluvial event. As a result 31 residential properties located along the Burren Road are affected by floodwaters. The Burren River and Millrace were investigated to locate where Improved Channel Conveyance could be applied. However, following an extensive review it was established that it is technically unfeasible to improve channel conveyance within flood cell 1. Model simulations have shown that improving channel conveyance along the main River Burren and the Millrace

by deepening bed-levels and underpinning the railway bridge (14BURN00220D) would only serve to increase the extent of flooding within flood cell 1 and subsequently exasperate flooding further downstream within the Carlow. Consequently this method was rejected.

Method	Tech	Econ	Env	Soc
Hard Defence	x	✓	?	?

The term Hard Defence 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.

For flood cell 1, a technical review was conducted to ascertain the optimum position of Hard Defences, benefitting the greatest number of properties.

In order to ascertain the effect of Hard Defences a hydraulic model was constructed to simulate the method. The model showed hard defences would protect to the 1% AEP flood event with an average height of 0.9m and a total length of 100m. As shown in Figure 8.3.5.3.1.1.1.4. Hard Defences are erected along the required stretch of the main Burren River.

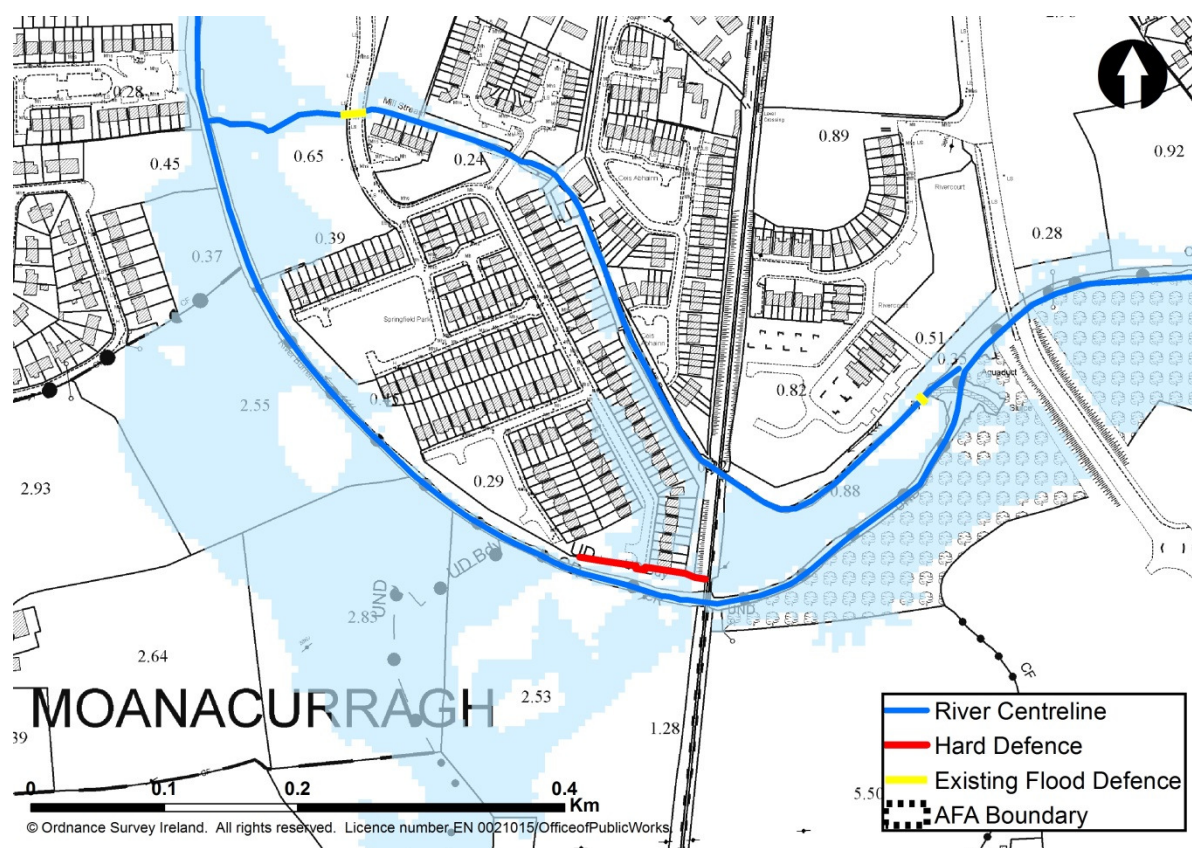


Figure 8.3.5.3.1.1.1.4 Location of Hard Defences in flood cell 1

In flood cell 1 Carlow County Council have installed flood defences, including a dam at the top of the

Millrace in front of the existing weir and pedestrian bridge and a flood gate at the downstream end of the Millrace. These defences form part of the 'Paupish Lane Flood Prevention Scheme' have been operational since November 2015 and are complementary to the hard defences identified here.

The estimated cost of the hard defence consisting mainly of a series of embankments is approximately €41,509 making this method economically unviable.

The River Barrow and River Nore SAC is within, upstream and downstream of Carlow. The Slaney River Valley SAC is over 6km east of Carlow, but this area is not hydraulically linked to the AFA. These hard defences would be set back from watercourse as much as possible due to SAC designation and catchment being a FPM sensitive area.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓		

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 on 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.

An assessment of the distribution of properties within flood cell 1 was carried out. If this scheme was implemented it would require the cluster of 31 properties to be relocated away from this at risk area to an area of less risk. An economic assessment has revealed that based on the current market value of these at risk properties this is estimated to cost €15,962,644 making this method economically unfeasible.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			

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.

A technical review was conducted to identify possible flow diversion routes. One solution might be to increase the amount of flow entering the Millrace (Ballinacarrig Reach), therefore reducing the amount continuing downstream of this point in the Burren River. However, the diversion of flow along and into this reach would not alleviate flooding within flood cell 1. Instead, there would be an increase of flooding to the north of the flood cell as a result. This FRM has therefore been seen as being technically unfeasible.



Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✗			
The application of flood warning / forecasting was tested at UoM scale. There is not a 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 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>While this method would not provide the required design 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 the pass through the screening process. 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 these properties is €346,478. This method is therefore economically feasible.</p> <p>This method would not provide the required 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.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other FRM works have been identified for this flood cell.				
<b>8.3.1.1 Summary of Feasibility Review – Flood Cell 1</b>				
<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"> <li>• Hard Defences</li> </ul> <p>Hard Defences has passed through the screening process, since this method can provide the full protection to all properties during the occurrence of a 1% AEP fluvial flood event.</p> <p>Individual Property Protection does not provide the required standard of protection and therefore should only be used should hard defences be deemed unsuitable later in the optioneering process.</p>				

## 8.3.1.2 Feasibility Review Summary for flood cell 2

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	reening Social
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				

## 8.3.1.3 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	✗			
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	✗			



Due to the presence and restrictive nature of the Ballinacarrig Bridge (14BURN00400E), flood waters back up at during a 1%AEP fluvial event resulting in the flooding of 2 residential properties within flood cell 2. The replacement/alteration of this structure would require an increase from its present capacity of 18 m<sup>3</sup>/s to 35m<sup>3</sup>/s. A culvert capacity assessment indicates that the constraints of the river bank and current road level restrict the upgrading of the bridge sufficiently to convey fluvial flows during a 1% AEP design event. In addition, the improvement of conveyance at this location would only add to flooding problems downstream, particularly within flood cell 1 therefore this measure is not considered technically feasible.

Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in the catchment/large size of the catchment the method is considered unsuitable to benefit flood cell 2. This method is technically unfeasible.

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 reducing 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 topography was carried out to locate possible storage areas. Two potential storage areas were identified upstream of flood cells 1 & 2 as shown in Figure 8.3.6.1.1.1.1.1, previously.

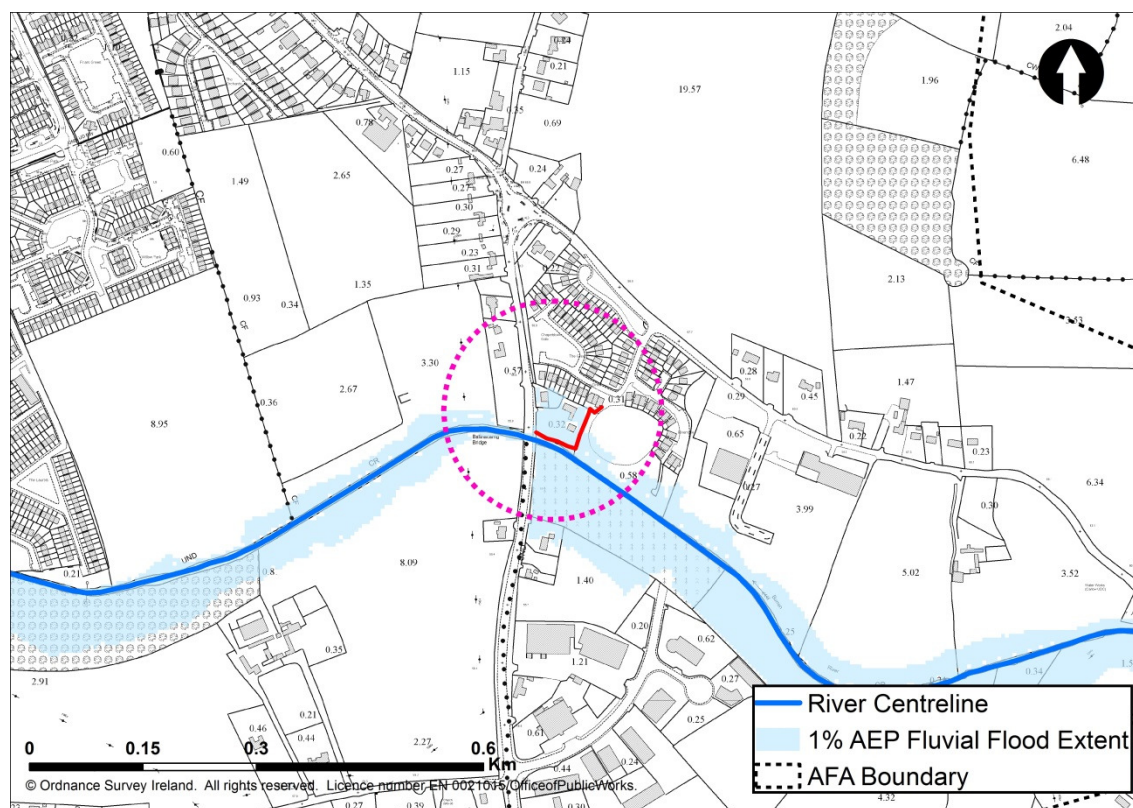
For flood cells 1 & 2 the technical review identified that if the upstream storage areas 1 and 2 are used simultaneously this would have the ability to reduce 1% AEP fluvial flow to a 50% AEP fluvial flow. Consequently, the all the properties at risk located within flood cell 2 would be protected. Construction of these storage areas would require a series of embankments with an average height of 4m and total length of approximately 460m. In addition, one culvert is to be provided per storage area to act as a flow control device and convey flow through the embankment. An economic review estimated the cost of constructing these two storage areas to be approximately €1,092,787 rendering this method economically unviable.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x			

Flood cell 2 is located within the vicinity of Ballinacarrig Bridge (14BURN000402D). This critical structure holds water back during a 1% AEP fluvial event. Two residential properties are flooded as a result of water overtopping the northern bank of the river upstream of the bridge. Flooding of these two properties could be significantly reduced by dredging and underpinning this bridge. It is estimated that this bridge would be required to convey a flow of approximately 35m<sup>3</sup>/s to prevent flooding, its current capacity is 18m<sup>3</sup>/s. A culvert capacity assessment established that the constraints of the river bank and current road level restrict the upgrading of the bridge sufficiently to convey fluvial flows during a 1% AEP design event. In addition, the improvement of conveyance at this location would only add to flooding problems downstream, particularly within flood cell 1 therefore this measure is not considered technically feasible.

Method	Tech	Econ	Env	Soc
Hard Defence	x	✓	?	?

A technical review was conducted to ascertain the effectiveness of Hard Defences within flood cell 2. Figure 8.3.6.1.1.1.1.2 shows the position of the Hard Defences required to protect properties during a 1% AEP fluvial flood event.



**Figure 8.3.6.1.1.1.1.2 Location of Potential Hard Defences within flood cell 2**

In order to ascertain the effect 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 1.6m and a total length of 100m. An economic review estimated the cost of the hard defences to be approximately €100,522 making this method economically viable.

The River Barrow and River Nore SAC is within, upstream and downstream of Carlow. The Slaney River Valley SAC is over 6km east of Carlow, but is not hydraulically linked to the AFA. These hard defences would be set back from watercourse as much as possible due to SAC designation and catchment being a FPM sensitive area.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓		
If this method was implemented it would require that the 2 residential properties are relocated away from this at risk area to an area of less risk. An economic assessment has revealed that based on the current market value of these at risk properties this would cost €1,029,848 making this method economically unfeasible.				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			

Diversion of Flow was considered as a FRM to alleviate flooding within flood cell 2. For flow diversion to work it involves diverting flow from upstream of the risk area and discharging it back into the River downstream. Development of potential flow routes is restricted by the presence of existing transport infrastructure, consequently this measure can be deemed technically unfeasible.

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			

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 technically unfeasible.

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

While this method would not provide the required design 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 the pass through the screening process. The estimated cost to provide protection measures for these properties is €44,399. This method is therefore economically feasible.

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.

Method	Tech	Econ	Env	Soc
Other Works	✓			

No other works were identified for this flood cell.

#### 8.3.1.4 Summary of Feasibility Review – Flood Cell 2

The following FRM method has been carried forward to address the flood risk arising from flood cells 2;

- Hard Defences

Hard Defences can provide the full protection to all properties within flood cell 2 during the occurrence of a 1% AEP fluvial flood event. The emplacement of Hard Defences would be the most efficient and economic method available. Individual Property Protection should therefore only be used should hard defences be deemed unsuitable later in the optioneering process.

#### 8.3.1.5 Feasibility Review Summary for flood cell 3

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	Social Screening
Do nothing	x			

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				

8.3.1.6 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	✗			
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	✗			
Flooding within flood cell 3 is mainly due to the presence of a critical structure (14KNOK00251J). Do Minimum activities such as the removal of vegetation and clearing this culvert of silt would be insufficient to achieve the required 1% SoP and protect the two properties at risk. Additional works would be required such as the replacement/alteration of the critical structure and improvement of the channel conveyance upstream of this structure. Therefore, 'Do Minimum' has been 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. Due to the high percentage of urbanisation present in the catchment/large size of the catchment the method is considered unsuitable to benefit flood cell 3. This method is technically unfeasible.				
Method	Tech	Econ	Env	Soc
Storage	✗			
The volume of water required to be stored upstream of the Burren River during the 1% AEP event before reaching flood cell 3 has been estimated to be 8,498m <sup>3</sup> . No suitable storage locations were identified, due to unsuitable topography. In summary, Upstream Storage as a FRM can be considered as technically unfeasible.				
Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✗	✓	?	?
In flood cell 3, a critical structure (14KNOK00256J) was found to surcharge during a 1% AEP fluvial event, causing flood flow to back up behind this structure. As a consequence, flood waters spill 'out of bank' on the right bank of the Knocknagee Stream flooding properties within flood cell 3. Upstream of this structure, relatively low banks located on the right bank of the stream contribute to flooding in flood cell 3. By increasing the channel capacity on the Knocknagee stream and improving the capacity of the critical structure, flooding within flood cell 3 could be reduced.  A capacity assessment was carried out to ascertain the size of the culvert required on the Knocknagee stream. Model results have shown that the present culvert is capable of conveying a maximum of 0.5m <sup>3</sup> /s,				

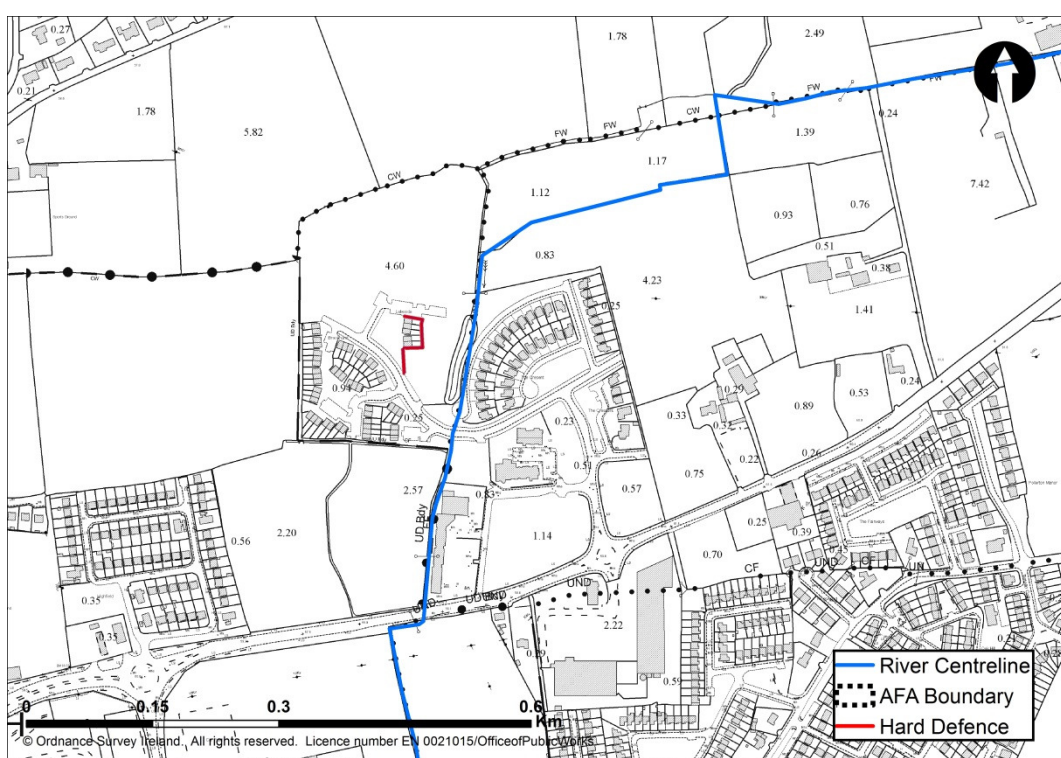


while 1.23m<sup>3</sup>/s is required to accommodate the peak of a 1% AEP fluvial event. If the diameter of the current culvert is increased from 0.4m to 1.5m this would provide sufficient capacity to convey the 1% AEP flows. This method is technically feasible; however the total estimated cost of these works is approximately €551,894.

The River Barrow and River Nore SAC is within, upstream and downstream of Carlow. The Slaney River Valley SAC is over 6km east of Carlow, but is not hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Hard Defence	✓	✓	?	?

A review was conducted to ascertain where Hard Defences would be required to protect existing properties located within flood cell 3. Figure 8.3.6.1.1.1.3 shows the location of the Hard Defences that are required to protect properties within flood cell 3 during a 1% fluvial flood event.



**Figure 8.3.6.1.1.1.1.3 Location of Hard Defences in flood cell 3**

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 fluvial flood event with an average height of 1.5m and a total length of 77m. An economic review estimated the cost of the hard defences to be approximately €31,962 making this method economically viable.

The River Barrow and River Nore SAC is within, upstream and downstream of Carlow. The Slaney River Valley SAC is over 6km east of Carlow, but is not hydraulically linked to the AFA. These hard defences would be set back from watercourse as much as possible due to SAC designation and catchment being a FPM sensitive area.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓		
If this method was implemented it would require that the 2 residential properties are relocated away from this at risk area to an area of less risk. An economic assessment has revealed that based on the current market value of these at risk properties it is estimated that this would cost €1,029,848 making this method economically unfeasible.				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			
A review was carried out to assess the suitability of a flow diversion that would divert the Knocknagee Stream away from the identified properties at risk. However, no possible alternative routes for the Knocknagee Stream are available due to the presence of other residential properties and urban infrastructure. Therefore, this FRM can be considered as being technically unfeasible.				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✗	✓	?	?
<p>The application of flood warning / forecasting was tested at UoM scale. A suitable location far enough upstream of flood cells 3 is available to provide sufficient warning. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.</p> <p>An economic review estimated that the cost of providing 1 hydrometric gauging station with simple forecasting systems would be approximately €47,492. This method is therefore economically viable.</p> <p>The proposed gauging station is not within any environmental designations and it is unlikely that flood forecasting would have any impact to designated sites in the vicinity of the Carlow AFA.</p>				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	?	?
While this method would not provide the required design 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. 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 these properties is €83,404. This method is therefore economically feasible.				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for this flood cell.				

### 8.3.1.7 Summary of Feasibility Review – Flood Cell 3

The following FRM methods have been carried forward to address the flood risk arising from flood cells 3;

- Improvement of Channel Conveyance
- Hard Defences

Hard Defences and Improvement of Channel Conveyance can provide the full protection to all properties within flood cell 3 during a 1% AEP fluvial flood event. Individual Property Protection and flood warning should therefore only be used should hard defences and/or improvement of channel conveyance is deemed unsuitable later in the optioneering process.

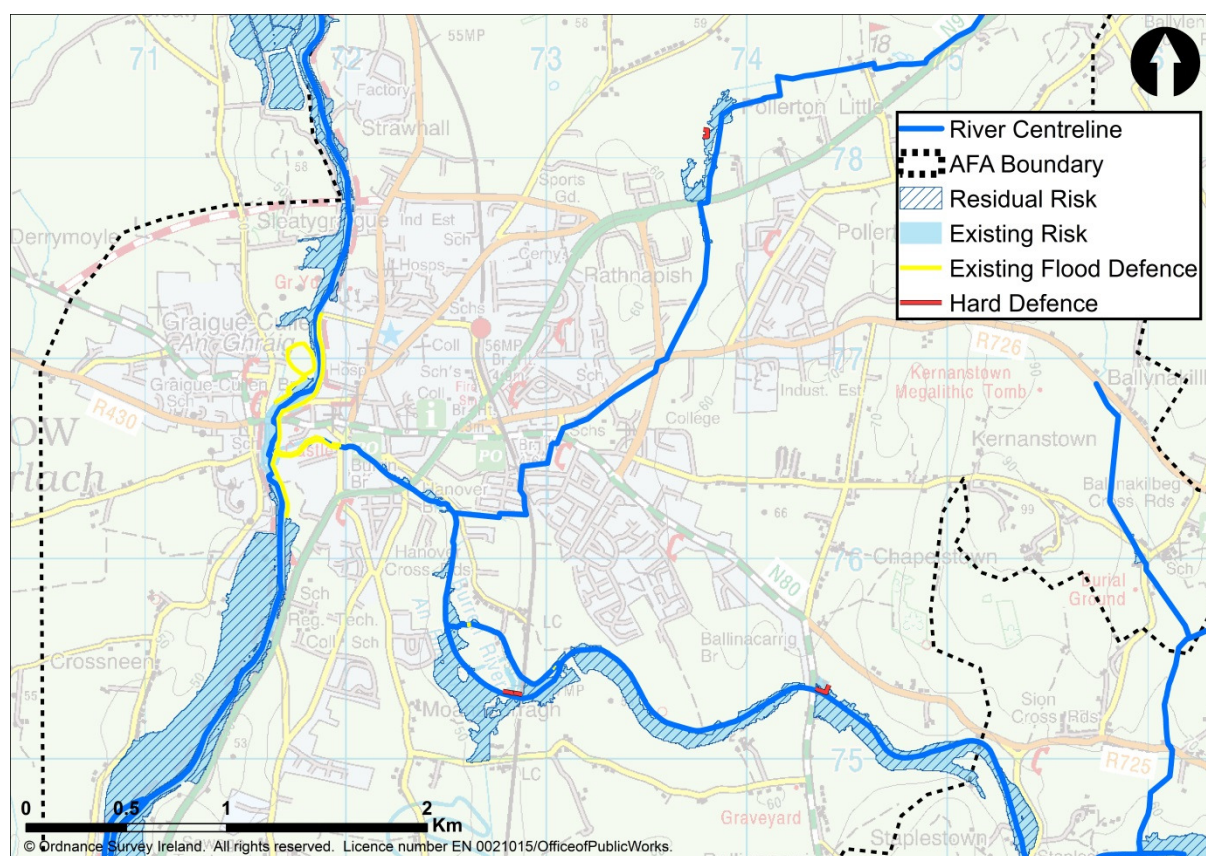
### 8.3.2 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Hard Defence	x	✓			
Improvement of channel conveyance	✓	x			

For flood cell 1, 2 and 3 Hard Defences (Hard Defence is the most economic approach for flood cell 1); can provide the full SoP.

For flood cell 3, Improvement of channel conveyance is an alternative to hard defences; so option 2 entails Improvement of channel conveyance (flood cell 3) and Hard Defence (flood cells 1 & 2) to provide the full SoP.

#### 8.6.7.1 Option 1 details - Hard Defences



**Figure 8.3.2.1.1.1.1.1 Carlow AFA Option 1**

At risk properties would be protected by a series of 'Hard Defences' consisting of flood embankments as shown in Figure 8.3.2.1.1.1.1.1. These hard defences would protect to the 1% AEP fluvial flood event with an average height of 1.1m and a total length of 276m.

Figure 8.3.2.1.1.1.1.1.1 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).

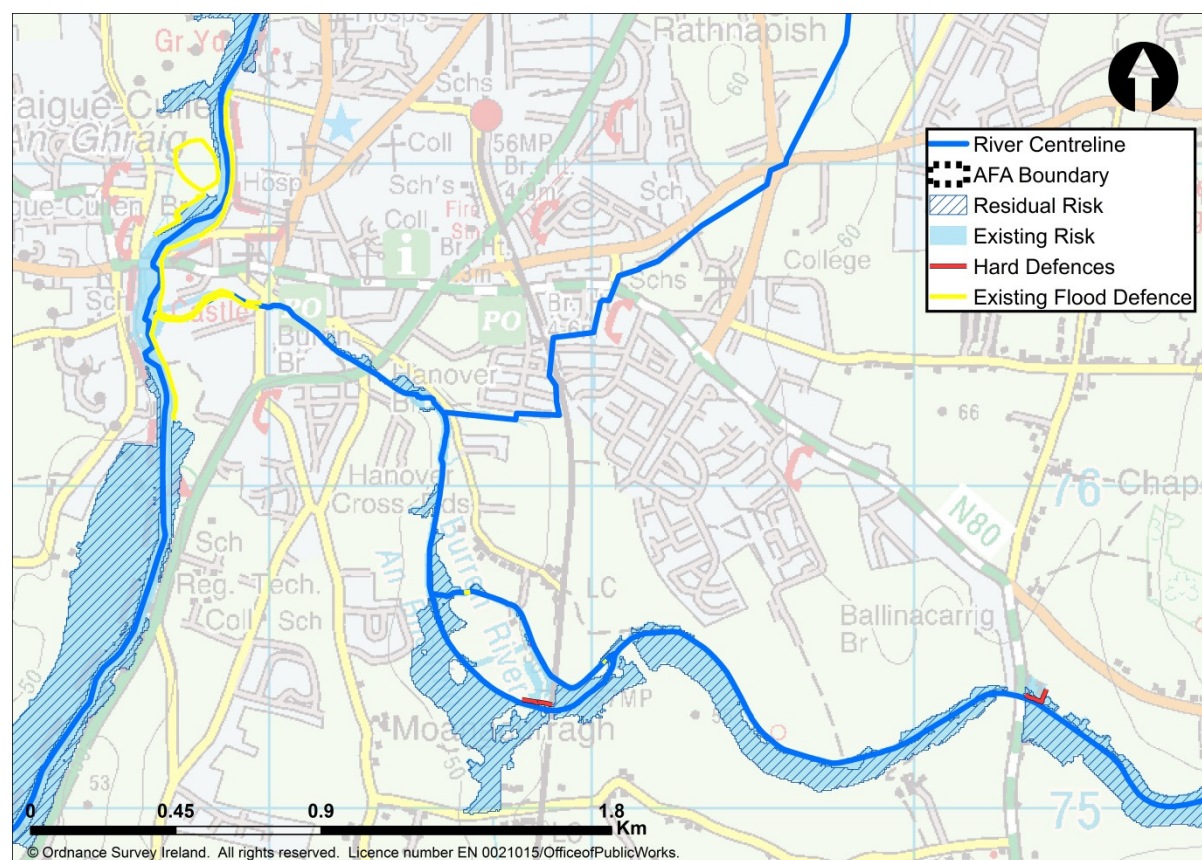
This FRM would protect to the 1% AEP flood levels. In addition to these methods the following was also identified at UoM level (see section 8.1) to be included in any potential option identified:

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

Option Item	Quantity	Construction Cost	
Embankment	0.3km length, 1.1m high (average)	€58,956	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
651	0.21	3108.65	
Economic Appraisal (Cost-Benefit Analysis) Outcomes -			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€8,482,650	€209,259	€846,524	4.05



### 8.3.2.2 Option 2 details - Hard Defences (flood cell 1 & 2) and Improvement of channel conveyance (flood cell 3)



**Figure 8.3.2.2.1.1.1.1 Carlow AFA Option 2**

At risk properties would be protected from a series of 'Hard Defences' consisting of flood embankments within flood cells 1 and 2, as shown in Figure 8.3.8. Improvement of channel conveyance would be applied to flood cell 3. The hard defences would protect to the 1% AEP fluvial flood event with an average height of 1.6m and a total length of **200m**.

Figure 8.3.2.2.1.1.1.1.1 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).

The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Embankment	0.2km length, 1.6m high (average)	€49,100	
Culvert upgrade/replacement	14KNOK00256J	€184,032	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
473	0.77	614.37	
Economic Appraisal (Cost-Benefit Analysis) Outcomes -			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€8,482,650	€769,106	€846,524	1.1

### 8.3.2.3 AFA Sensitivity to Future Changes

During a MRFS 1% AEP flood event there is an increase in the flood extent throughout Carlow AFA. Notable areas include Henry Street, Maryborough Street and Ninety-Eight Street, located to the NW of Carlow AFA. Significant increases in flooding are also notable at the Millrace, Burrin Road and Staplestown Road. During a HEFS 1% flood event, the most notable increase in flood extent is most extensive at the confluence of the Burrin and Barrow Rivers.

During a MRFS 1% AEP flood event there would be a significant increase in flood extent. This would result in an additional 645 properties being at risk bringing the property count from 35 in the present day 1% AEP event to 680. The AAD would increase from €394,872 to €5,398,701. As a result Carlow AFA would be considered to be at high vulnerability from the MRFS. This large increase of flood receptors is the result of the breaching of the current flood defence schemes.

During a HEFS 1% AEP flood event there would be a significant increase in flood extent. This would result in an additional 1149 properties being at risk bringing the property count from 35 in the present day 1% AEP event to 1184. The AAD would increase from €394,872 to €20,956,849. As a result Carlow AFA would be considered to be at high vulnerability from the HEFS.

This large number of additional properties affected by future scenarios indicates a significant increased to the annual average damage and the Carlow area of assessment would be considered to be at high vulnerability. The potential options associated with flood cells 1, 2 and 3 have only been assessed to their adaptability to climate change. This report does not consider the vulnerability, adaptability or sustainability of existing flood defences presence throughout Carlow AFA.

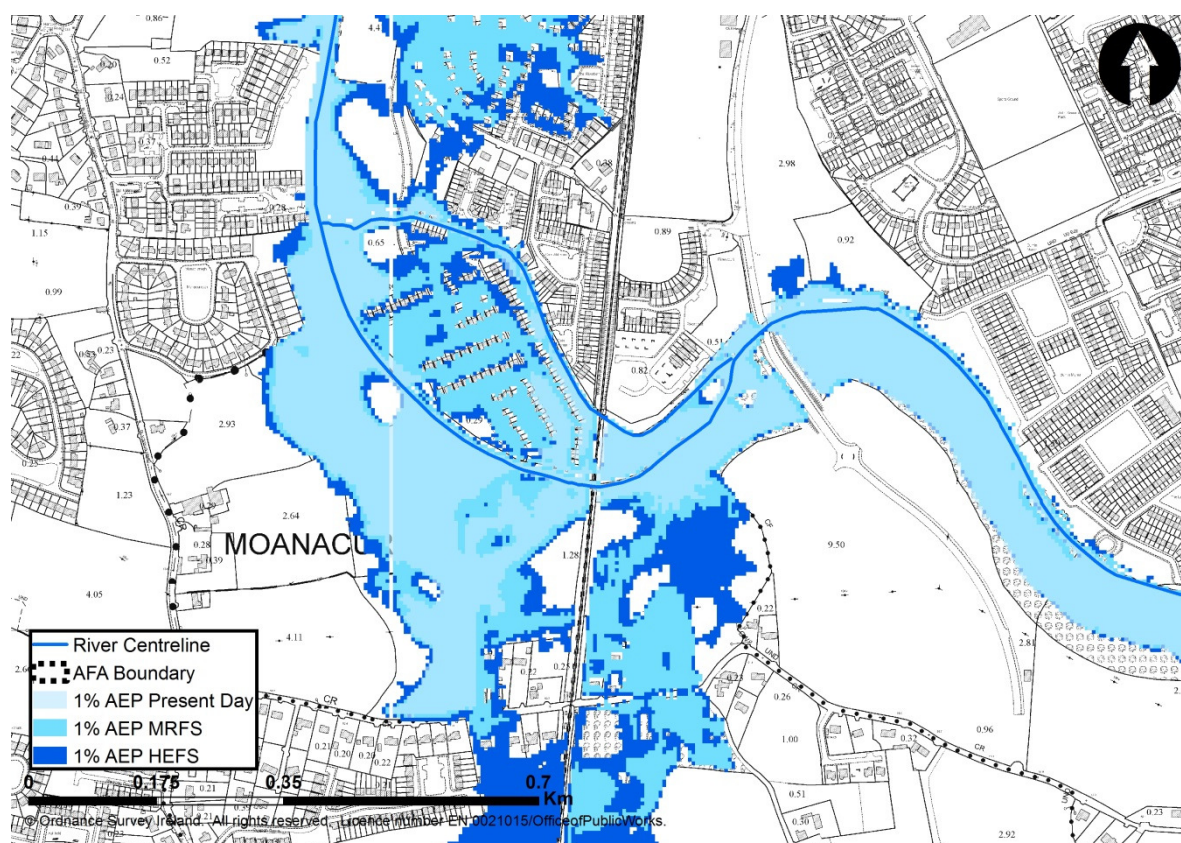


Figure 8.3.2.3.1.1.1.1.1 Carlow Future Change Flood Extents (Flood Cell 1)





### 8.3.2.4 Future Change Adaptability

The following discusses the adaptability of the potential FRM methods proposed within Carlow AFA:

**Hard Defence Flood Cell 1** - This method could be adapted by increasing the height of the embankment and extending its length. A review of the effect of the MRFS and the HEFS showed that the length of the embankment, with the additional of more walls might need to be extended by 1.5km and 2km, respectively. The height of the hard defence would probably have to be increased from an average height of 0.9m to 1.5m and 1.7m, for the MRFS and HEFS, respectively. This method is considered to have a **moderate to poor** adaptability

**Hard Defence Flood Cell 2** - This method could be adapted by increasing the height of the embankment and extending its length. A review of the effect of the MRFS and the HEFS showed that these Hard Defences might need to be increased from 1.6m (average) to 2.1m and 2.4m average for the MRFS and HEFS, respectively. This method is considered to be of a **poor adaptable**.

**Hard Defence Flood Cell 3** - This method could be adapted by increasing the height of the embankment. A review of the effect of the MRFS and the HEFS showed that these embankments might need to be increased from 0.6m (average) to 0.9m and 1.1m, respectively. This method is considered to be **readily to moderate adaptable**.

**Improved Channel Conveyance Flood Cell 3** - This method could be adapted by increasing the culvert capacity of the Knocknagee Stream. The current proposal is to upgrade the present culvert to a diameter of 1.5m. If the flow were to increase to the MRFS or the HEFS this culvert would still be of a sufficient to convey the 1% AEP flow. Design consideration would be required to allow for this increase in size for the future. This method is considered to be **Readily Adaptable**.

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 these methods other methods aimed at reducing future flood risk has been discussed in section 8.1 at UoM scale. These methods will reduce the vulnerability of potential future receptors. Given that Carlow is highly developed currently this would have little impact to overall area. Given that 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.
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. Options 1, 2 and 3 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 the most adaptable to the MRFS and HEFS. However alternative FRM methods could be added to option 2 to provide an increased SoP. Options 2 could include additional Hard Defences.
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, and the potential impacts of climate change. Based on this future change adaptability assessment the table below summarises how well each option achieves this objective.



Summary of Option Adaptability		
Option	Description	Score
Option 1 – Hard Defence (FC 1)	Option is adaptable at a moderate cost, difficulty and impact	1
Option 2 – Hard Defence (FC1 & 2) and Improvement of Channel Conveyance (FC3)	Option is adaptable at a moderate cost, difficulty and impact	1

### 8.3.2.5 Local Authority Comments

Local Authority representatives reviewed the options November 2015.

### 8.3.2.6 Summary

There is good confidence in both the hydrology and hydraulics of the Carlow AFA model due to the presence of a gauging station (Barrow New Bridge & Ballinacarrig) and flood extent verification events.

The following potential options, with a BCR  $\geq 0.5$  have been identified:

- Option 1 – Hard Defence (FC 1, 2 & 3)
- Option 2 – Hard Defence (FC1 & 2) and Improved Channel Conveyance (FC3)

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 Carlow 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. However, any interactions with the drainage system in this highly urbanised area may need to be addressed during the development of the preferred option.

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 assumptive approach be incorporated into detailed design.

Due to the existing flood relief scheme a relatively low residual risk was identified in Carlow 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

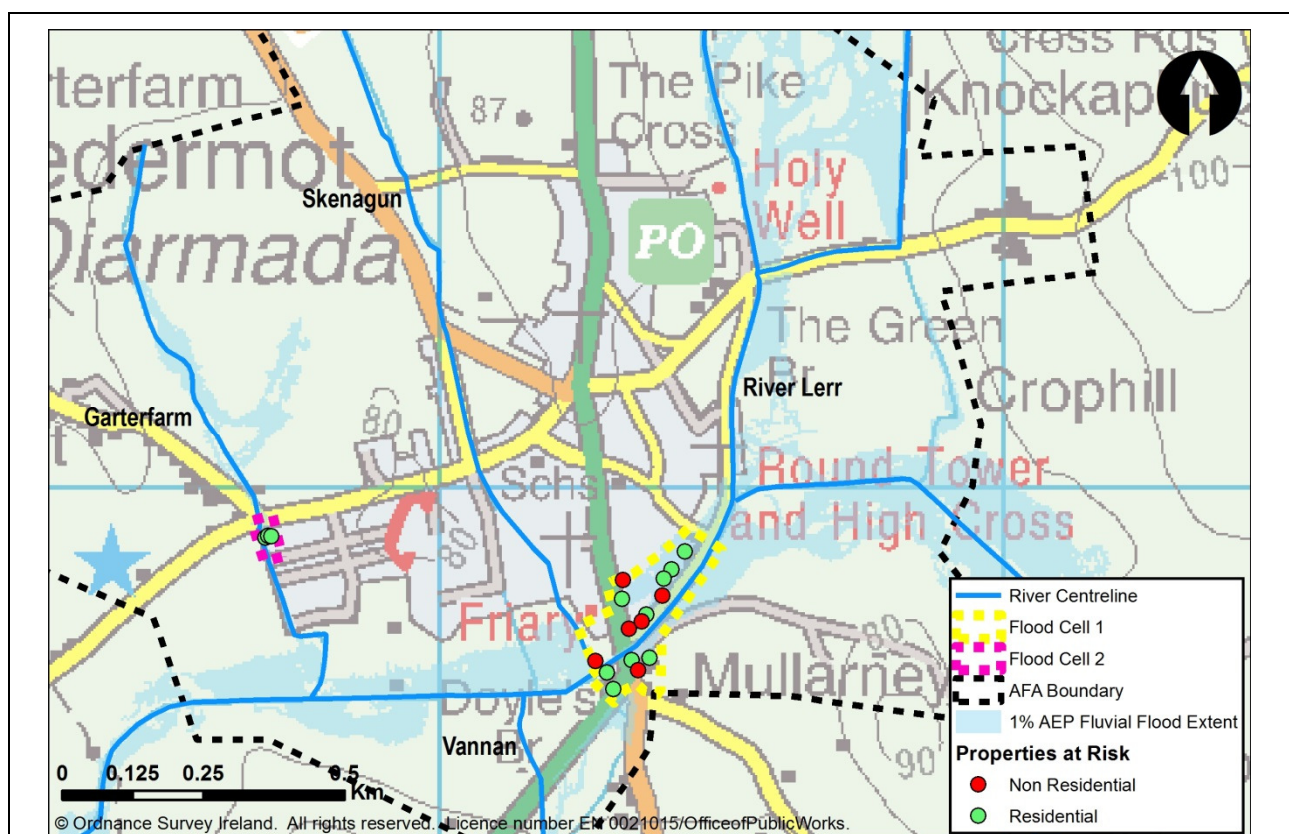
### 8.6 Castledermot Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Castledermot	Kildare	140156	AFA	Final	15/06/2016

#### 8.6.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.6.2 Flood Cells



**Figure 8.6.1 Castledermot AFA Flood Cells within a 1% AEP Fluvial Flood Extent**

#### Flood Cell 1:

Six residential and nine commercial properties along the banks of the River Lerr are affected by flooding during the 1% AEP event. High water levels in the Lerr also back up into the Skenagun watercourse and a flow path from the Vannan also affects properties in flood cell 1. Flood cell one has a number of fluvial flood sources to consider and the flood risk has therefore been considered complex.

**Flood Cell 2:**

Three residential properties are affected during the 1% AEP event as water spills from the Garterfarm stream upstream of a long culvert 14GART00096I. Flood cell two contains few properties which are affected by a single flood mechanism, the flood risk is therefore considered local.

**Summary of Flood Cells:**

As shown in Figure 8.6.1 the main flood risk originates directly from the River Lerr and indirectly via tributaries. Due to the complexity and interaction of the flood sources within flood cell 1 it is appropriate that it is screened as a complex flood cell. Flood cell 2 is a discrete area with few properties at risk and a single flood mechanism to consider. It is therefore appropriate to screen this flood cell as a standalone area.

On completion of the optioneering screening assessment flood cells will be combined to form complete options for the Castledermot AFA.

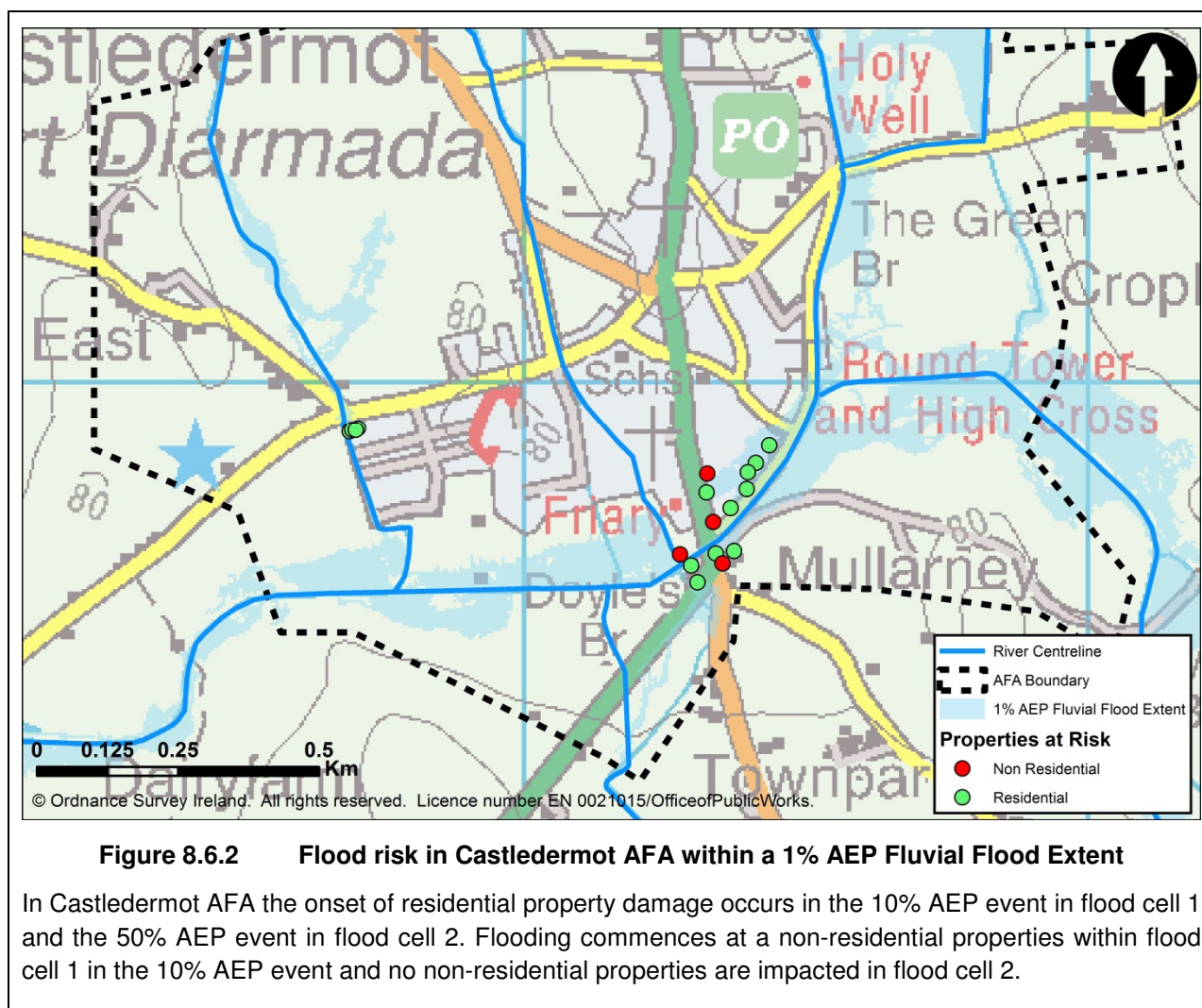
**8.6.3 Existing Regime**

The 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 River Lerr is part of the River Lerr and Graney River Drainage Scheme. Further details of this scheme are presented in section 6.3.

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

### 8.6.4 Summary of Flood Risk within SSA boundary



### 8.6.5 Monetary Damage and Benefit

	Flood Cell 1	Flood Cell 2	Total in AFA
Annual Average Damage (AAD)	€64,865	€6,405	€79,821
Present Value Damage (pvD)	€1,393,436	€137,591	€1,714,722
Preferred Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	15	3	18
Minimum Present Value Benefit	€1,025,716	€133,692	€1,159,408
Capped Minimum Present Value Benefit	€1,006,395	€133,692	€1,140,087

\*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.

**8.6.5 Short Listing FRM Methods – Complex Cells**

Method	Review Comment	Continue Screening
		Flood Cell 1
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	✓



## 8.6.5.1 Feasibility Review Summary for Complex 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    ! - Progress, potential for significant impacts identified

## 8.6.5.2 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 therefore was rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional Maintenance	✗			
This method considers whether improvements can be made to augment the 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 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	x			

This method can include clearance of channels and is also 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 a low right bank which is allowing the River Lerr to spill onto the Hamilton Road and into surrounding properties. Addressing the issue may benefit properties during more frequent AEP events, however there would be minimal impact to the properties at risk during the 1% AEP and no impact on the properties at risk from the Skenagun or Vannan. This is an unacceptable outcome in terms of contributing to achieving a 1% AEP standard of flood protection and this method was rejected from the screening process.

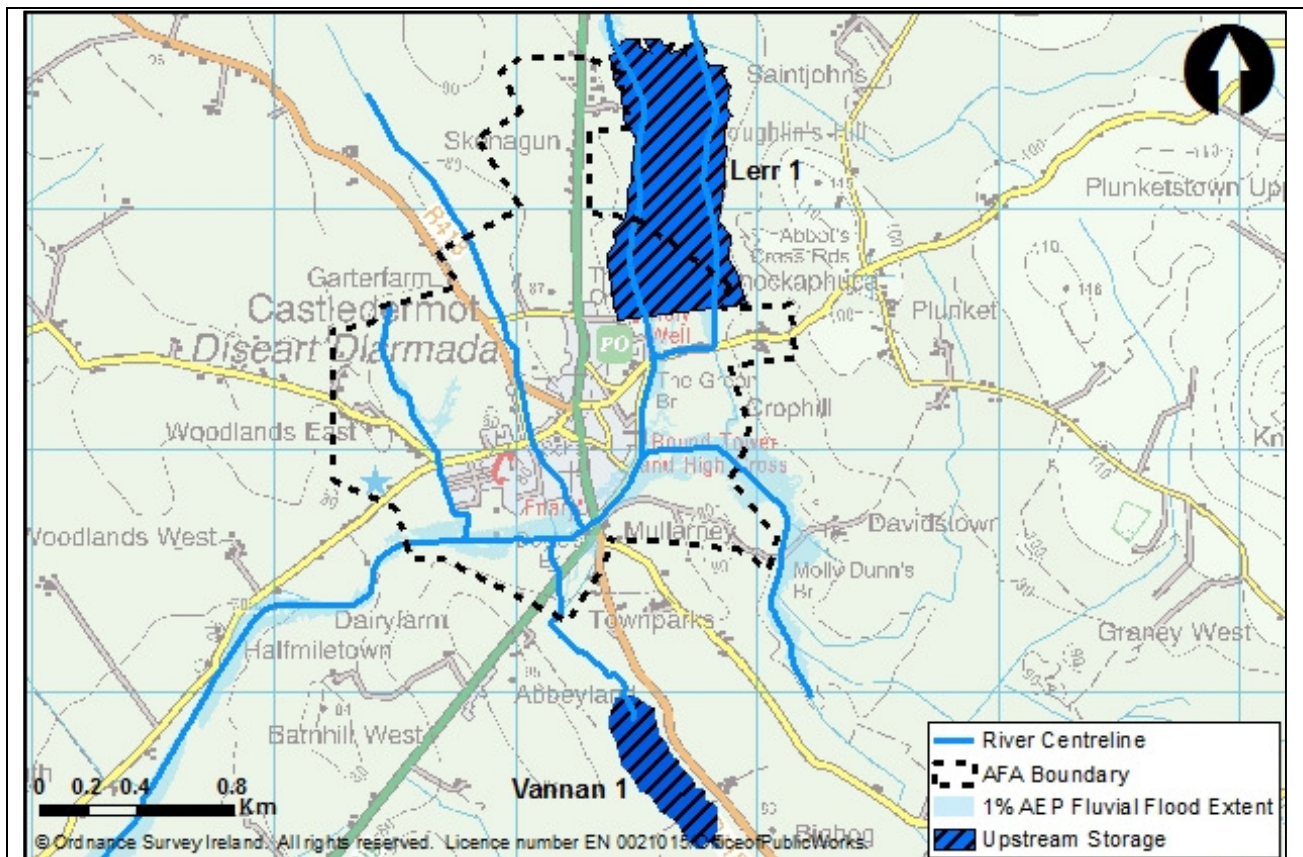
Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the large size of the catchments the method is considered unsuitable to benefit flood cell 1. This method is technically unfeasible.

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 reducing 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.

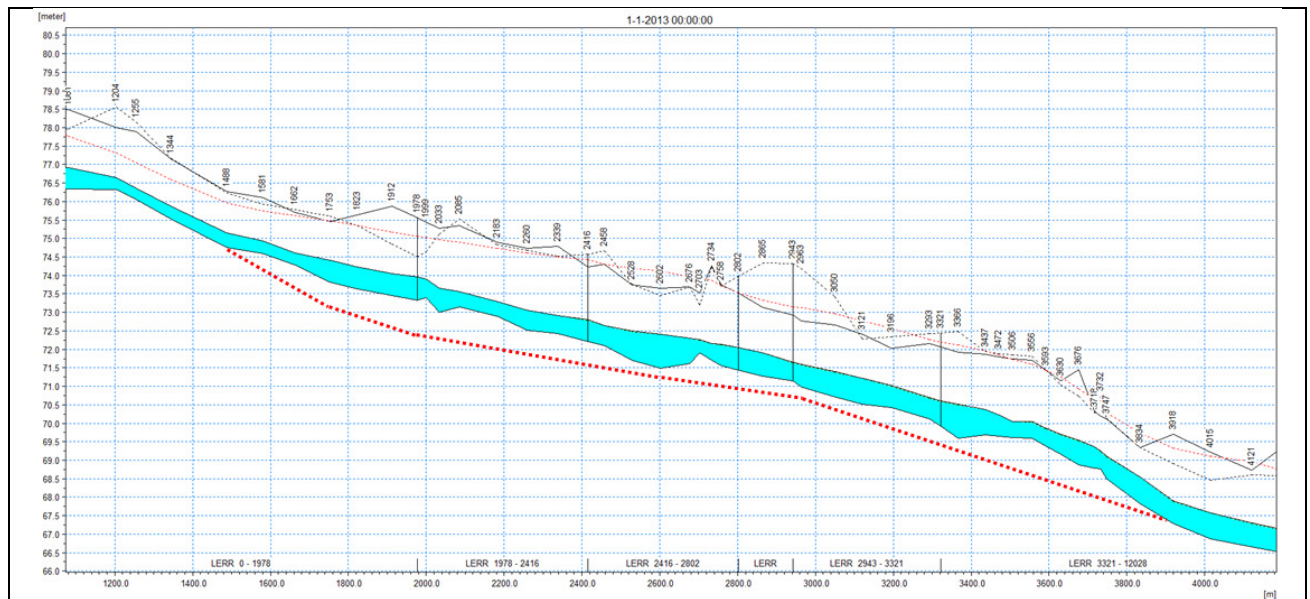
To achieve the 1% AEP SoP for flood cell 1, a combination of storage areas is required, Lerr 1 and Vannan 1, as shown in Figure 8.4.3. For Lerr 1, the storage volume required would be 614,982m<sup>3</sup>, with 619,904m<sup>3</sup> available. Vannan 1 would require storage of 12,725m<sup>3</sup> with an available storage capacity of 19,896m<sup>3</sup>. In combination, these 2 storage areas would provide full protection for the properties at risk during the 1%AEP flood event. The total cost of implementing these storage areas would be €3.6m which is economically unviable and this method has therefore been removed from the optioneering process.



**Figure 8.6.3 Potential Storage Locations benefitting for Flood Cell 1**

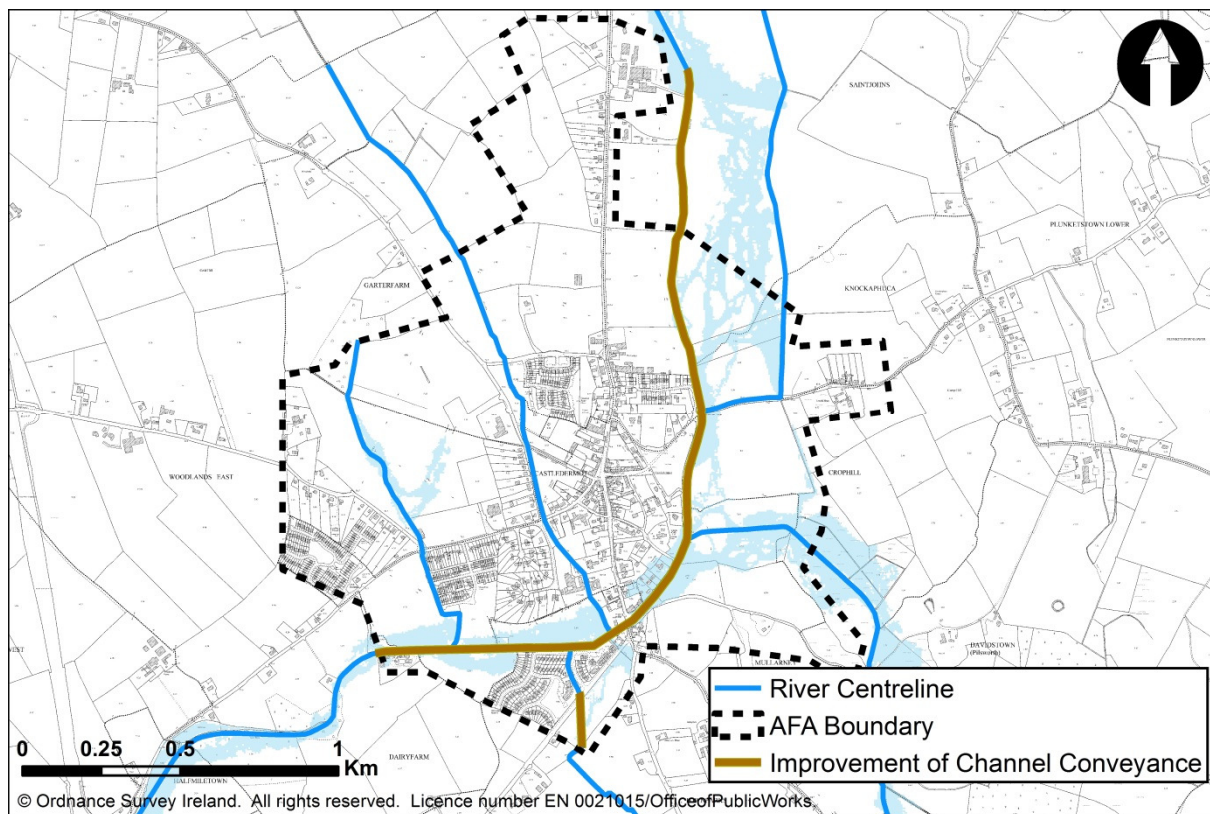
Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✓	✓	!	✓
<p>This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed level, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse and reducing roughness of the channel.</p> <p>A review of the various techniques was carried out and lowering and widening the channel along with increasing conveyance through existing structures was found to be the most appropriate way of implementing this method. The channel profile of the River Lerr and structures have been analysed for both high points and restrictive areas, the long section of the watercourse is shown in Figure 8.6.4. The Castledermot hydraulic model was used to identify the required cross sectional area of the River Lerr channel needed to convey the 1% AEP flow of approximately 28m<sup>3</sup>/s, in some places this would require the bed level to be lowered by 1m. This method would require 2.4km of the River Lerr to be dredged and widened, requiring approximately 10,455m<sup>3</sup> to be excavated. This work would protect properties affected directly by the River Lerr.</p>				





**Figure 8.6.4 Long Section of the River Lerr**

Additionally the overland flow path from the Vannan watercourse would be prevented if long culvert 14VANN00031I was upgraded from a 0.5m diameter pipe to a 1.05m diameter pipe. Potential locations for improvement of channel conveyance for both watercourses are shown in Figure 8.6.5.



**Figure 8.6.5 Potential locations for Improvement to Culvert Conveyance**

An economic review of the works required on both the Lerr and Vannan watercourses estimated the cost to be approximately €1.8m. While this method is not economically viable it may be cost effective when evaluated with a lower BCR and should therefore be considered further.

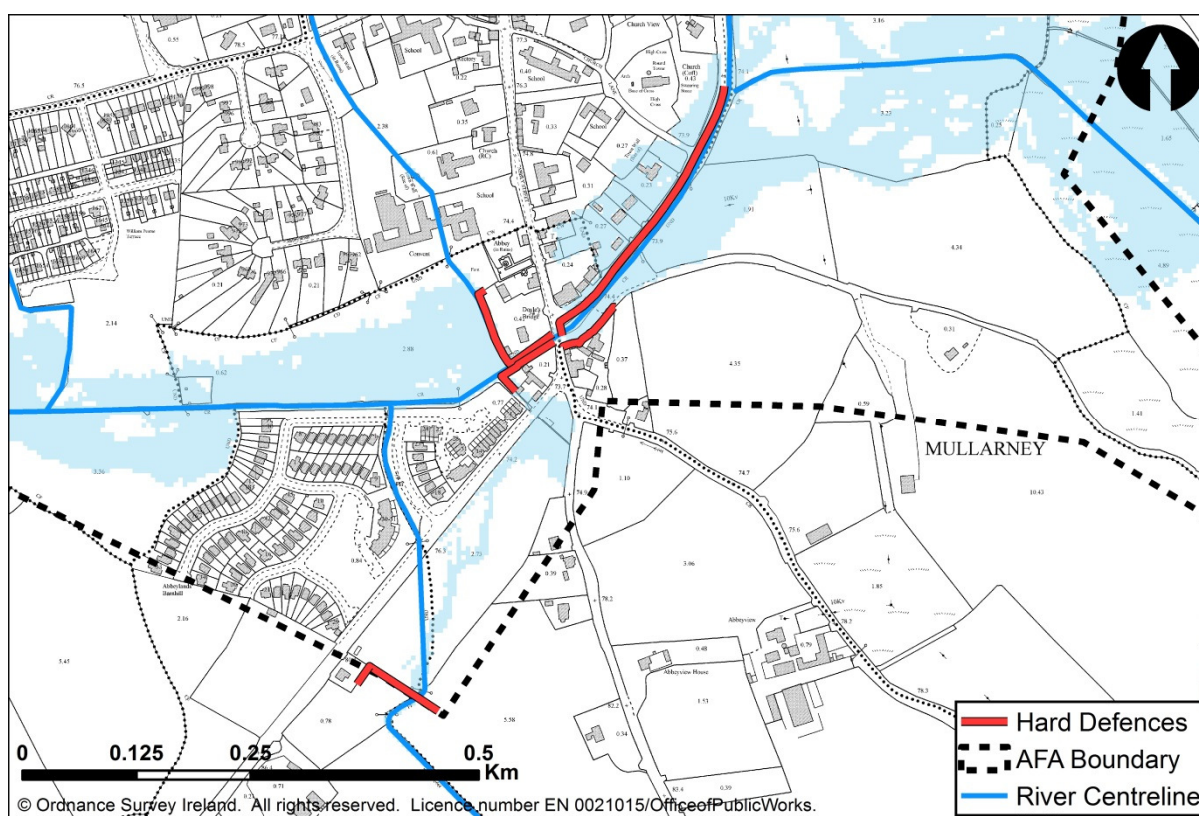
The River Barrow and River Nore SAC is within, upstream and downstream of Castledermot. The AFA is

within the Barrow Freshwater Pearl Mussel sensitive area. The Slaney River Valley SAC and Holdenstown Bog SAC are over 8km to the east of Castledermot, however are not hydraulically linked to the AFA.

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 8.4.5 shows the location of the Hard Defences required to protect properties during the 1% AEP event.



**Figure 8.6.6 Location of Hard Defences (Standalone) for 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 0.9m and a total length of 690m. There would also be 165m of road raising required. An economic review estimated the cost of the hard defences to be approximately €2m. While this method is not economically viable it maybe be cost effective when evaluated with a lower BCR and should therefore be considered further.

The River Barrow and River Nore SAC is within, upstream and downstream of Castledermot. The AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slaney River Valley SAC and Holdenstown Bog SAC are over 8km to the east of Castledermot, however are not hydraulically linked to the AFA.



Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✗		
<p>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 clusters of properties are located.</p> <p>The cost to relocate all 15 affected properties in flood cell 1 to an area of lower risk would be €5.7m making this method economically unviable.</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 1. Due to the topography of the land, a flow diversion route was not considered technically feasible and this method was removed from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✓	✓	✓	✓
<p>The application of flood warning / forecasting was tested at UoM scale. Suitable locations have been found far enough upstream of flood cell 1 to provide sufficient warning. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.</p> <p>An economic review estimated that the cost of providing 5 hydrometric gauging stations with simple forecasting systems would be approximately €237,461. This method is therefore economically viable.</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 required 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</p>				

properties is €215,356, so this method is economically viable.

It is unlikely that Individual Property Protection would have any impact on designated sites in the vicinity of the properties at risk. The River Barrow and River Nore SAC is within, upstream and downstream of Castledermot. The Slaney River Valley SAC and Holdenstown Bog SAC are over 8km to the east of Castledermot, however they are not hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Other Works	x			

No other works were identified for these flood cells

#### 8.6.5.3 Summary of Feasibility Review – Flood Cell 1

The following FRM method has been identified to address the flood risk arising from flood cell 1;

- Improvement of Channel Conveyance
- Hard Defences

Improvement of Channel Conveyance and Hard Defences can provide the full SoP to all properties during the 1% AEP fluvial flood events.

Flood Warning/Forecasting and Individual Property Protection can only provide partial protection to properties. These methods should therefore only be used should all other methods be deemed unsuitable later in the optioneering process.

### 8.6.6 Short Listing FRM Methods – Local Cells

Method	Review Comment	Continue Screening
		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	✓

## 8.6.6.1 Feasibility Review Summary of FRM 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				

## 8.6.6.2 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do nothing	✗			
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 therefore was rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional Maintenance	✗			
Historical flood data and channel survey data indicated that the present day flood risk in Castledermot is not attributable to vegetation, debris or blockages. While existing maintenance should continue on the rivers, increased activities will not significantly address the current flood risk and therefore will not be				

pursued under the CFRAM Study.

Method	Tech	Econ	Env	Soc
Do Minimum	x			

Within flood cell 2 there is little opportunity to reduce the flood extent with a do minimum approach. This is an unacceptable outcome in terms of contributing to achieving a design SoP and this method was therefore rejected from the screening process.

Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in the catchment the method is considered unsuitable to benefit flood cell 2. This method is technically unfeasible.

Method	Tech	Econ	Env	Soc
Storage	✓	✓	!	✓

For flood cell 2 there is one possible storage area, Garterfarm 1, as shown in Figure 8.4.6. The volume of water required to be stored would be 1,075m<sup>3</sup> with available storage of 2,296m<sup>3</sup>. The estimated cost to carry out this method would be €409,255. While this method is not economically viable it may be cost effective when evaluated with a lower BCR and should therefore be considered further.

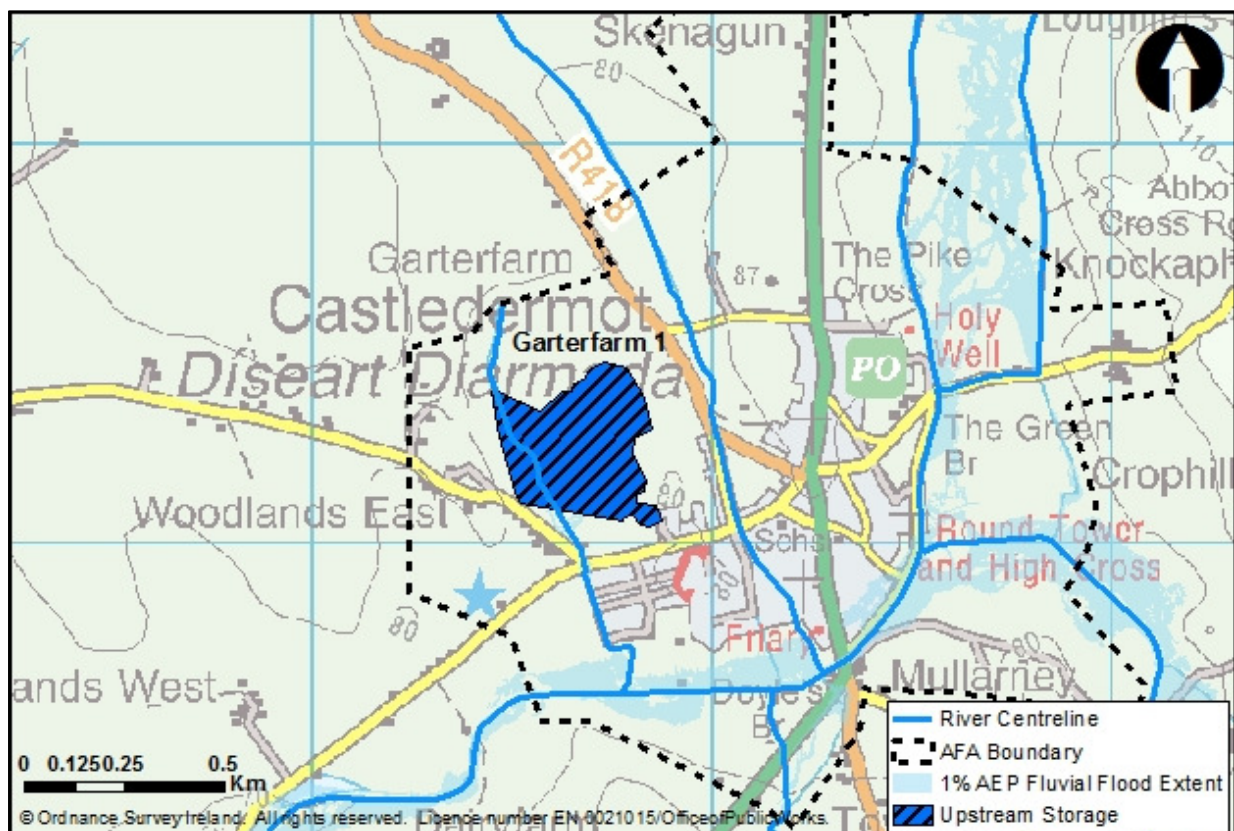


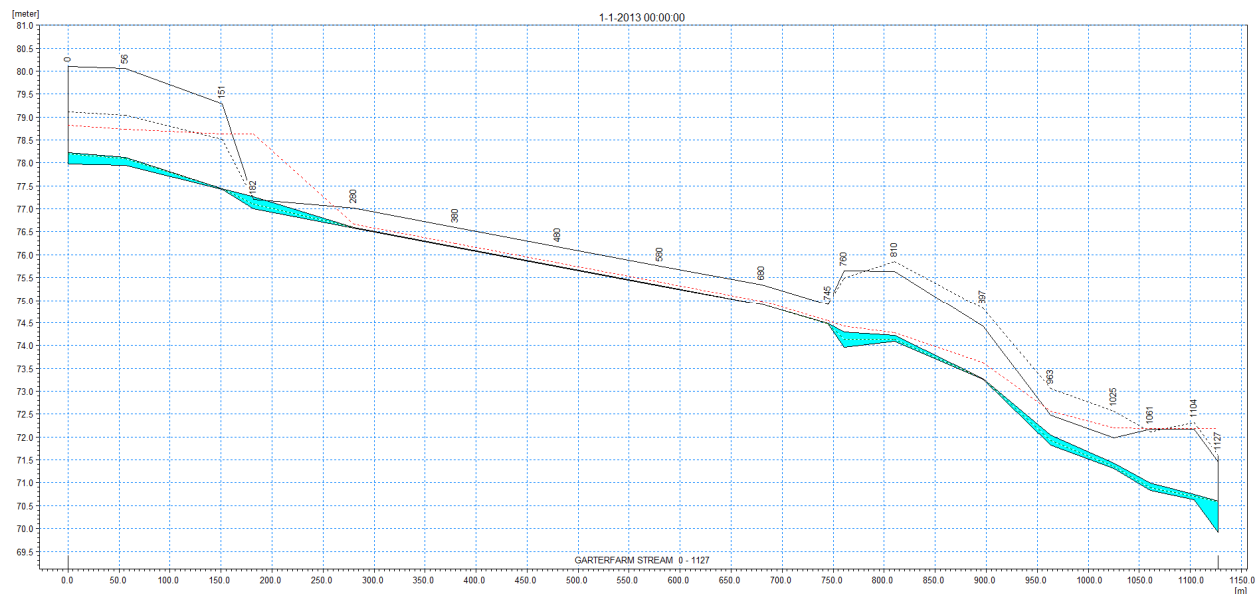
Figure 8.6.7 Storage for Flood Cell 2



The River Barrow and River Nore SAC is within, upstream and downstream of Castledermot. The AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slaney River Valley SAC and Holdenstown Bog SAC are over 8km to the east of Castledermot, however they are not hydraulically linked to the AFA.

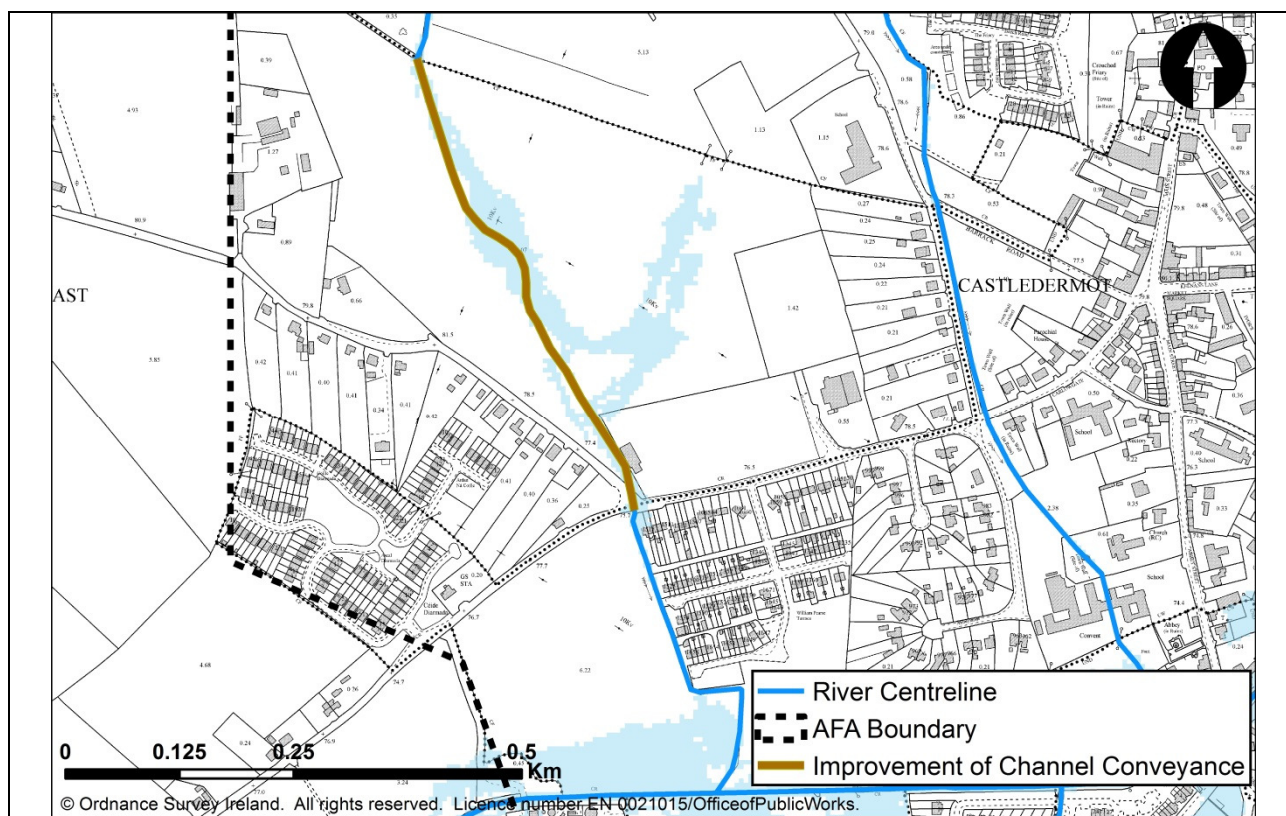
Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✓	✓	!	✓

A review of the various FRM method techniques was carried out and increasing conveyance through an existing structure was found to be the most appropriate way of implementing this method. The long section of the Garterfarm Stream and structures have been analysed for both high points and restrictive areas, it is evident from the long section of the watercourse as shown in Figure 8.6.8 that the long culvert 14GART00096I has insufficient capacity to convey the 1% AEP flows.



**Figure 8.6.8 Long Section of the Garterfarm Stream**

The 560m long culvert (location shown in Figure 8.6.9) would need to be upgraded from a 0.2m diameter pipe to a 0.375m diameter pipe to fully convey the 1% AEP flow of approximately 0.05m<sup>3</sup>/s.



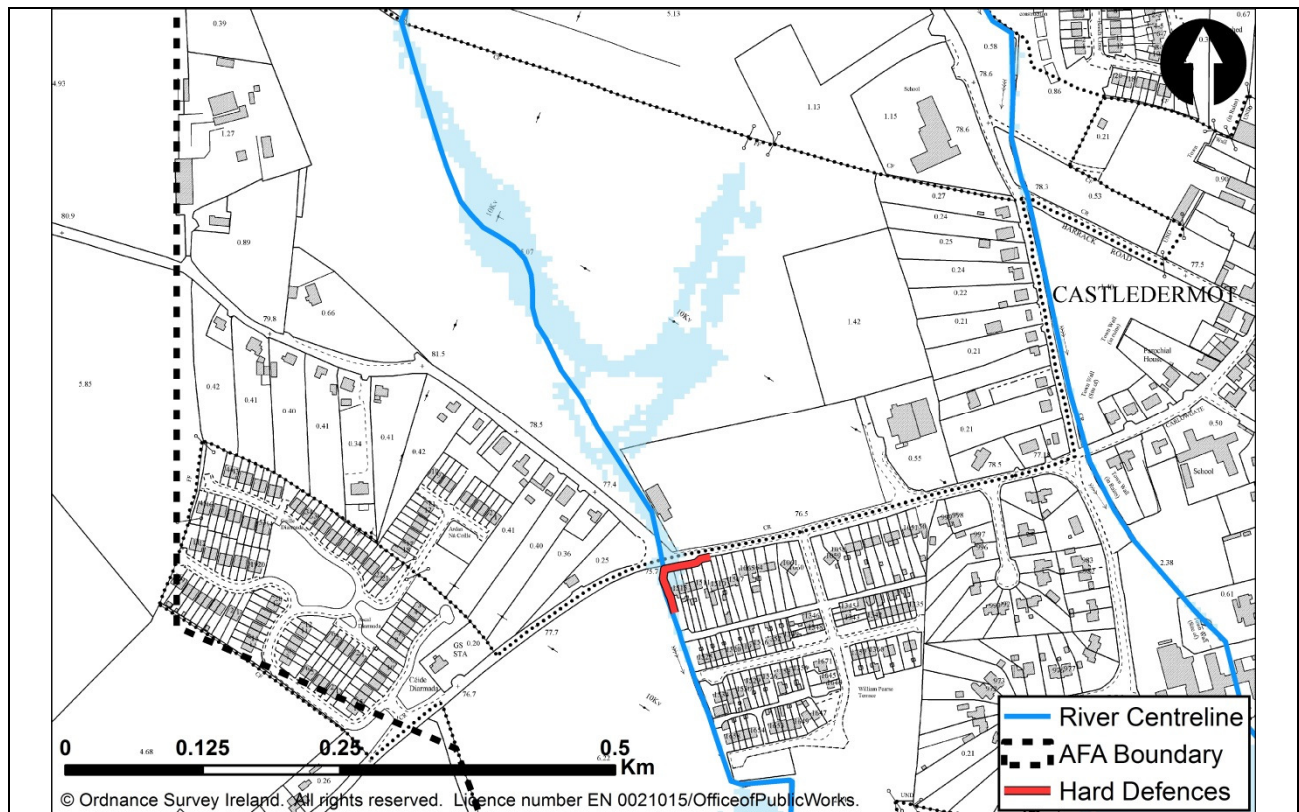
**Figure 8.6.9 Potential location of Improvement to Culvert Conveyance on the Garterfarm Stream**

An economic review of the works required on the Garterfarm Stream estimated the cost to be approximately €531,055. While this method is not economically viable it maybe be cost effective when evaluated with a lower BCR and should therefore be considered further.

The River Barrow and River Nore SAC is within, upstream and downstream of Castledermot. The AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slaney River Valley SAC and Holdenstown Bog SAC are over 8km to the east of Castledermot, however they are not hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	!	✓

A review was carried out to ascertain where Hard Defences would be required to protect the existing properties in flood cell 2. Figure 8.6.10 shows the location of the Hard Defences required to protect properties during the 1% AEP event. 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 0.7m and a total length of 85m. The estimated cost to carry these works out would be €266,497. While this method is not economically viable it maybe be cost effective when evaluated with a lower BCR and should therefore be considered further.



**Figure 8.6.10 Location of Hard Defence in flood cell 2**

The River Barrow and River Nore SAC is within, upstream and downstream of Castledermot. The AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slaney River Valley SAC and Holdenstown Bog SAC are over 8km to the east of Castledermot, however they are not hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓	✓	?

The three properties at risk during the design event in flood cell 2 may be suitable for relocation however the cost to relocate these properties, based on the market value, is €1.5m, which may be economically viable. This method should only be considered as a last resort if no other viable methods are available due to the potentially significant social impacts of relocating properties.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			

A review was carried to identify locations where a flow diversion route could be constructed in the vicinity of flood cell 2. Due to the topography of the land, a flow diversion route was not considered technically feasible and was removed from the screening process.

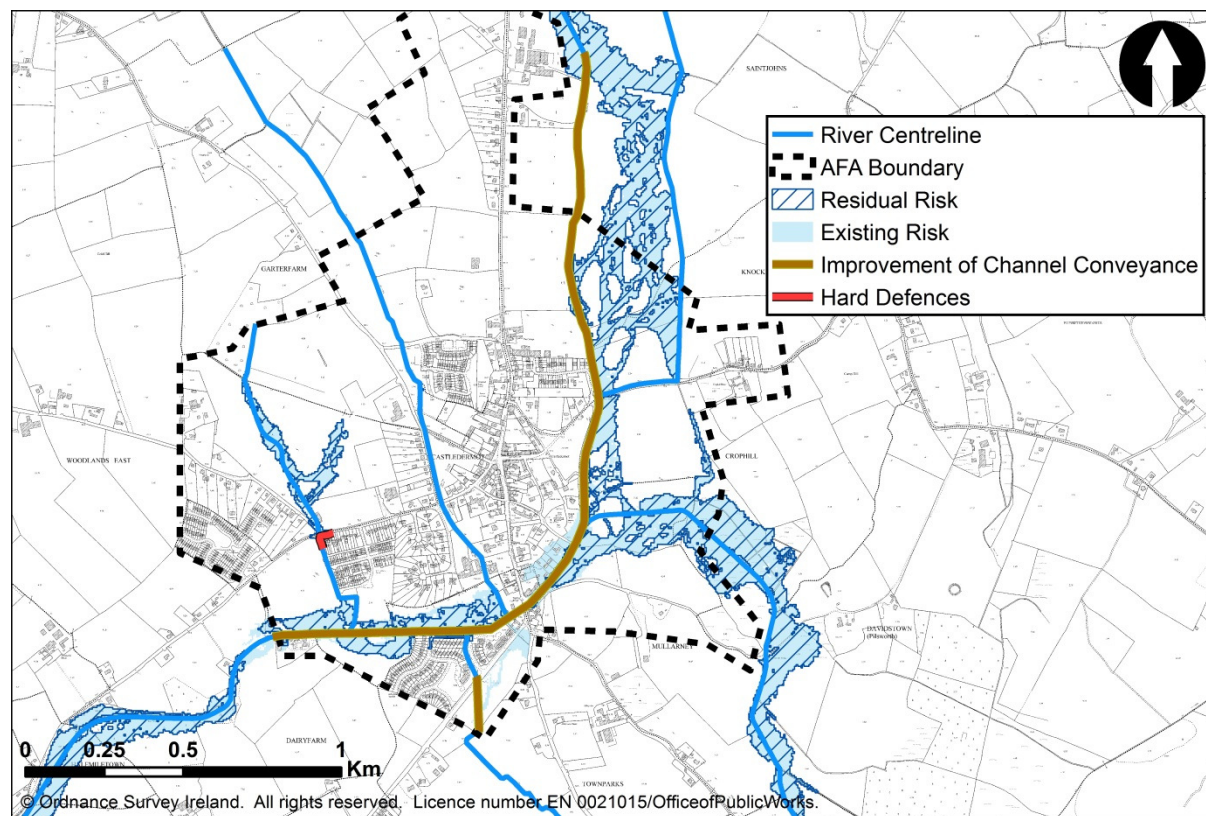
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			
The application of flood warning / forecasting was tested at UoM scale. There is no suitable location far enough upstream to place a gauge which would provide sufficient warning for flood cell 2. This method is technically unfeasible.				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓
The cost of individual property protection for the 3 properties affected in flood cell 2 would be €26,141, which may be economically viable. However, it does not provide the full SoP required and with other options able to provide this, IPP should only be considered should all other options be deemed unsuitable later in the optioneering process.				
Method	Tech	Econ	Env	Soc
Other Works	x			
No other works were identified for this flood cell				
<b>8.6.6.3 Summary of Feasibility Review – Flood Cell 2</b>				
<p>The feasibility review stated that Relocation of properties should only be considered if no other viable methods are available. The following FRM methods are available to address the flood risk arising from flood cell 2 (and therefore relocation of properties is no longer considered for this flood cell);</p> <ul style="list-style-type: none"> <li>• Storage</li> <li>• Improvement of Channel Conveyance</li> <li>• Hard Defences</li> </ul> <p>Hard Defences provide a significantly lower cost solution than the Storage and Improvement of Channel Conveyance methods. Individual Property Protection can only provide partial protection and should therefore only be used if there are no methods identified as being suitable later in the optioneering process.</p> <p>Consequently, hard defences is the preferred method and is carried forward to address the flood risk arising from flood cell 2.</p>				

### 8.6.7 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4
Improvement of Channel Conveyance	✓			
Hard Defences	✓	✓		
<p>The List below provides an overview of the methods which have been deemed as viable solutions within each of the flood cells. Various combinations of these methods have been considered to create 2 possible options for the Castledermot AFA.</p> <p>Flood Cell 1 –</p> <ul style="list-style-type: none"> <li>Improvement of Channel Conveyance</li> <li>Hard Defences</li> </ul> <p>Flood Cell 2 –</p> <ul style="list-style-type: none"> <li>Hard Defences</li> </ul>				



### 8.6.7.1 Option 1 Details – Improvement of Channel Conveyance & Hard Defences



**Figure 8.6.11 Castledermot Option 1**

At risk properties within flood cell 1 would be protected by improvement of channel conveyance on the Lerr and Vannan Rivers. This would entail the excavation of approximately 10,455m<sup>3</sup> of bed material on the River Lerr along with the underpinning of 4 bridge structures and the improvement of a culvert on the Vannan River.

At risk properties in flood cell 2 would be protected by hard defences consisting of walls. The new hard defences would protect to the 1% AEP flood event with an average height of 0.7m and a total length of 85m.

Figure 8.6.11 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).

The combination of these methods would protect to the 1% AEP flood. 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:

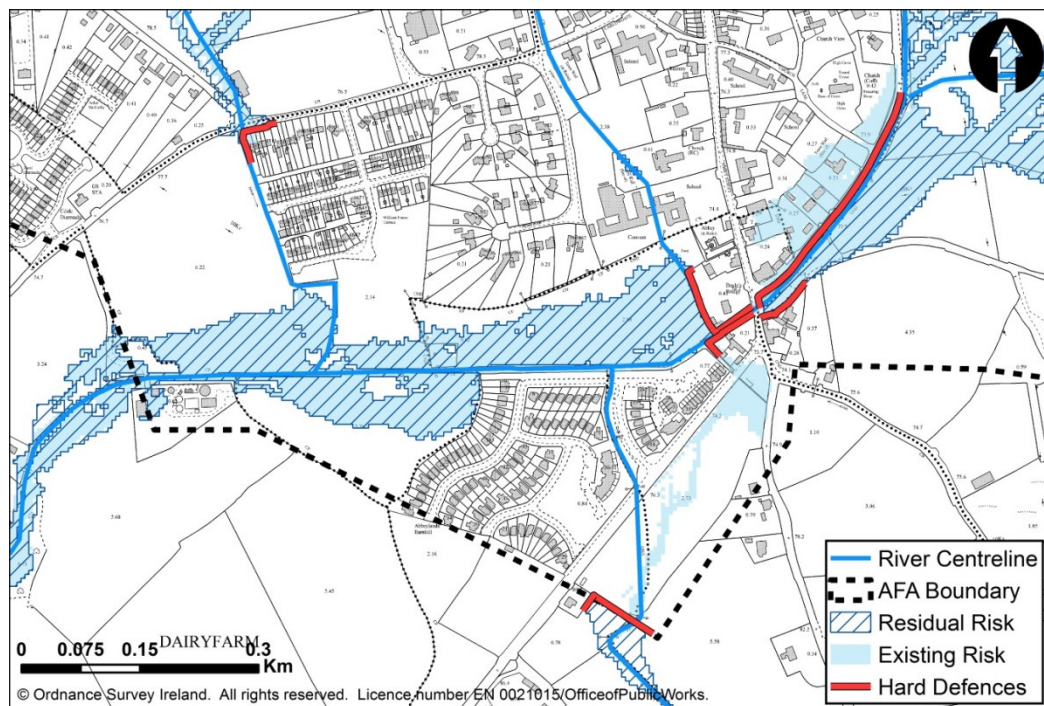
- Planning and Development Control
- Building Regulations
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Retaining wall	85m length, 0.7m high (average)	€106,025	
In channel excavation	Lerr River, 10455m³, bed level lowered 1m (average)	€334,734	
Bridge Underpinning	<ul style="list-style-type: none"><li>• 14LEER01006D</li><li>• 14LEER00931D</li><li>• 14LEER00853D</li><li>• 14LEER00831D</li></ul>	€217,908	
Culvert upgrade	Vannan River, 10455m³, bed level lowered 1m (average)	€246,525	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
-414	2.26	-183.68	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€1,714,722	€2,255,294	€1,140,087	0.51

### 8.6.7.2 Option 2 Details – Hard Defences

At risk properties in both flood cell 1 & 2 would be protected by hard defences consisting of walls, embankments and a road raise. The new hard defences would protect to the 1% AEP flood event with an average height of 0.9m and a total length of 776m.

Figure 8.6.12 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).



**Figure 8.6.12 Castledermot Option 2**

Option Item	Quantity	Construction Cost	
Retaining wall	612m length, 0.8m high (average)	€792,948	
Embankment	163m length, bed level lowered 1.2m (average)	€38,605	
Road Raise	75m	€128,370	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
-76	2.3	-33.03	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€1,714,722	€2,308,752	€1,140,087	0.5

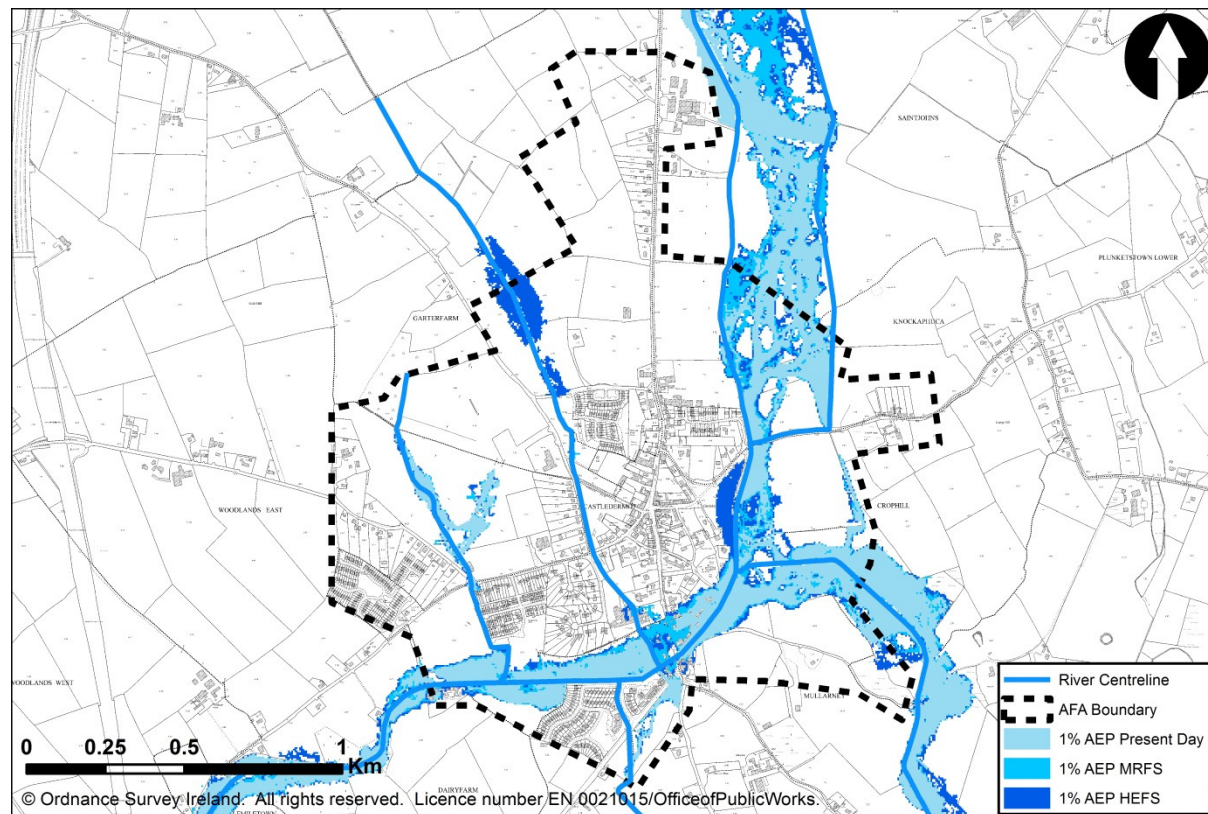
### 8.6.7.3 AFA Sensitivity to Future Change

As shown in Figure 8.6.13, during a MRFS 1% AEP flood event the increase in flood extent is minimal due to the topography in the area. Nine additional properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €79,821 to €230,230. As a result Castledermot AFA would be considered to be at moderate vulnerability from the MRFS.

During the HEFS 1% AEP flood event the flood extent is significantly larger than the MRFS in some areas. An additional 12 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €79,821 to €579,130. As a result Castledermot AFA would be considered to be at moderate vulnerability from the HEFS.

The main area of additional flood risk is in the Abbey Street Road area.

The number of additional properties affected by future scenarios indicates a significant increase to the annual average damage and the Castledermot area of assessment would be considered to be at moderate vulnerability. Options should be assessed to their adaptability to climate change.



**Figure 8.6.13 Future Change Flood Extents within Castledermot AFA**



#### 8.6.7.4 Future Change Adaptability

The following discusses the adaptability of the potential FRM methods proposed in Castledermot AFA:

**Improvement of Channel Conveyance Flood Cell 1** - This method could be adapted by dredging the channel deeper. The current proposal is to deepen and widen the channel to 9m width and 2.1m deep. If the flow were to increase the channel would need to be 9m x 2.4m to convey the MRFS flow or 9m by 2.8m to convey the HEFS flow. Additionally there are 4 bridges located in this stretch of river which would need underpinning. Finally the culvert upgrade suggested for the Vannan River could be adapted by increasing the recommended pipe diameter from 1.05m to 1.35m diameter.

As this method involves earthworks and minor structural works this method is considered to have **poor** adaptability.

**Hard Defences Flood Cell 1** - This method could be adapted by increasing the height of the walls and embankments and extending their length. A review of the effect of the MRFS and the HEFS showed that hard defences would need to be increased from an average of 0.9m up to 1.2m and 1.5m respectively. This additional hard defence height could be accommodated. The review also showed that a significant length of additional wall would be required for the HEFS event, which could be accommodated. To ensure that the walls would be adaptable the design would need to account for the potential increase on hard defence height. The embankments would also require space for a larger footprint. This method is considered to have a **moderate adaptability**.

**Hard Defences Flood Cell 2** - This method could be adapted by increasing the height of the walls. A review of the effect of the MRFS and the HEFS showed that hard defences would need to be increased from an average of 0.6m up to 0.61m and 0.8m respectively. This additional hard defence height could be accommodated. The review also showed that no additional lengths of wall are required. To ensure that the walls would be adaptable the design would need to account for the potential increase on wall height. This method is considered to be **readily adaptable**.

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 Castledermot is a fairly small rural town there maybe potential for some of these methods to impact on the area being assessed. Since there is a 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. This is most relevant to options with methods with poor adaptability, such as option 1.
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. Options 1 & 2 would create this situation.
3. **Does the option deliver co-benefits?** Option 1 requires less hard defences and therefore is more aesthetically pleasing than option 2, therefore option 1 has an additional social co-benefit.
4. **Does the option provide flexibility?** A review of the potential options show that option 2, Hard Defences, is the most adaptable to the MRFS and HEFS. However alternative FRM methods could be added to all options to provide an increased SoP. Option 1 could include



Hard Defences.

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, option 1 with channel modification is most easily reverted.

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

#### Summary of Option Adaptability

Option	Description	Score
Option 1 – Improvement of Channel Conveyance (FC1) & Hard Defences (FC2)	Option is adaptable only at significant cost, difficulty and impact	1
Option 2 - Hard Defences (FC1 & FC2)	Option is adaptable at moderate cost, difficulty and impact	3

#### 8.6.7.5 Local Authority Comments

LA representatives reviewed preliminary options in December 2015.

Following comments from Kildare County Council the options have been reviewed.

#### 8.6.7.6 Summary

There is moderate confidence in both the hydrology and hydraulics of the Castledermot AFA due to a lack of flood extent verification events and no gauging station present on the model extents.

The following potential options, with a BCR  $\geq 0.5$  have been identified:

- Option 1 – Improvement of Channel Conveyance (FC1) & Hard Defences (FC2)
- Option 2 - Hard Defences (FC1 & FC2)

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 Castledermot 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

Communities are located downstream of the Castledermot AFA that could be affected by the potential option identified. The flows at the model boundary were reviewed for the 1% AEP current scenario versus the 1% AEP with the options in place scenarios. There are negligible flow differences between the hydraulic model simulations. In addition any interactions with the drainage system in the urbanised area may need to be addressed during the development of the preferred option.

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

It should be noted that this area is moderately sensitive to climate change. Option 1 is suitable for an assumptive approach whereas option 2 is suitable for an adaptive approach to 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

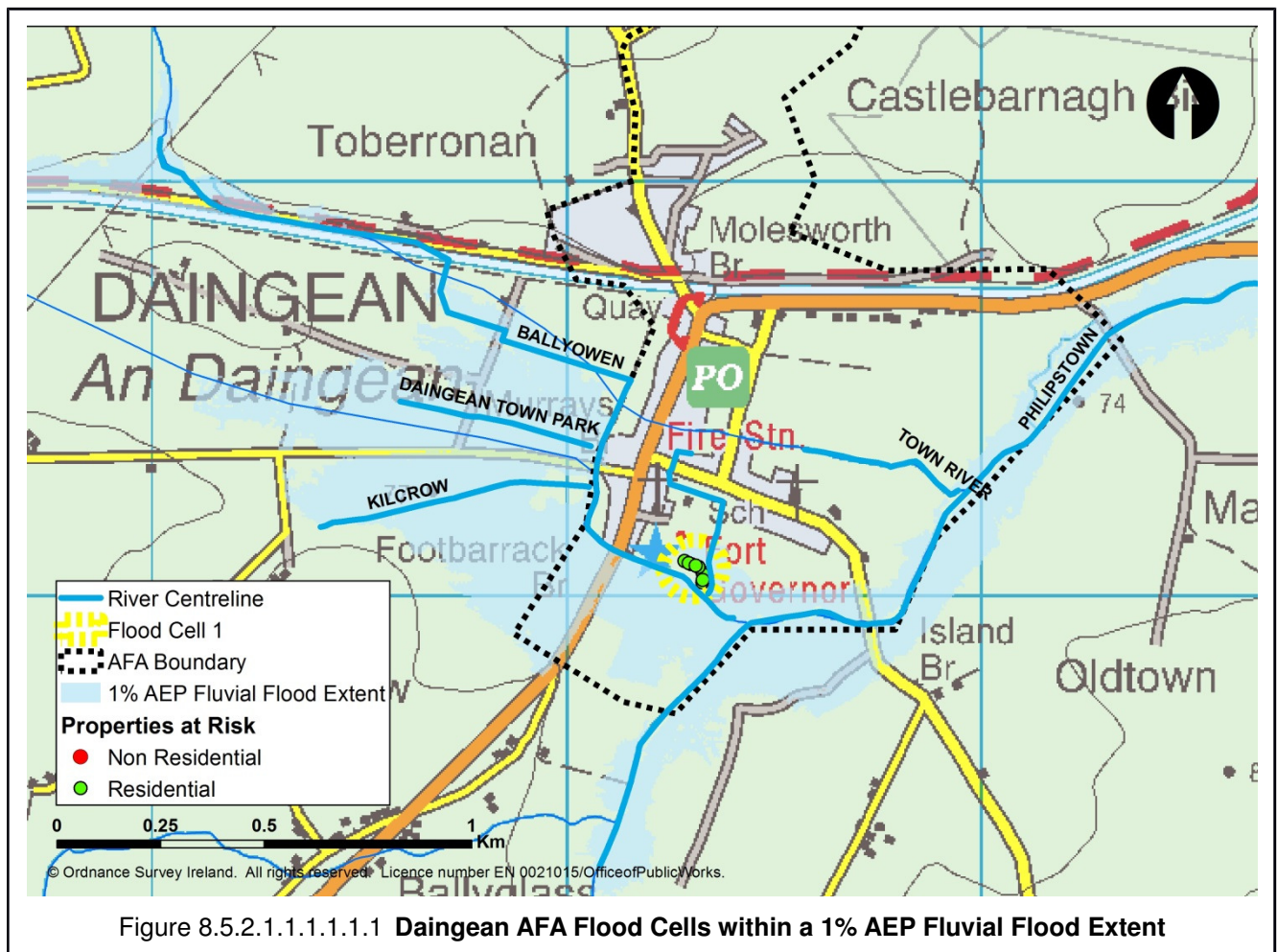
### 8.7 Daingean Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Daingean	Offaly	140159	AFA	Final	15/06/2016

#### 8.5.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.5.2 Flood Cells



**Flood Cell 1:**

All properties in Daingean at risk of flooding due to a 1% AEP fluvial event are contained in a single flood cell. Within flood cell 1, the Ballyowen River joins with Daingean Town Centre River. Modelling results have shown that during a 1% AEP fluvial event there is 'out of bank' flooding close to this confluence, with the flooding strongly influenced by a network of connective channels located within the town. Upstream of flood cell 1, the Daingean Town Park and Kilcrow stream drain the Town Parks area discharging to the Ballyowen River (Figure 8.5.1). Approximately 0.13km downstream of flood cell 1 the Ballyowen River joins the Philipstown River. As a flood event progresses, high water levels in the Philipstown River cause a backwater effect along the channel network leading to flooding of several properties along Castlekealy Lawns, within flood cell 1. Due to the interaction of fluvial flooding sources associated with flood cell 1, it is considered as complex.

**Summary of Flood Cell:**

As shown in Figure 8.5.1 the main flood risk associated with Daingean AFA is contained within a single flood cell. Due to the interaction of fluvial flooding sources associated with this flood cell, it is considered as complex and will be screened as a standalone area. (section 8.5.6)

On completion of the optioneering screening assessment all flood cells will be combined to form complete options for the Daingean AFA as detailed in section 8.5.6.

**8.5.3 Existing Regime**

The 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).

A number of Daingean watercourses are located within the Barrow Drainage District. Further details of operations in this district are presented in section 6.3. The other watercourses within Daingean which are not located within the Barrow Drainage District are, for the most part, in private lands and are not the responsibility of Offaly County Council who nevertheless carry out ad-hoc maintenance to the rivers where resources allow. The existing regime does not provide the preferred SoP.

### 8.5.4 Summary of Flood Risk within SSA boundary



Figure 8.5.4.1.1.1.1.1.1 Flood risk in Daingean AFA within a 1% AEP Fluvial Flood Extent

In Daingean AFA the onset of residential property damage occurs in the 5% AEP event. There are no non-residential properties at risk within this AFA.

### 8.5.5 Monetary Damage and Benefit

	Flood Cell 1	Total in AFA*
Annual Average Damage (AAD)	€ 3,451	€ 3,451
Present Value Damage (pvD)	€74,134	€74,134
Preferred Standard of Protection (SoP)	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	9	9
Minimum Present Value Benefit	€38,322	€38,322
Capped Minimum Present Value Benefit	€38,322	€38,322

\*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.



**8.5.6 Short Listing FRM Methods – Complex Cells**

Method	Review Comment	Continue Screening
		Flood Cell 1
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 at UoM SSA - Reject	✗
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 at UoM SSA - Reject	✓
Public Awareness Campaign	Consider at UoM SSA - Reject	✓
Individual Property Protection	Consider Further	✗
Other Works	Consider Further	✓

## 8.5.5.1 Feasibility Review Summary for Complex Cell (flood cell 1)

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

## 8.5.6.1 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	x	✓	?	?
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.  Offaly County Council has recently initiated a maintenance regime on the Philipstown River, which Offaly County Council believe resulted in a tangible reduction the flood risk over the 2015/2016 winter. These				

initial works have demonstrated that additional maintenance has a beneficial impact on flood risk however it is not capable of achieving the required SoP in isolation and was therefore eliminated from the screening process.

Method	Tech	Econ	Env	Soc
Do Minimum	✓			

This method can include clearance of channels and is also 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 are no obvious locations where the do minimum method would greatly reduce flood risk. This is an unacceptable outcome in terms of contributing to achieving a 1% AEP standard of protection and this method was therefore rejected from the screening process.

Land Use Management	x	-	?	?

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 reducing 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.

An assessment was conducted to locate possible Storage areas. Three potential storage areas were identified to reduce the impact of flooding in flood cell 1 as shown in Figure 8.5.6.1.1.1.1.1

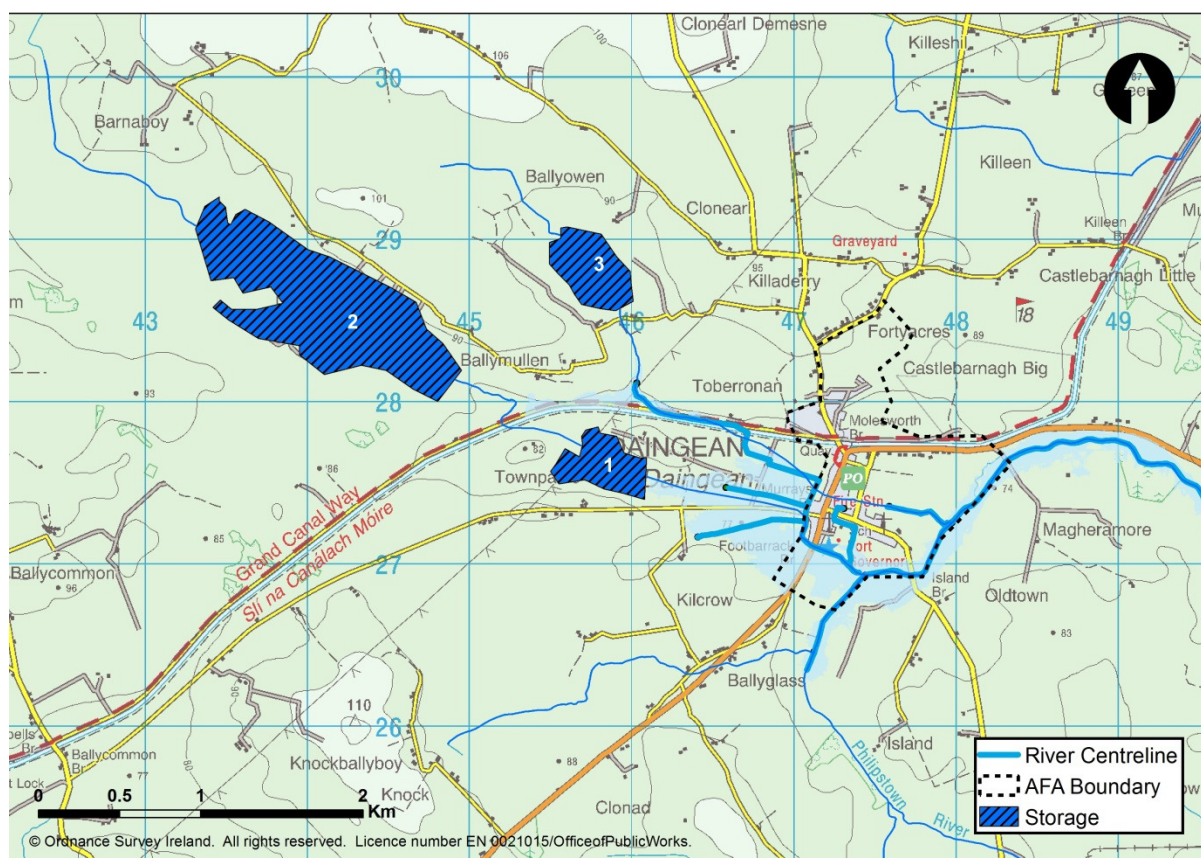


Figure 8.5.6.1.1.1.1.1.1 Potential Storage Areas Daingean Flood Cell 1

The volume of water required to be stored on the Ballyowen watercourse has been estimated to be 746,091m<sup>3</sup>. Storage area 2 could potentially hold this volume and hence achieve the design SoP for the properties at risk within flood cell 1. Storage areas 1 and 3 are too small and therefore will not be considered further. Construction of storage area 2 would require a series of embankments with an average height of 3.9m and total length of approximately 265m. In addition, one culvert and one overtopping weir would be required to act as flow control structures and convey flow through/ over the embankment. An economic review estimated that the cost of constructing storage area 2 is approximately €1,557,560 rendering this FRM as economically unviable.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

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.

Properties within flood cell 1 are at risk from flooding originating from Daingean Town Centre Stream and backwater flooding from the Ballyowen and Philipstown Rivers. Consequently, dredging of Daingean Town Centre Stream channel in isolation would not alleviate flooding. In order for channel conveyance to be effective in Daingean, a section of the Philipstown River requires improvement. Figure 8.5.6.1.1.1.1.2 and Figure 8.5.6.1.1.1.1.3 show sections of the Philipstown River where Improved Channel Conveyance might be considered.



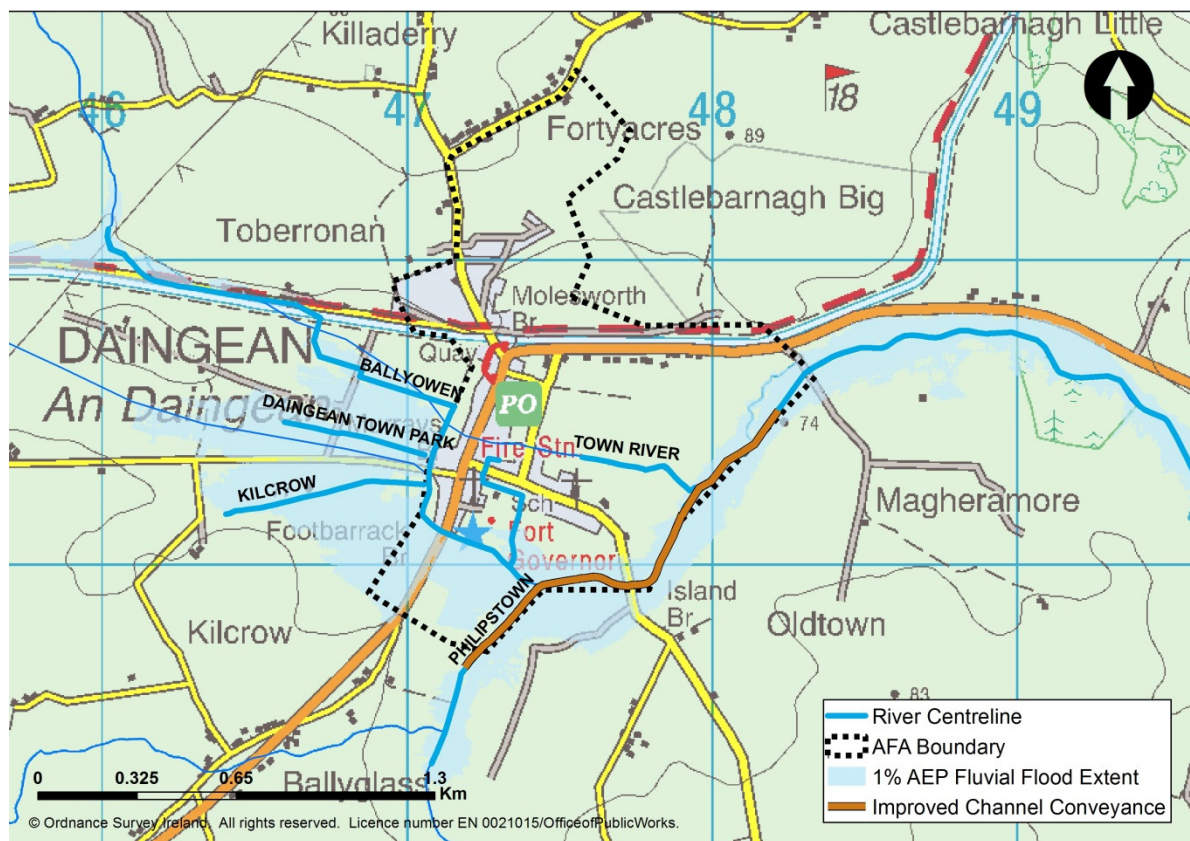


Figure 8.5.6.1.1.1.1.2 Location of Channel Improvement

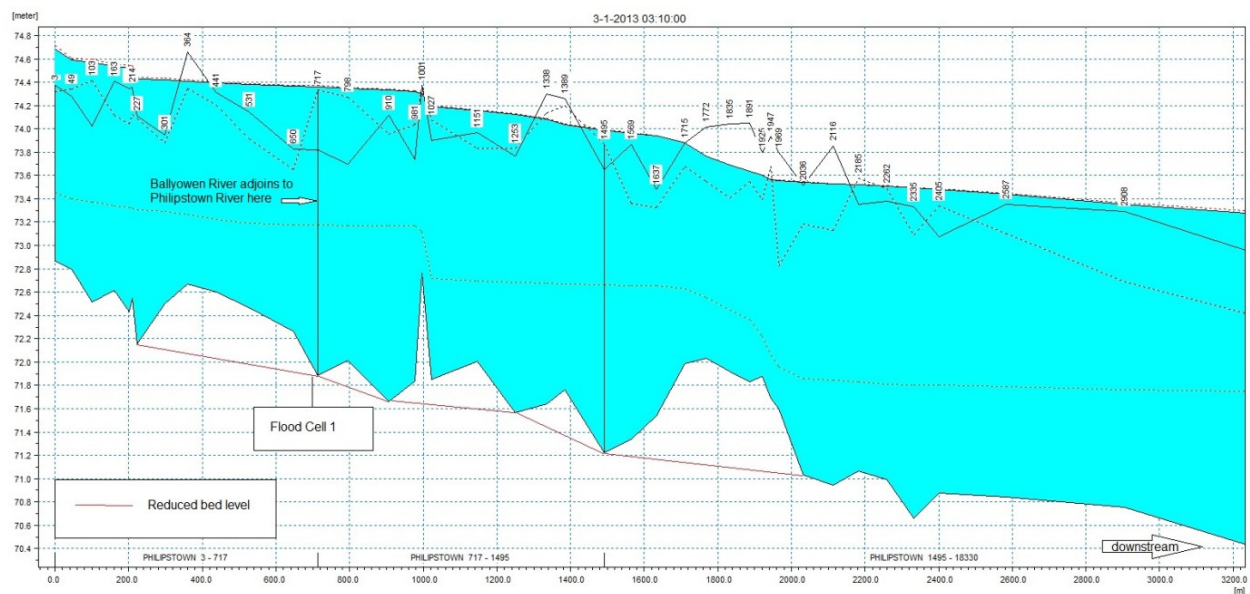


Figure 8.5.6.1.1.1.1.3 Potential Areas for Improvement of Channel Conveyance (Philipstown River)

It would be technically feasible to lower the bed level along these river channels and reduce the flood risk. This would involve dredging approximately 1.7km of channel and underpinning 2 bridges. The estimated cost would be €1,044,954 making this method economically unviable.



Method	Tech	Econ	Env	Soc
Hard Defences	x	✓		

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.

For Daingean, a technical review was conducted to ascertain the optimum arrangement of Hard Defences, benefitting the greatest number of properties. Figure 8.5.5.3.1.1.1.6 shows the location of Hard Defences required to provide a SoP of 1% AEP.



Figure 8.5.5.3.1.1.1.6 Location of Potential Hard Defences within Daingean

In order to ascertain the effect of Hard Defences a hydraulic model was constructed to simulate the method. The model showed that hard defences (consisting of embankment) with an average height of 0.79m and a total length of 150m would protect to the 1% AEP flood event. An economic review estimated the cost of these hard defences to be approximately €88,487 making this method economically unviable

Method	Tech	Econ	Env	Soc
Flood Warning / Forecasting	x	✓		
<p>The application of flood warning / forecasting was tested at UoM scale. A suitable location far enough upstream of flood cell 1 is available to provide sufficient warning. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.</p> <p>An economic review estimated that the cost of providing the five recommended hydrometric gauging stations with simple forecasting systems would be approximately €237,461, rendering this method as uneconomical.</p>				
Method	Tech	Econ	Env	Soc
Relocation of properties	x	✓		
<p>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 clusters of properties are located.</p> <p>In practice it is always technically possible to relocate properties, however considering the socially negative impacts it should only be considered should no other method be found suitable. There are 9 properties at risk within flood cell 1, during the occurrence of a 1% AEP fluvial event. Although it is technically feasible to relocate these properties elsewhere, it is estimated that this would cost €4,634,316; therefore making this method economically unviable.</p>				
Method	Tech	Econ	Env	Soc
Diversion of Flow	x			
<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 technical review has identified that it is possible to divert flow from the Daingean Town Centre Stream upstream of the risk area and discharge it back into the Philipstown river downstream. In this instance, a new channel could be excavated to the east across fields and then joined with Philipstown River rather than Ballyowen River, as shown in Figure 8.7.7. This would effectively re-direct the Daingean Town Centre Stream away from the 'at risk' properties at Castlekealy Lawns.</p>				

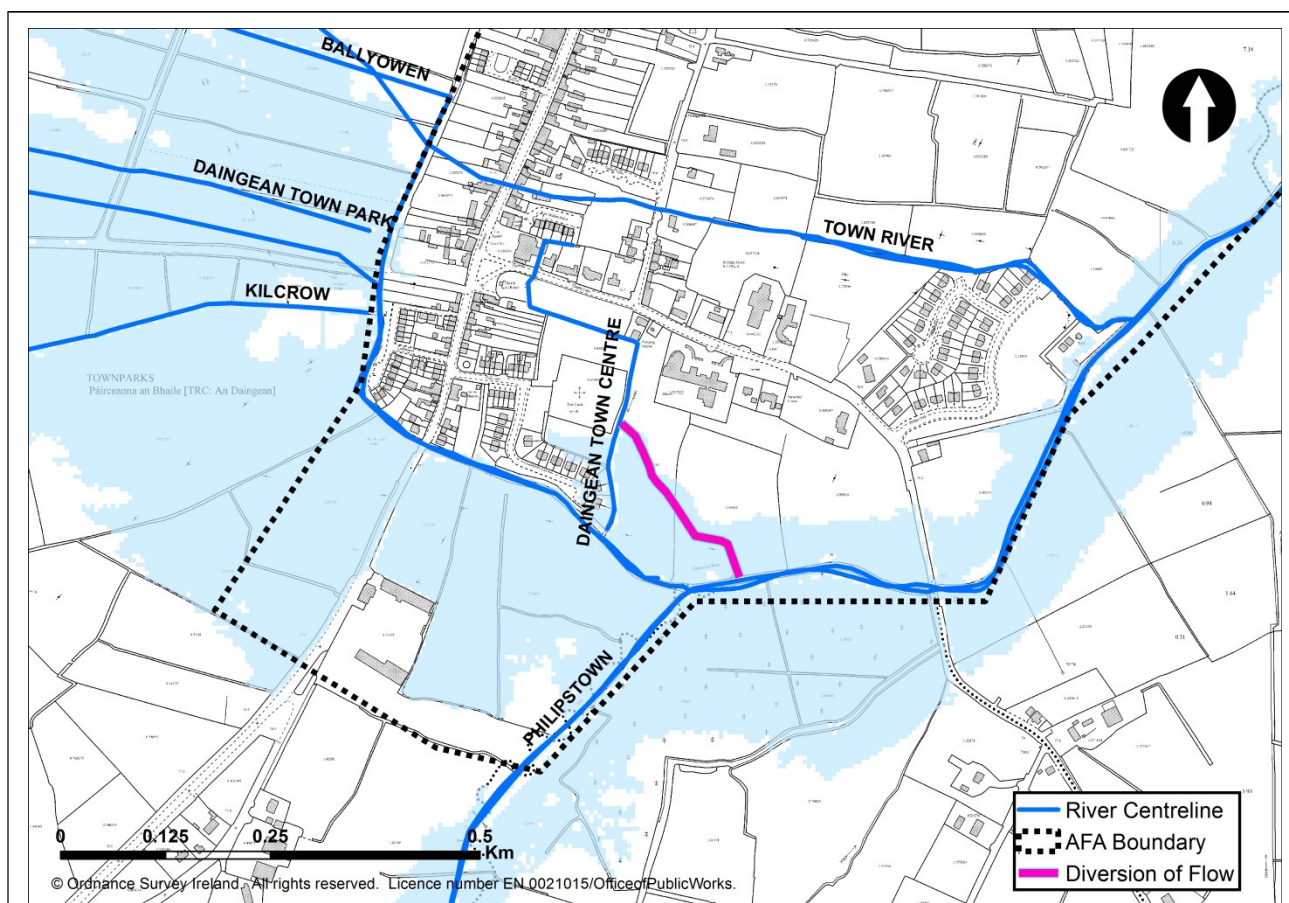


Figure 8.5.5.3.1.1.1.7 Location of Flow Diversion for Flood Cell 1

Modelling simulations have revealed that this scheme would be of little benefit in alleviating flooding in flood cell 1, since it does not address the backwater issues originating from the Ballyowen and Philipstown Rivers. Flow diversion can therefore be viewed as technically unfeasible.

Method	Tech	Econ	Env	Soc
Individual Property Protection	x	✓		

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.

While this method would not provide the required design 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 the pass through the screening process.

It is estimated that 'Individual Property Protection' of the 9 properties within flood cell would cost €93,362 making this scheme economically unviable.

Method	Tech	Econ	Env	Soc
Other Works	x			
No other works were identified for this flood cell.				
<b>8.5.6.2 Summary of Feasibility Review – Flood Cells 1</b>				
<p>The following FRM methods have been carried forward to address the flood risk arising from flood cell 1.</p> <ul style="list-style-type: none"> <li>Land Use Management</li> </ul> <p>Land Use Management should be considered as a pilot study in Daingean since all other FRM have been deemed unsuitable in the Selection of Options stage.</p>				



### 8.5.6 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Land Use Management	x				

No FRM options have been identified which offer the full SoP to all properties. It would therefore be recommended that the existing regime continue along with any other measure proposed in Daingean.

#### 8.5.6.1 Option 1 details – Maintain Existing Regime & Land Use Management

As no FRM options have been identified which offer the full SoP to all properties, it is recommended that Land Use Management is considered as a pilot for the Daingean AFA. In addition to Land Use Management as a potential option, it is recommended that the existing regime is maintained.

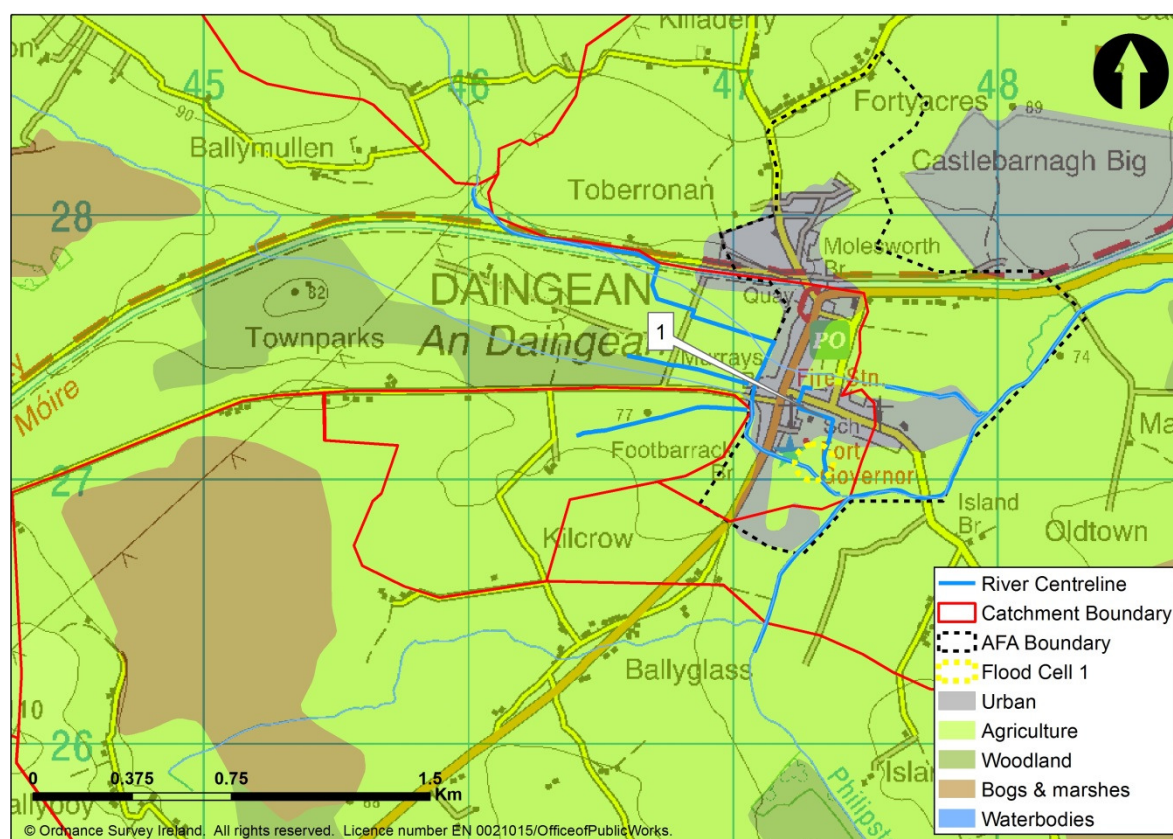


Figure 8.5.6.3.1.1.1.6 Daingean AFA Option 1

Daingean AFA is within the Barrow Freshwater Pearl Mussel sensitive area and Daingean Bog NHA is just upstream of the AFA. Land use management should be assessed to identify land use features which would reduce the surface water runoff. This option has potential to provide multiple benefits to agriculture, the environment and specifically the Barrow Freshwater Pearl Mussel habitat in addition to reducing the flood risk. The amount of sediment and pollutants entering the watercourse should therefore also be considered during any further studies.



The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio
-	-	-
<b>Economic Appraisal (Cost-Benefit Analysis) Outcomes</b>		
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)
€74,134	-	€38,322

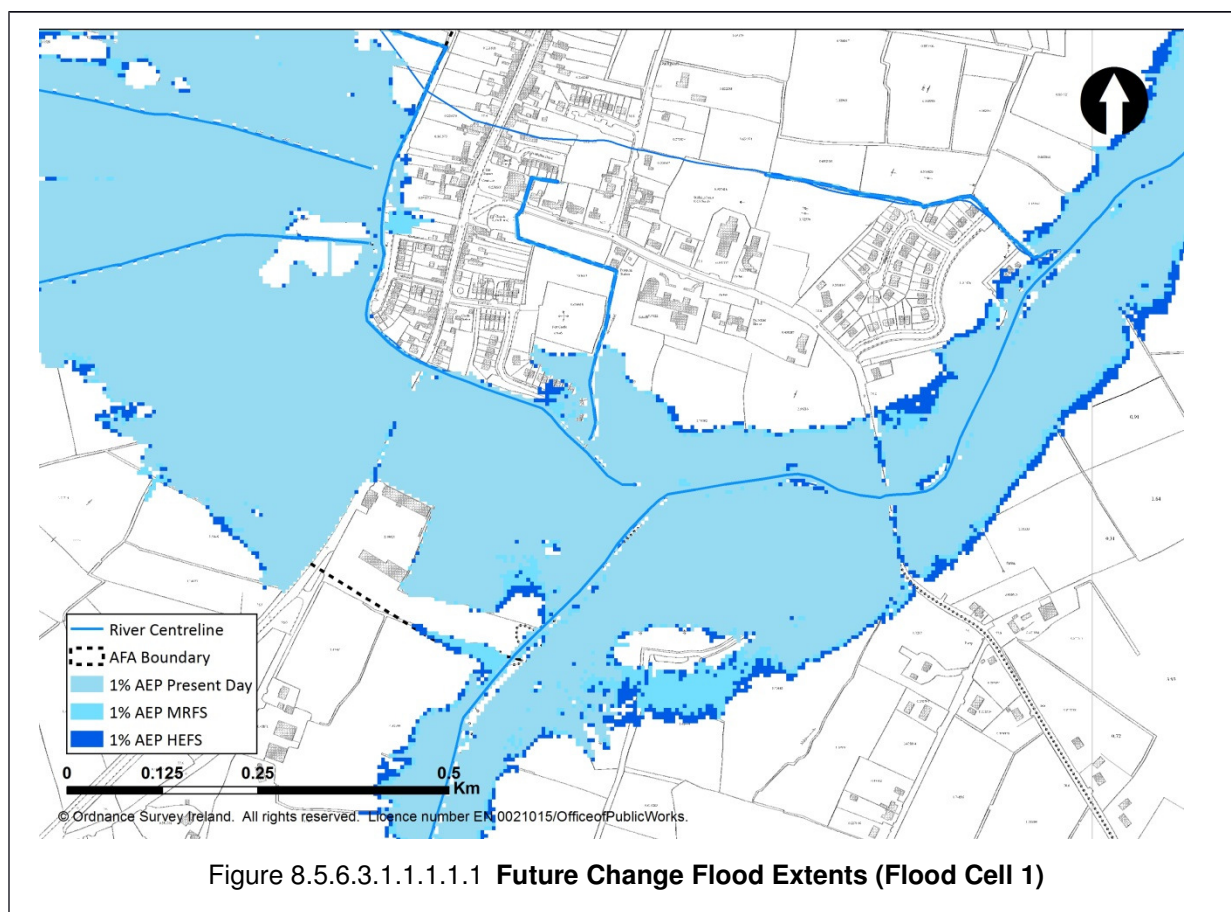
### 8.5.6.3 AFA Sensitivity to Future Change

During a MRFS and HEFS 1% AEP flood events the increase in flood extent associated with Daingean is minimal. These flood extents are restricted by the fluvial basin terrain associated with Daingean, see *Figure 8.5.6.3.1.1.1.1.1*. The main area of additional flood risk is located to the south and east of Daingean AFA. To the south of the AFA, two large warehouses are at risk. While to the east of the AFA, several storage tanks located close to the Philipstown River are affected.

During a MRFS 1% AEP flood event it is estimated that an additional 3 properties are to at risk of flooding when compared to the present day flood risk. This would bring the property count from 9 in the present day 1% AEP event to 12. The AAD would increase from €3,451 to €288,358. As a result Daingean AFA would be considered to be at moderate vulnerability from the MRFS.

During the HEFS 1% AEP flood event the flood extent, while larger than the MRFS, is minimal also. An additional 6 properties are estimated to be at flood risk when compared to the present day flood risk. This would bring the property count from 9 in the present day 1% AEP event to 15. The AAD would increase from €3,451 to €341,375. As a result Daingean AFA would be considered to be at moderate vulnerability from the HEFS.

As a result Daingean AFA would be considered to be at moderate vulnerability from the MRFS and HEFS.



#### 8.5.6.4 Future Change Adaptability

The following discusses the adaptability of the potential FRM **methods** proposed in Daingean AFA:

**Land Use Management** – In principle, this FRM method is readily adaptable, depending on methodologies applied, following the pilot exercise. This method is considered to be **readily** adaptable.

**Maintain Existing Regime** – This method could be easily adapted by maintaining and increasing the current maintenance regime when needed. This method is considered to be **readily** adaptable.

The potential **option** identified has 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. Since the town of Daingean is currently situated along the banks of several rivers and the Philipstown River floodplain, there is still some scope for some of these methods to impact on the area being assessed. Since there is an increase in the number of properties affected in the MRFS and HEFS there is a need to ensure that the owners and users of future receptors at risk are prepared through methods such as public awareness campaign.
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 restrict the water making water levels more sensitive to increased flow. No hard defences have been included in the suggested option.
3. **Does the option deliver co-benefits?** No co-benefits have been identified.
4. **Does the option provide flexibility?** A review of the potential options show that all options , are adaptable to the MRFS and HEFS.
5. **Does the option allow for deferring/removing or abandoning?** Considering that no structural FRM have formed part of the Daingean options, there is no requirement for deferring, removal or abandonment.

An objective for the suggested 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 the table below summarises how well each option achieves this objective.

#### Summary of Option Adaptability

Option	Description	Score
Option 1- Maintain Existing Regime & Land Use Management	Option is readily adaptable at low difficulty and impact	5

#### 8.5.6.5 Local Authority Comments

LA representatives reviewed preliminary options in December 2015. Offaly Council Council (OCC) reviewed the proposed potential option relating to Daingean AFA. It was of the opinion that the new maintenance regime has made a tangible reduction to the flood risk. As there are no cost beneficial options that provide the preferred SoP, progressing, OCC would agree with the maintenance regime being continued.

#### 8.5.6.6 Summary

There is good confidence in both the hydrology and hydraulics of Daingean model due to the presence of a gauging station and flood extent verification events.

The following potential option, with a BCR  $\geq 0.5$  have been identified:

- Option 1 – Maintain Existing Regime & Land Use Management

Methods also were identified at UoM level (see section 8.1) that are applicable to Daingean 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 Daingean AFA shows a moderate vulnerability and sensitivity to climate change and is suitable for an assumptive approach be incorporated into detailed design.

Very low risk was identified in Daingean AFA however the existing regime should be maintained to retain the current SoP. Land use management has been identified as a possible option to manage future flood risk.

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

## 8. OPTIONEERING OF SSA'S

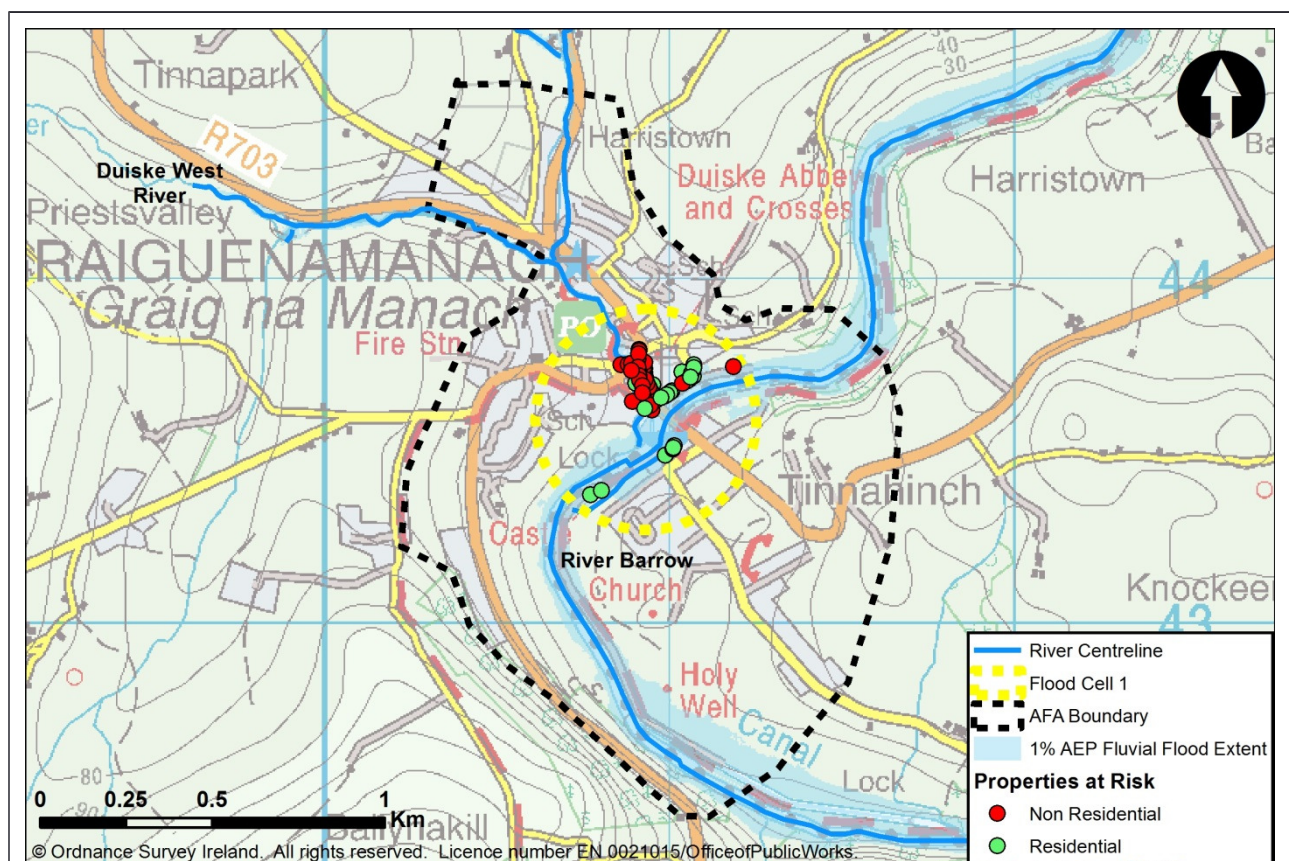
### 8.8 Graiguenamanagh optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Graiguenamanagh	Kilkenny	140162	AFA	Final	15/06/2016

#### 8.6.1 Source of flooding

Fluvial	Coastal Mechanism 1	
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#### 8.6.2 Flood Cells



**Figure 8.6.2.1.1.1.1.1 Graiguenamanagh AFA Fluvial Flood Cells within a 1% Fluvial Flood Extent**

#### Flood Cell 1:

Out of bank flooding, would occur due to a combination of insufficient channel capacity and culvert capacity. As the Duiske West River flows through Graiguenamanagh it passes through a series of



bridges, some of which have been identified as critical structures causing raised water levels. During a 1% AEP fluvial event flood water rises sufficiently to cause out of bank flooding at properties along the river's edge, along Main Street and along The Quay. Insufficient channel capacity and the Bridge ID:14BARO04768D also restrict flow along the River Barrow causing out of bank flooding impacting properties on The Quay.

#### Summary of Flood Cells:

As shown in Figure 8.6.2.1.1.1.1.1 the main flood risk originates from the Duiske West and River Barrow. Due to the complexity and interaction of the flooding, it is considered appropriate to screen the flood risk together in one cell in the optioneering process.

Sixty four properties are at risk in flood cell 1. Due to the nature of the flood mechanism and the extent of the flooding associated with a 1% fluvial event, it is appropriate to screen flood cell 1 as a standalone area, see section 8.6.6

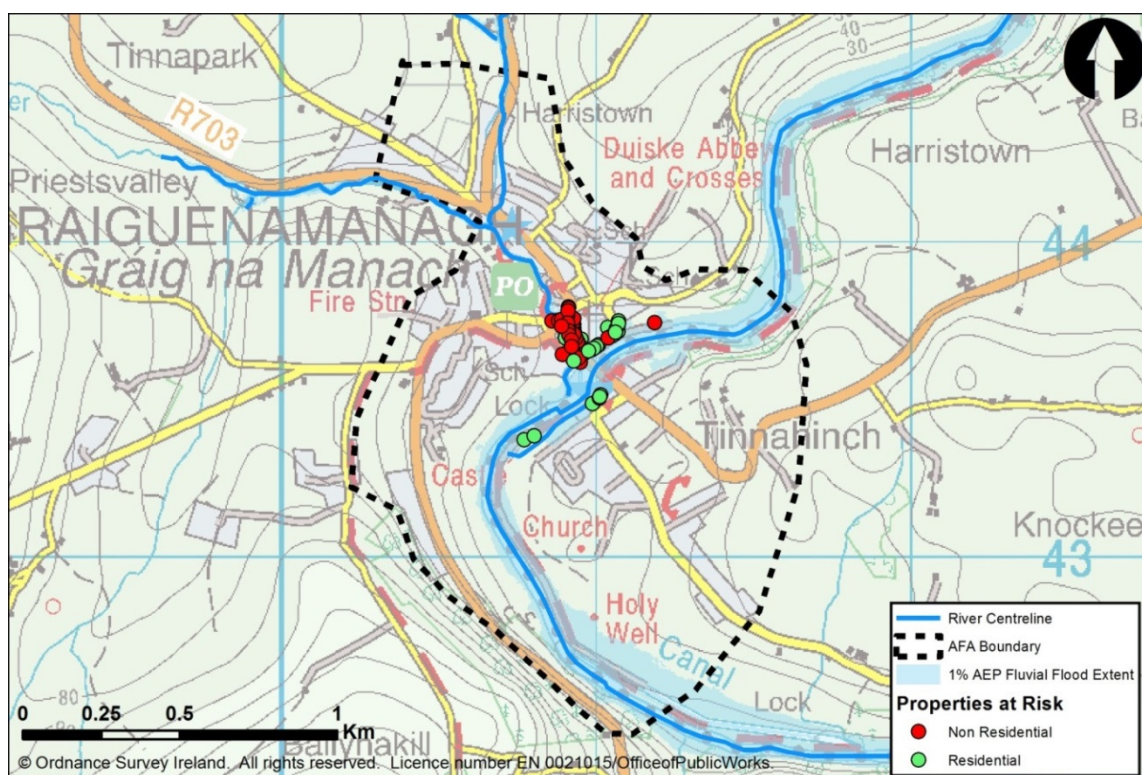
On completion of the optioneering screening assessment flood cell 1 will be used to form complete options for the Graiguenamanagh AFA as detailed in section 8.8.7.

### 8.6.3 Existing Regime

The 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 River Barrow and other watercourses within Graiguenamanagh AFA are not located within a Drainage District or an Arterial Drainage scheme. They are, for the most part, in private lands and are not the responsibility of Kilkenny or Carlow County Councils. Nevertheless, inspections and maintenance are carried out as and when resources are available.

### 8.6.4 Summary of Flood Risk within SSA boundary



**Figure 8.6.4.1.1.1.1.1 Fluvial Flood risk in Graiguenamanagh AFA within a 1% Fluvial Flood Extent**

In Graiguenamanagh AFA the onset of residential and non-residential property damage occurs in the 50% AEP event.

### 8.6.5 Monetary Damage and Benefit

	Flood Cell 1	Total in AFA
Annual Average Damage (AAD)	€1, 671,919	€1,672,771
Present Value Damage (PvD)	€ 35,916,173	€ 35,934,469
Preferred Standard of Protection (SoP)	1%AEP	1%AEP
Number of Properties Benefiting from Design SoP	64	64
Minimum Present Value Benefit	€ 34,049,882	€ 34,049,882
Capped Minimum Present Value Benefit	€ 10,260,826	€ 10,260,826

\*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.

**8.6.6 Short Listing FRM Methods – Complex Cells (Flood Cell 1)**

Method	Review Comment	Continue Screening
		Flood Cell 1
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	✓

## 8.6.6.2 Feasibility Review Summary of FRM 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 impacts identified    ! - Progress, potential for significant impacts identified

## 8.6.6.3 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do nothing	✓			

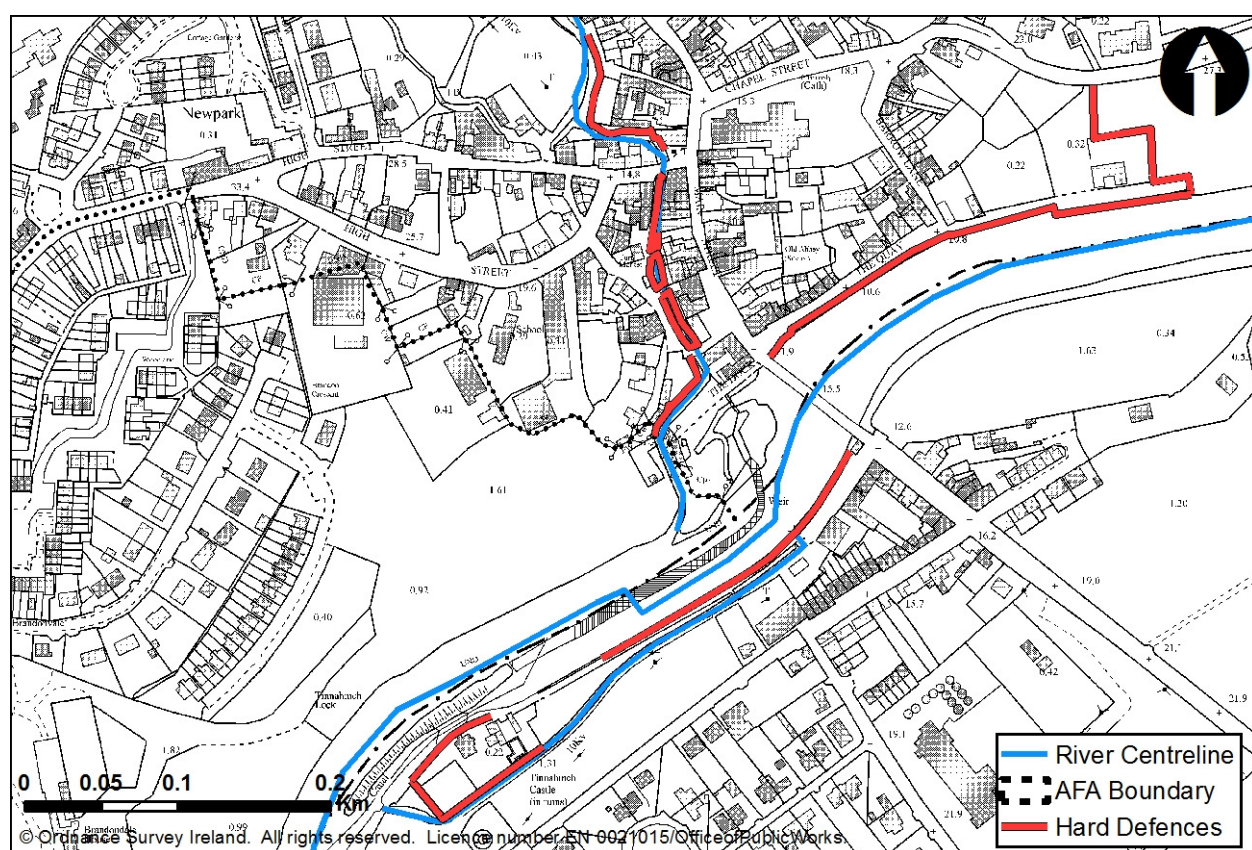
The do nothing FRM method would involve stopping the current maintenance regime. This would not provide the preferred SoP and therefore was rejected from the screening process.

Method	Tech	Econ	Env	Soc
Additional Maintenance	x			
<p>This method considers whether improvements can be made to augment the 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.</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	x			
<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 1 there are no obvious locations where the do minimum method would greatly reduce flood risk. Additional channel clearance would have minimal impact on the overall flood risk due to the capacity restriction and the location of receptors. This is an unacceptable outcome in terms of contributing to achieving a 1%AEP standard of flood protection and this method was rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	x			
<p>The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in the catchments the method is considered unsuitable to benefit flood cell 1. This method is technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Storage	x			
<p>This method considers areas where flood water can be stored and then released at a controlled rate, therefore reducing the flow rate along the HPW and reducing the level of flood risk. This can be achieved by using existing or creating new 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> <p>The volume of water required to be stored on the Duiske West watercourse before reaching flood cell 1 has been estimated to be 396,686m<sup>3</sup> and the available storage is 32,320m<sup>3</sup>. The required volume of water to be stored on the River Barrow is 39,266,082m<sup>3</sup>, a review of the surrounding land was carried out but no suitable location was found to accommodate this volume of water. This method is therefore considered technically</p>				



unfeasible.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		
<p>This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed levels, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse, reducing roughness of the channel and sealing manholes. A review of the various FRM method techniques, as listed above, was carried out for flood cell 1 and the following techniques were found to be the most appropriate way to implement this method.</p> <p>Within flood cell 1, flooding arises from the 1% AEP fluvial flood event in the Duiske West watercourse and the River Barrow. Channel excavation and bridge underpinning was examined as an option to alleviate the fluvial flooding along the Duiske West,. It is not possible to widen the channel because of the close proximity of properties along the Duiske West, therefore the only option is to lower the bed level. It is estimated that 2688m<sup>3</sup> of material would need to be excavated from the channel and 7 bridges would need underpinning (ID:14DWST00006D,14DWST00022D,14DWST00021D,14DWST00020D,14DWST00017D,14DWST00013D and 14DWST00021D).</p> <p>To alleviate the fluvial flooding along the River Barrow, channel excavation, bridge underpinning and weir removal was examined. It is estimated that 144,000m<sup>3</sup> of material would need to be excavated from the channel, one bridge underpinned (ID:14BARO04768D) and 2 weirs removed (ID:14BARO04759W &amp; 14BARO04638W).</p> <p>This method is technically feasible, however the total estimated cost of these works is approximately €16.7m making this method economically unviable.</p>				
Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	!	✓
<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 the existing properties in flood cell 1. Figure 8.6.6.3.1.1.1.1.1 shows the location of the Hard Defences required to protect properties during the 1% AEP event. In order to ascertain the effectiveness of Hard Defences a hydraulic model was constructed to simulate the method. The model showed hard defences with an average height of 1.56m and a total length of 1.31km would protect to the 1% AEP flood event. It has been highlighted that within Graigunemangh there are ground water flow issues, this is not simulated with the hydraulic model however sheet piling has been included in the costing of this method to ensure the risk from this flood mechanism is taken into consideration. The estimated cost to carry these works out would be €9.2m making this method economically viable.</p>				



**Figure 8.6.6.3.1.1.1.1 Location of Hard Defences in flood cell 1**

The River Barrow and River Nore SAC is within, upstream and downstream of Graiguenamanagh. The Blackstairs Mountains SACs are over 7km upcatchment of the AFA to the east. The River Nore SPA is over 7km to the south west of Graiguenamanagh, however is not hydraulically linked to the AFA. Graiguenamanagh is within the Barrow Freshwater Pearl Mussel sensitive area. The Ballymurphy and Mountain / Aughnabrisk FPM habitats and sensitive areas are upstream of Graiguenamanagh by 3km and 7km respectively. The Barrow River Valley pNHA is over 10km downstream. The Blackstairs Mountains pNHAs are over 7km upcatchment of the AFA to the east and IWeBS key sites are in the vicinity. The proposed hard defences are within the SAC designated site, this will have an impact on the River Barrow SAC within the flood cell.

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 community of many at risk properties. Its use is more applicable for discrete areas where single properties or clusters of properties are located.

In practice it is always technically possible to relocate properties, however considering the socially negative impacts it should only be considered should no other method be found suitable. All 64 properties at risk during the 1% AEP event which may be suitable for relocation. The capped market value for the affected properties was approx. €19.8m which is in excess of the Present Value Benefit. This method was therefore considered

economically unviable.

Method	Tech	Econ	Env	Soc
Diversion of Flow	x			
<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 1. Due to the surrounding topography, no location was found where this method could be carried out. This method is therefore considered technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			
<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 properties along the Duiske West River in flood cell 1. This method is technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Individual Property Protection	x			
<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 areas 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>Flood cell 1 contains a large number of grouped properties, and there are predicted flood depths greater than 0.6m for 31 of the 64 properties impacted by flooding. This method is therefore technically unfeasible as a standalone option for the whole AFA.</p> <p>There is a pilot community flood response project for Graiguenamanagh, to progress flood alert and community flood response schemes. These schemes are intended to facilitate a community based response to flood events by improving the resilience and preparedness of the local community. The scheme includes the provision of an early flood warning system and flood barriers for individual property protection in Graiguenamanagh. The proposed scheme will include a detailed building survey to identify all potential flow paths through the affected properties. The survey will also consider the type of foundation and floor in the property along with other factors which may affect the viability of any proposed measures.</p>				
Method	Tech	Econ	Env	Soc



Other Works	x			
No other works were identified for this flood cell.				

#### 8.6.6.4 Summary of Feasibility Review – Flood Cell 1

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

- Hard Defences.

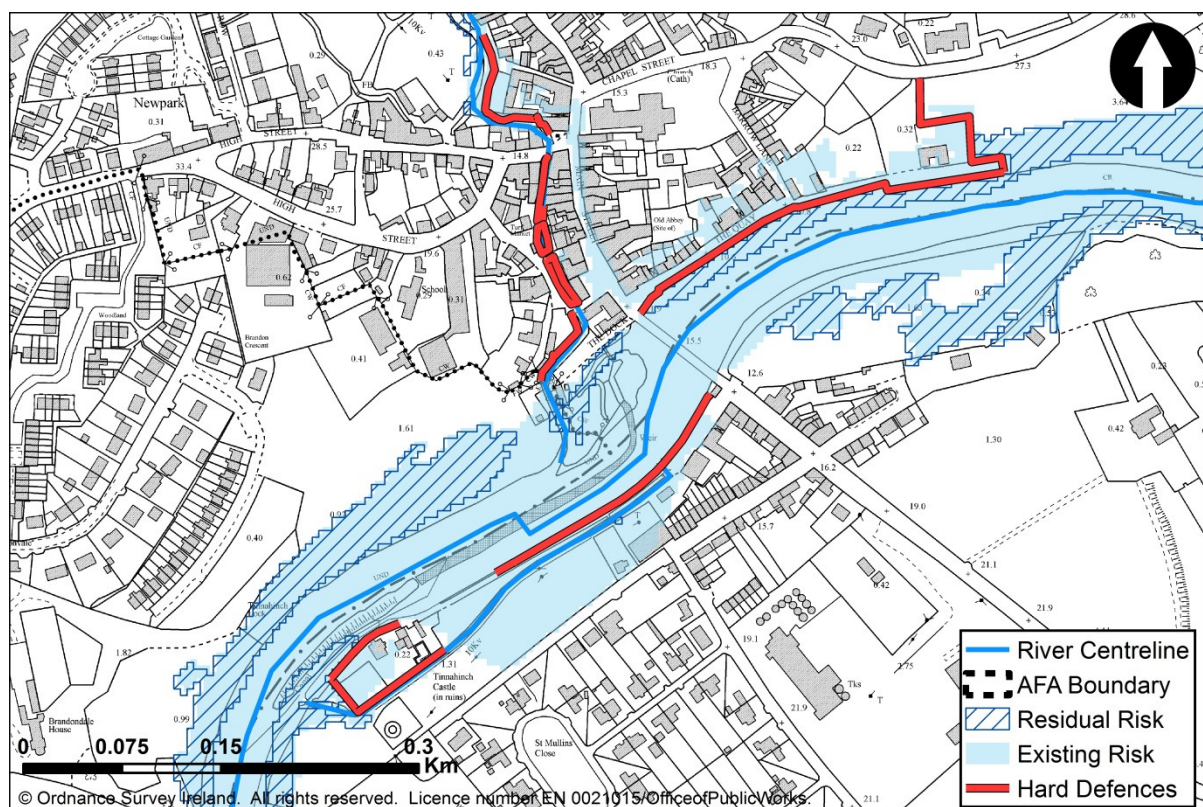
Hard Defences provide the full protection to all properties during the 1% AEP fluvial flood event.

### 8.6.7 Selection of Options

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

Hard Defences can provide the full SoP to all properties.

#### 8.6.7.1 Option 1 details - Hard Defences



**Figure 8.6.7.1.1.1.1.1 Graiguenamanagh AFA Option 1**

At risk properties would be protected by a series of flood walls with sheet piling, flood embankments with sheet piling and flood walls. The hard defences will provide a SoP of 1% AEP for fluvial flood events. The

hard defences have an average height of 1.56m and a total length of 1.31km.

Figure 8.6.7.1.1.1.1.1.1 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).

The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Wall	994m length, 1.5m high (average)	€3,821,984	
Embankment	268m length, 2.2m high (average)	€322,124	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
1096	9.20	119.01	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€1,672,771	€9,204,904	€10,260,826	1.11

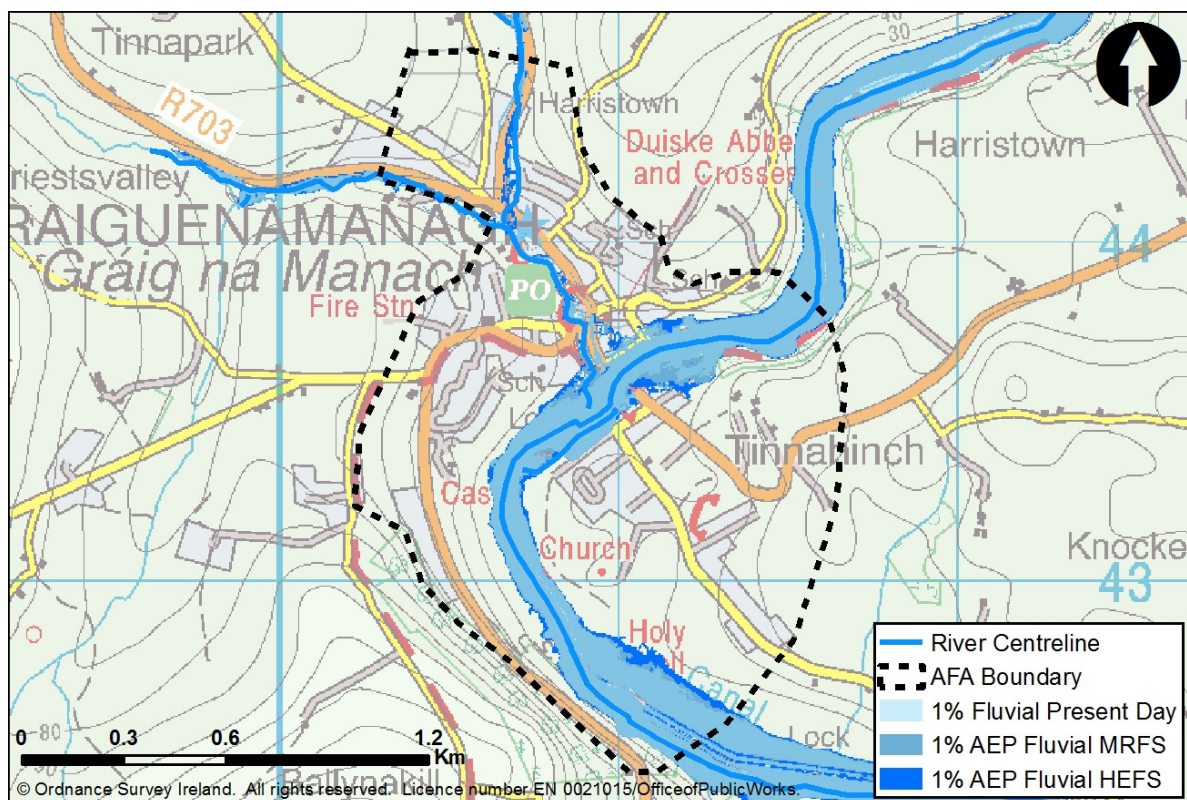
### 8.6.7.2 AFA Sensitivity to Future Change

Figure 8.6.7.2.1.1.1.1 shows the future 1% AEP flood extents under the MRFS and HEFS. During a MRFS 1% AEP flood event there is a significant change to the flood extents due to the topography of the surrounding area. An additional 21 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €1,672,771 to €2,168,743. As a result Graiguenmanagh AFA would be considered to be at high vulnerability from the MRFS.

During a HEFS 1% AEP flood event there is significant change to the flood extents also. An additional 35 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €1,672,771 to €4,771,919. As a result Graiguenmanagh AFA would be considered to be at high vulnerability from the HEFS.

The main area of additional flood risk is along Main Street and the Quay.

As there are additional properties affected by future scenarios there will be increases to the annual average damage and the Graiguenmanagh AFA would be considered to be at high vulnerability. Options were assessed to their adaptability to climate change.



**Figure 8.6.7.2.1.1.1.1 Climate Change Flood Extents**

### 8.6.7.3 Future Change Adaptability

The following discusses the adaptability of the potential FRM **methods** proposed in Graiguenmangh AFA:

**Hard Defences Flood Cell 1** - This method could be adapted by increasing the height of the walls and embankments and extending their length. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from an average of 1.6m to 2.4m and 2.5m respectively. To ensure that the walls would be adaptable the design would need to account for the potential increase on wall height. The embankments would also require space for a larger footprint. This method is considered to have a poor adaptability.

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 Graiguenmangh has large rural areas these methods could have a significant impact to overall area. As properties are affected in the MRFS and HEFS there is a need to ensure that future receptors at risk are prepared. This is most relevant to options with methods with poor adaptability.
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 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?** Alternative FRM methods could be added to any option 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. Based on this future changes adaptability assessment the table below summarises how well each option achieves this objective.

#### Summary of Option Adaptability

Option	Description	Score
Option 1 – Hard Defences	Option is adaptable at significant cost, difficulty and impact	1



8.6.7.4

#### 8.6.7.5 Local Authority Comments

LA representatives reviewed preliminary options in December 2015.

Local authorities raised a number of concerns including the Quay access being cut off. It was suggested a previous solution in this area was rejected. It was discussed if the defences at the boathouse could be shortened. Defences which are located tight to the back of properties may impact light getting into rooms. There is a sewage pipe issue in the Duisk River. It was agreed the Duisk River could not be diverted due to rising ground levels. There is a pumping station located beside SuperValu. It may be possible to clear Banker's garden and another eye of the Bridge.

#### 8.6.7.6 Summary

There is good confidence in both the hydrology and hydraulics of the Graiguenamangh AFA due to the presence of a gauging station and flood extent verification events.

The following potential options, with a BCR  $\geq 0.5$  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 Graiguenamanagh 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

Communities are located upstream and downstream of the Graiguenamangh AFA that could be affected by the potential option identified. The flows at the model boundaries were reviewed for the 1% AEP current scenario versus the 1% AEP with the option in place scenario. There are negligible flow differences between the hydraulic model simulations. In addition any interactions with the drainage system in the urbanised area may need to be addressed during the development of the preferred option.

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 assumptive 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

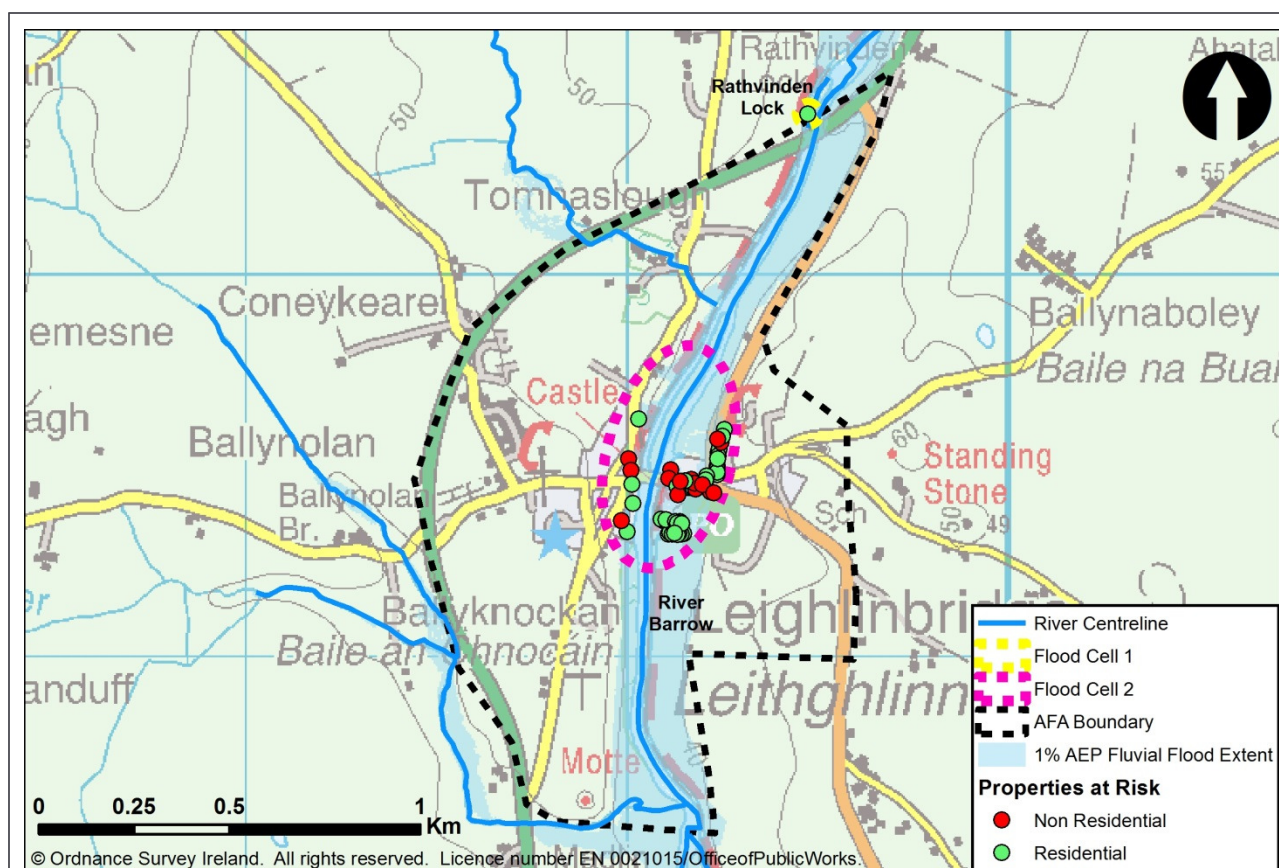
### 8.9 Leighlinbridge Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Leighlinbridge	Carlow	140166	AFA	Final	15/06/2016

#### 8.7.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.7.2 Flood Cells



**Figure 8.7.2.1.1.1.1.1 Leighlinbridge AFA Flood Cells within a 1% AEP Fluvial Flood Extent**

#### Flood Cell 1:

Out of bank flooding would occur on Rathvinden Lock, a millstream off the River Barrow, during a 1% AEP flood event due to insufficient channel capacity and would inundate the floodplain. One property would be affected by flooding during a 1% AEP flood event. Flood cell 1 is a discrete area affected by a single flood mechanism so is considered local.

#### Flood Cell 2:

Out of bank flooding would occur on both banks of the River Barrow as it passes through the centre of Leighlinbridge. During a 1% AEP flood event due to insufficient channel capacity affecting 56 properties. Flood cell 2 encompasses the majority of flood risk within the Leighlinbridge AFA. It is located downstream of flood cell 1 however it is a discrete area with a single flood mechanism and is therefore considered local.

#### Summary of Flood Cells:

As shown in Figure 8.7.2.1.1.1.1.1 the main flood risk originates from the River Barrow, in addition a single property is at risk at Rathvinden Lock. Flood cells 1 & 2 are discrete areas and it is considered appropriate that they are screened as standalone areas assessing options applicable to localised works (section 8.9.6).

On completion of the optioneering screening assessment all flood cells will be combined to form complete options for the Leighlinbridge AFA as detailed in section 8.7.7.

### 8.7.3 Existing Regime

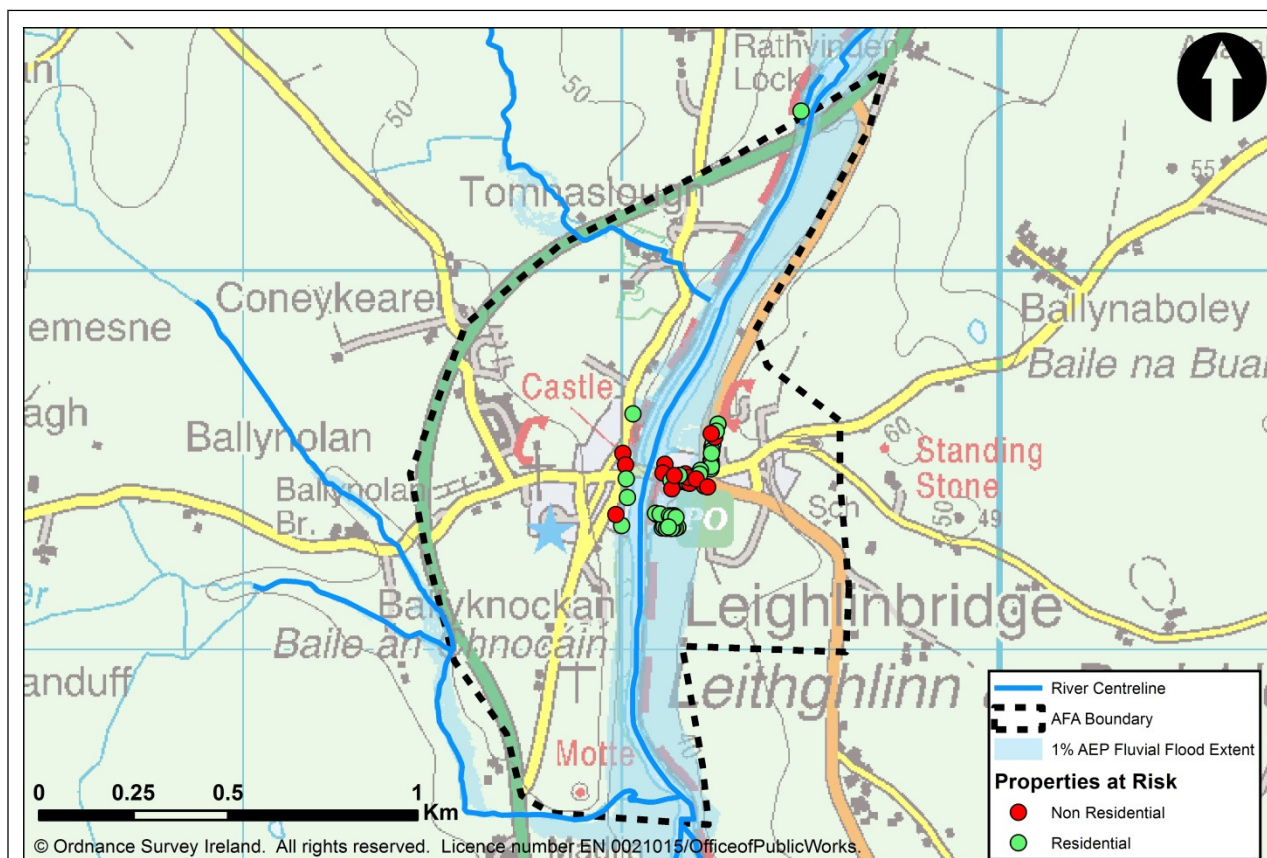
The existing regime considers all activities currently carried out which impact on the management of flood risk. The level and frequency of maintenance is considered, along with inspection, and any other specific activity (for example the operation of locks, barrages, sluice gates and valves).

The watercourses within Leighlinbridge are not located within a Drainage District or an Arterial Drainage scheme. They are, for the most part, in private lands and are not the responsibility of Carlow County Council. Nevertheless, inspection and maintenance are carried out as and when resources are available.

### 8.7.4



### 8.7.3 Summary of Flood Risk within SSA boundary



**Figure 8.7.4.1.1.1.1.1 Flood risk in Leighlinbridge AFA within a 1% AEP Fluvial Flood Extent**

In Leighlinbridge AFA the onset of residential property risk occurs in the 2% AEP event in flood cell one and in the 20% AEP event in flood cell two. Flooding commences at non-residential properties in the 50% AEP event in flood cell two. There are no non-residential properties at risk in flood cell one.

### 8.7.5 Monetary Damage and Benefit

	Flood Cell 1	Flood Cell 2	Total in AFA
Annual Average Damage (AAD)	€3,286	€1,345,707	€1,349,944
Present Value Damage (pvD)	€70,586	€28,908,488	€28,999,499
Preferred Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	1	56	57
Minimum Present Value Benefit	€50,115	€27,225,009	€27,275,124
Capped Minimum Present Value Benefit	€50,115	€3,855,781	€3,905,896

\*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.

**8.7.5 Short Listing FRM Methods – Local Cells**

Method	Review Comment	Continue Screening
		Flood Cell 1
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	✓

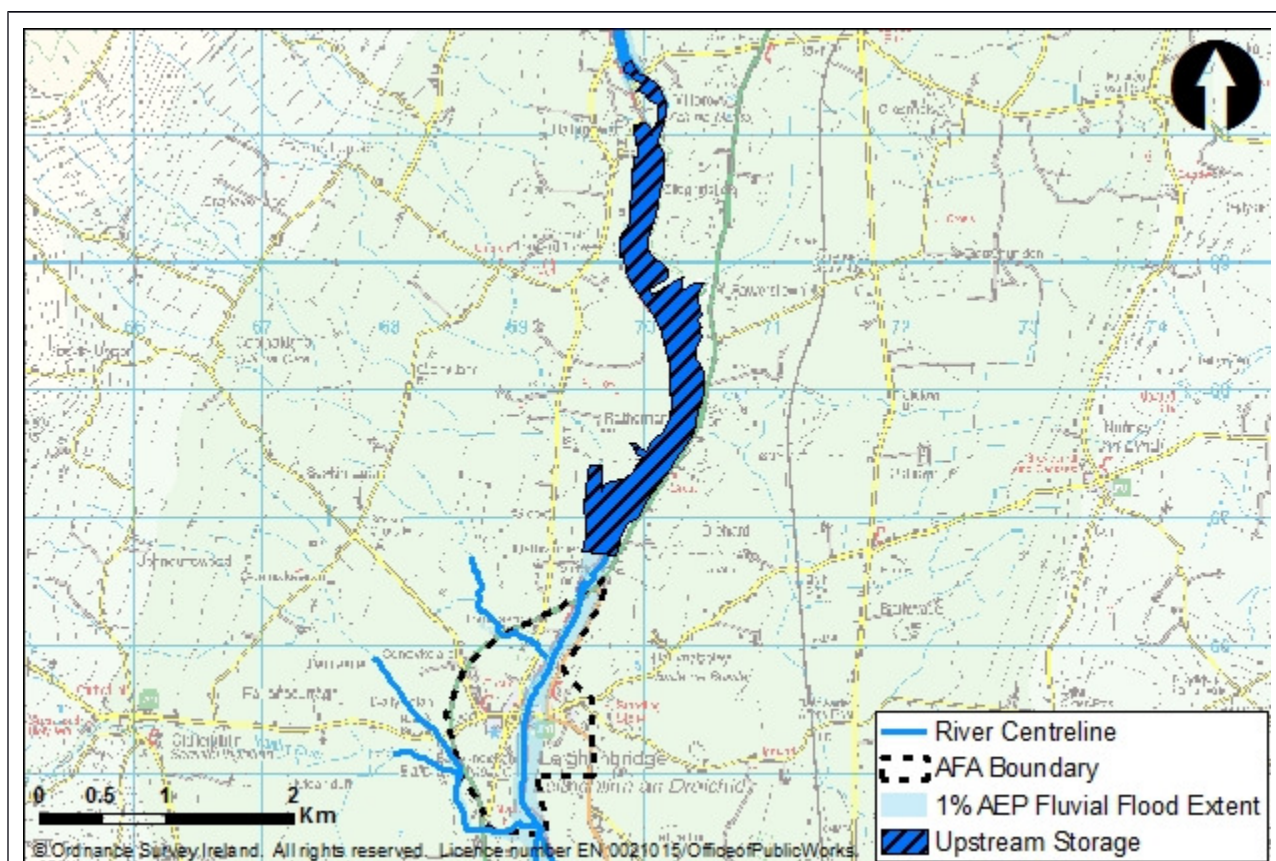
## 8.7.5.1 Feasibility Review Summary for Local Cell (flood cell 1)

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	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 significant impacts identified    ! - Progress, potential for significant impacts identified				

## 8.7.5.2 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 therefore was rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional maintenance	✗			
This method considers whether improvements can be made to augment the 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	x			
<p>This method can include clearance of channels and is also 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 1, there are no locations where a do minimum approach would have a significant impact on the overall flood risk. This is an unacceptable outcome in terms of contributing to achieve a 1% AEP standard of flood protection and therefore this method was rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	x			
<p>The application of land use management measures was tested at UoM scale. Due to the large size of the catchments the method is considered unsuitable to benefit flood cell 1. This method is technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Upstream Storage	x			
<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 reducing 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> <p>Due to the locations of flood cells 1 and 2 in Leighlinbridge, they have been reviewed together when investigating the possibility of upstream storage, as shown in Figure 8.7.5.2.1.1.1.1. The volume of water required to be stored on the River Barrow before reaching flood cells 1 and 2 has been estimated to be 12,600,245m<sup>3</sup> with an available storage of 257,005m<sup>3</sup>. This method is therefore considered technically unfeasible.</p>				



**Figure 8.7.5.2.1.1.1.1 Potential Storage for Flood Cells 1 & 2**

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

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.

Properties in Flood cell 1 are affected by high water levels in the River Barrow. A substantial section of the River Barrow would require dredging in order to reduce water levels enough to protect properties within flood cell 1; the extent of the dredging would extend past the location of flood cell 2 and also provide protection to properties at risk within this flood cell. Dredging the River Barrow would need to be carried out in conjunction with underpinning of 2 bridge structures and the removal of 2 weirs. The length of the river to be lowered (between chainages 6855m and 14302m) is approximately 7km requiring an estimated 223,320m<sup>3</sup> of material to be excavated.

This method is technically very complex and in addition costs are estimated at €29.9m which is economically unviable. This FRM method has been removed from the screening process.

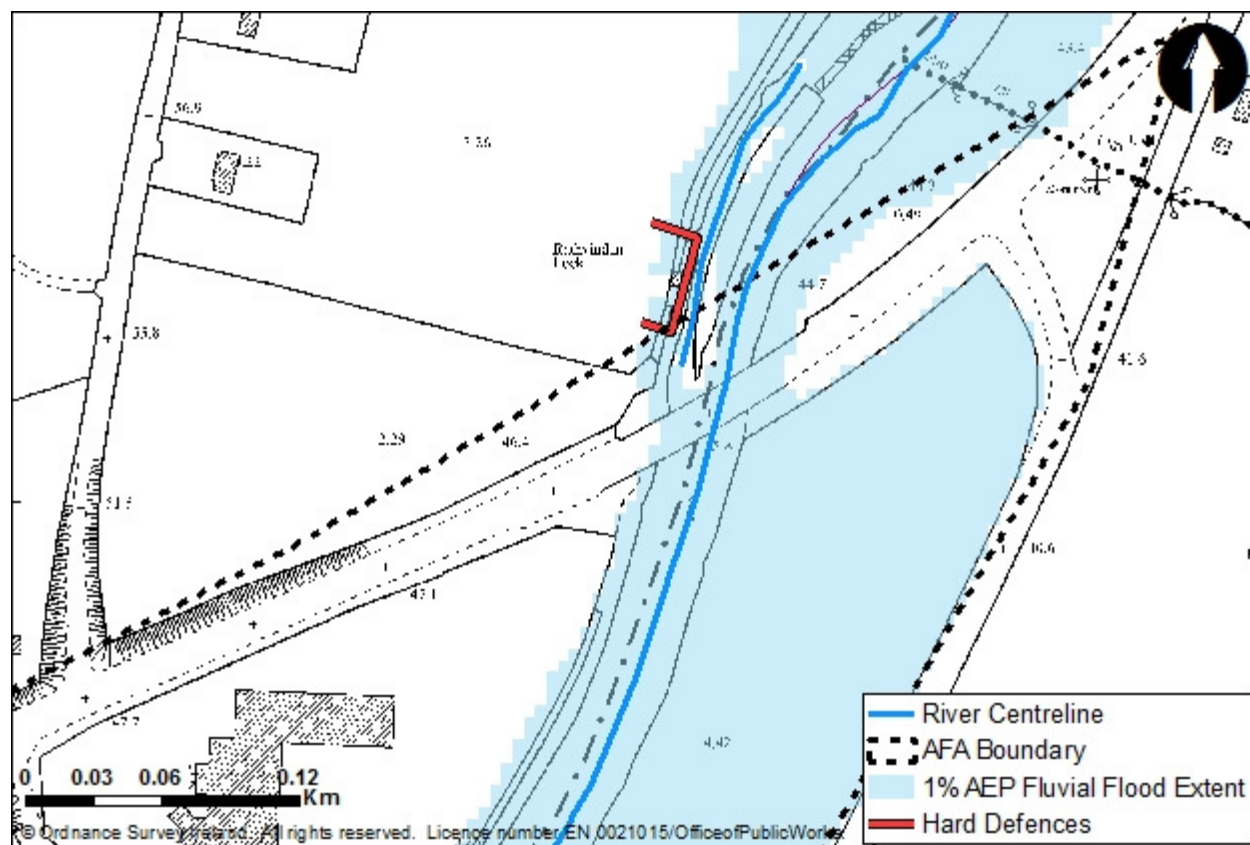
Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	?	✓

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 the property in flood cell 1 from flooding. Figure 8.7.5.2.1.1.1.2 shows the location of the Hard Defences required to protect properties during the 1% AEP event.



**Figure 8.7.5.2.1.1.1.2 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 2.27m and a total length of 79m. An economic review estimated the cost of the hard defences to be approximately €485,753 making this method economically viable. It should be noted a section of wall is required to be 3.08m high which may have additional social implications.

The River Barrow SAC is within, upstream and downstream of Leighlinbridge. However FRM Methods have been placed outside the designated areas where possible.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓	?	?
<p>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 clusters of properties are located.</p> <p>The cost to relocate the affected property in flood cell 1 to an area of lower risk would be €514,924 making this method economically viable. This method should only be considered as a last resort if no other viable methods are available due to the potentially significant social impacts of relocating properties.</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 out to identify locations where a flow diversion route could be constructed in the vicinity of flood cell 1. No viable routes were found due to the greatly varying topography of the land in this area so this method is considered technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x	-	✓	✓
<p>This method is considered in section 8.1 at UoM scale. The screening found flood warning/forecasting to be technically feasible on the River Barrow for Leighlinbridge and could provide approximately 41hrs warning. With this warning time available it is estimated that some flood damage would be avoided however as this method can only provide partial protection it should only be reviewed if all other methods are deemed unsuitable later in the optioneering process.</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>A review was carried out of the possibility of Individual Property Protection for flood cell 1. The cost of applying this method would be €11,618 making it economically viable. However, this method would not provide the required SoP so would not be technically the best method to use.</p> <p>This method is unlikely to have any negative environmental or social impacts. Individual Property Protection should only be considered if no other FRM method passes through the optioneering process.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for these flood cells				

**8.7.5.3 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

Due to the socially negative impacts associated with Relocation of Properties the method should only be considered if no other method is found suitable. Hard Defences will provide the full protection to all properties during the 1% AEP flood event, while Flood Warning/Forecasting and Individual Property Protection can only provide partial protection to all properties. These methods should therefore only be used should all other methods be deemed unsuitable later in the optioneering process.

**8.7.6 Short Listing FRM Methods – Local Cell (flood cell 2)**

## 8.7.6.1 Feasibility Review Summary of FRM Methods for flood cell 2

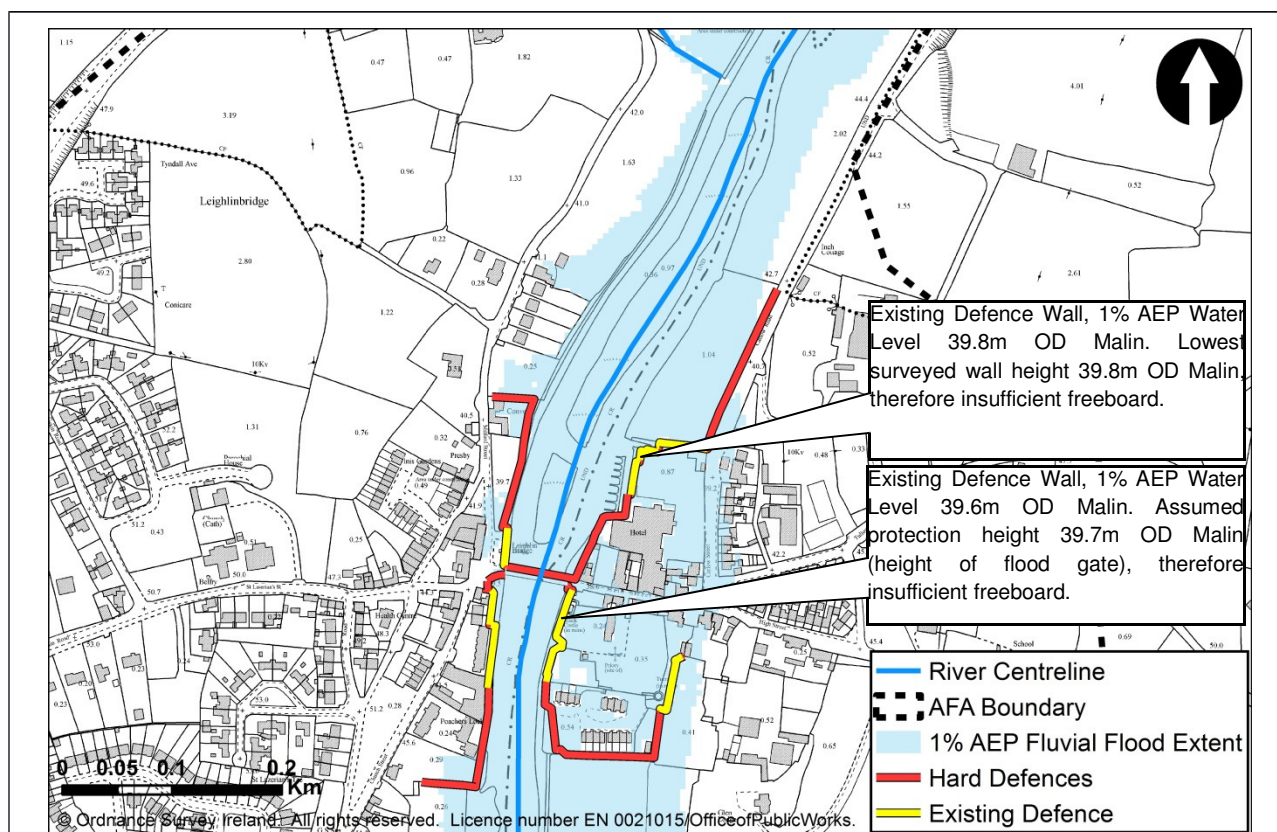
Method	Technical Screening	Economic Screening	Environmental Screening	Social Screening
Do nothing	✓			
Additional Maintenance	✗			
Do Minimum	✗			
Land Use Management	✗			
Storage	✗			
Improvement of Channel Conveyance	✗	✓		
Hard Defences	✗	✓	?	✓
Relocation of properties	✓	✓		
Diversion of Flow	✗			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

## 8.7.6.1 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	✗			
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	✗			
Within flood cell 2, there are no locations where a do minimum approach would have a significant impact on the overall flood risk. This is an unacceptable outcome in terms of contributing to achieve a 1% AEP standard of flood protection and therefore this method was 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. Due to the large size of the catchment the method is considered unsuitable to benefit flood cell 2. This method is technically unfeasible.				
Method	Tech	Econ	Env	Soc
Storage	✗			
As stated in the screening for flood cell 1, upstream storage would benefit both flood cells. Therefore flood cells 1 & 2 were reviewed together when investigating the possibility of the FRM method. The volume of water required to be stored on the River Barrow before reaching flood cells 1 and 2 has been estimated to be 12,600,245m <sup>3</sup> with an available storage of 257,005m <sup>3</sup> therefore this method is technically unfeasible Figure 8.7.5.2.1.1.1.1 shows the storage location which was investigated.				
Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✗	✓		
As stated in the screening for flood cell 1, improvement of channel conveyance would benefit both flood cells. Therefore flood cells 1 & 2 were reviewed together when investigating the possibility of the FRM method. This method was technically feasible but economically unviable.				
Method	Tech	Econ	Env	Soc
Hard Defences	✗	✓	?	✓
<p>A review was carried out to ascertain where additional Hard Defences would be required to protect the existing property in flood cell 2. Figure 8.7.6.1.1.1.1.1 shows existing hard defences and the location of additional hard defences required to protect properties during the 1% AEP event. In order to ascertain the effectiveness of Hard Defences and test the heights of existing defences a hydraulic model was constructed to simulate the method.</p> <p>The model showed existing hard defence heights are sufficient to protect properties however there is insufficient free board in two sections of existing defences, as labelled on Figure 8.7.6.1.1.1.1.1. An additional cost has been included to extend the height of these defences. It should also be noted that all existing defences require further survey and analysis to verify their condition and to ensure they are sufficient to withstand a 1% AEP event.</p> <p>The existing defences need to be combined with additional hard defences as shown in Figure 8.7.6.1.1.1.1.1. The additional defences require an average height of 1.2m and an approximate total length of 1.1km. It is also advised that all flood gates are upgraded to automatic flood gates, this cost has been included in the FRM method. The estimated cost to carry these works out would be approximately €2m making this method economically viable.</p>				





**Figure 8.7.6.1.1.1.1.1 Location of Hard Defences in Flood Cell 2**

The River Barrow SAC is within, upstream and downstream of Leighlinbridge. However FRM Methods have been placed outside the designated areas where possible.

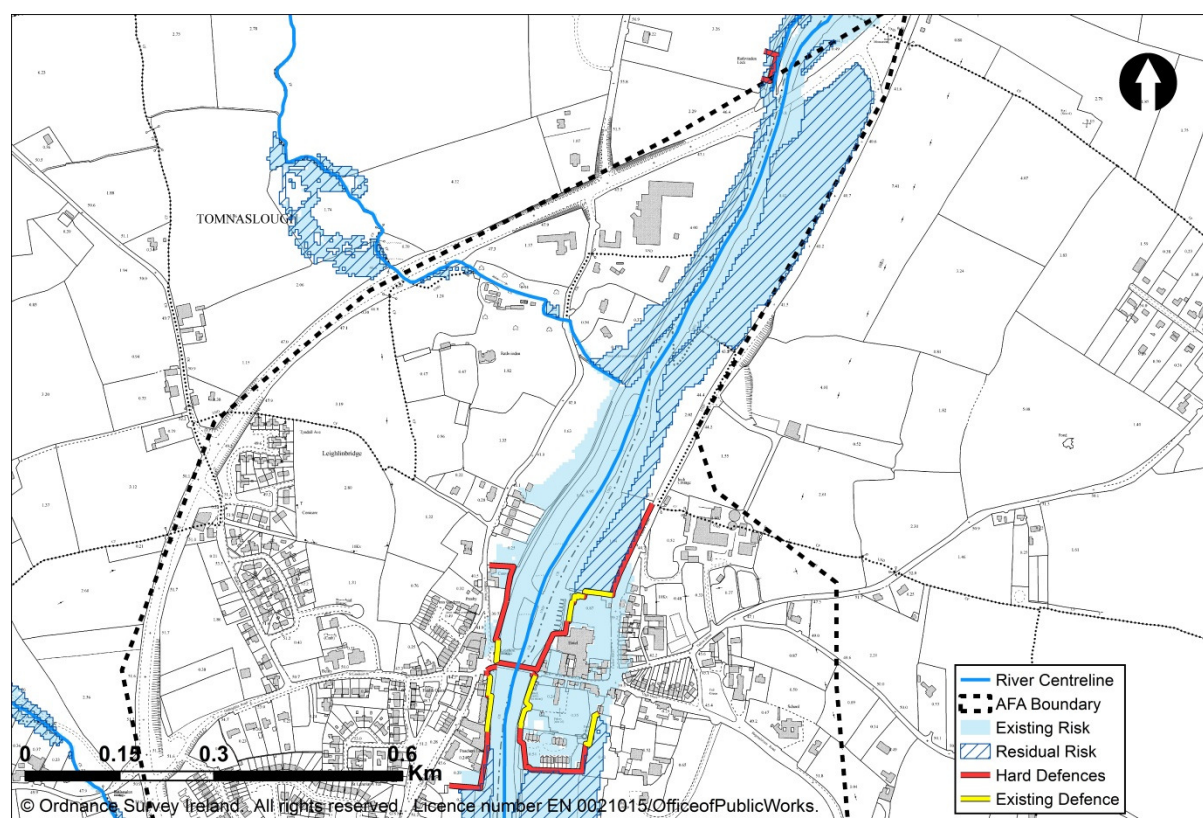
Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓		
The cost to relocate the affected properties in flood cell 2 to an area of lower risk would be €25,460,814 making this method economically unviable.				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			
A review was carried out to identify locations where a flow diversion route could be constructed in the vicinity of flood cell 2. No viable routes were found due to the greatly varying topography of the land in this area so this method is considered technically unfeasible				

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x	-	✓	✓
This method is considered in section 8.1 at UoM scale. The screening found flood warning/forecasting to be technically feasible on the River Barrow for Leighlinbridge and could provide approximately 41hrs warning. With this warning time available it is estimated that some flood damage would be avoided however as this method can only provide partial protection it should only be reviewed if all other methods are deemed unsuitable later in the optioneering process.				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓			
12 of the 56 properties affected during the 1% AEP event are flooded to depths greater than 0.6m making IPP a technically unfeasible method for these properties. This method was therefore not considered further in the screening process.				
Method	Tech	Econ	Env	Soc
Other Works	x			
No other works were identified for this flood cell				
8.7.6.2 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 2;</p> <ul style="list-style-type: none"> <li>• Hard Defences</li> </ul> <p>Hard Defences will provide the full protection to all properties during the 1% AEP flood event, while Flood Warning/Forecasting can only provide partial protection to all properties. This method should therefore only be used should all other methods be deemed unsuitable later in the optioneering process.</p>				

### 8.7.7 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5	
Hard Defences		x				
The most applicable local works measure selected for flood cell 1 and flood cell 2 is hard defences.						

## 8.7.7.2 Option 1 details - Hard Defences



**Figure 8.7.7.2.1.1.1.1 Leighlinbridge AFA Option 1**

At risk properties would be protected from existing and new flood embankments, walls and automatic flood gates. The new hard defences would protect to the 1% AEP flood event with an average height of 1.2m and a total length of 1.1km alongside the existing defences in Leighlinbridge.

Figure 8.7.7.2.1.1.1.1.1 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).

The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Additional Wall	376m length, 1.5m high (average)	€1,154,830	
Exisitng Wall	193m length, 1m high (average)		
Additional Embankment	538m length, 1m high (average)	€106,230	
Automatic Flood Gates	220m length, 1.5m high (average)	€92,000	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
805	3.29	244.56	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€28,999,499	€3,291,151	€3,905,896	1.19

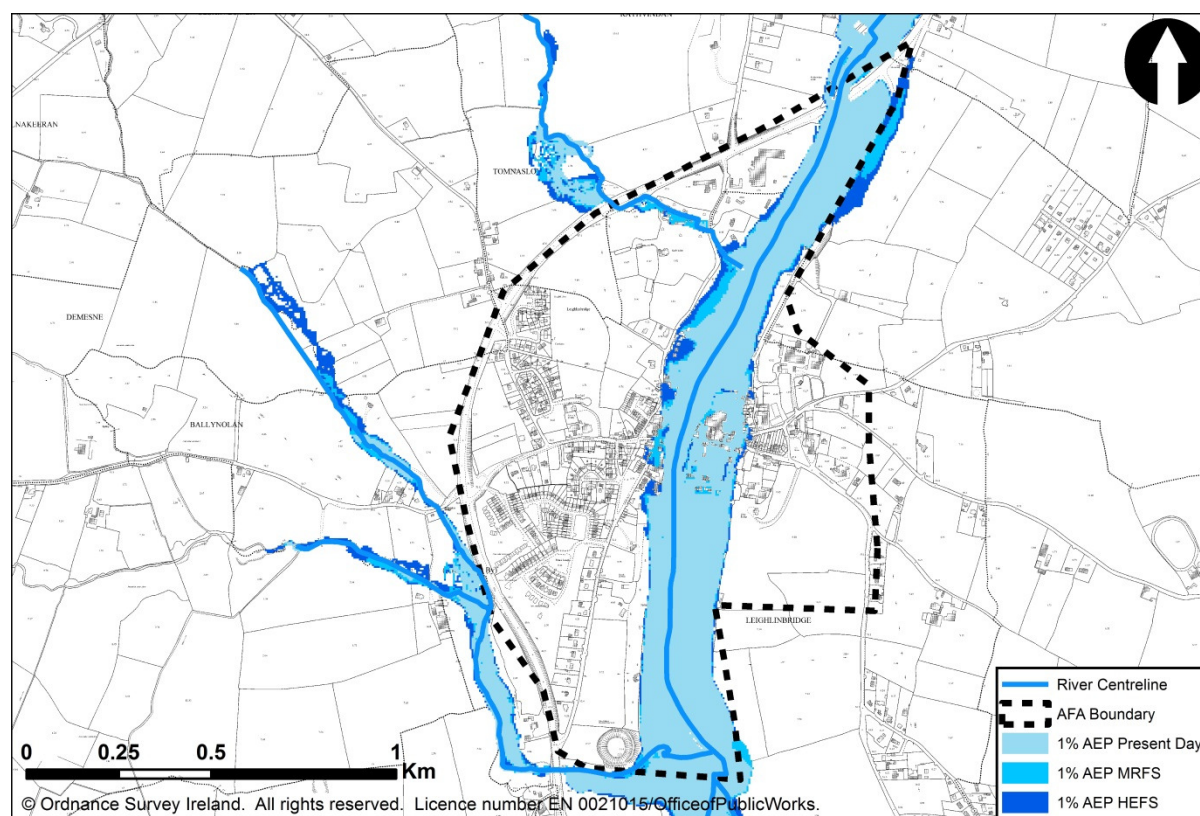
### 8.7.7.3 AFA Sensitivity to Future Change

As shown in Figure 8.7.1.1.1.1.1.1, During a MRFS 1% AEP flood event the increase in flood extent is minimal due to the topography in the area. An additional 12 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €1,349,944 to €2,412,518. As a result Leighlinbridge AFA would be considered to be at high vulnerability from the MRFS.

During the HEFS 1% AEP flood event the flood extent, while larger than the MRFS, is minimal also. An additional 21 properties are estimated to be at flood risk when compared to the present day flood risk. The AAD would increase from €1,349,944 to €5,246,985. As a result Leighlinbridge AFA would be considered to be at high vulnerability from the HEFS.

The main area of additional flood risk is in the town centre at Main Street however properties are also being affected on the Seskin Stream where no properties were at risk during the present day flood risk.

The number of additional properties affected by future scenarios indicates a moderate increase to the annual average damage and the Leighlinbridge area of assessment would be considered to be at high vulnerability. Options should be assessed to their adaptability to climate change.



**Figure 8.7.1.1.1.1.1.1 Future Change Flood Extents**



#### 8.7.7.4 Future Change Adaptability

The following discusses the adaptability of the potential FRM **methods** proposed in Leighlinbridge AFA:

**Hard Defences Flood Cell 1** - This method could be adapted by increasing the height of the wall. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from 3m to 3.4m and 4.2m respectively. This additional wall height could not be accommodated. This method is considered to be **not adaptable**.

**Hard Defences Flood Cell 2** - This method could be adapted by increasing the height of the walls and embankments and extending their length. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from an average of 1.2m to 2.2m and 2.9m respectively. This additional wall height could be accommodated. The review also showed that the additional length of wall preferred could be accommodated. To ensure that the walls would be adaptable the design would need to account for the potential increase on wall height. The embankments would also require space for a larger footprint. This method is considered to have a **moderate to poor** adaptability.

The potential **options** identified have been further assessed using 5 criteria in an attempt to identify low – or regret combinations of measures.

1. **Does the option reduce vulnerability?** In addition to these methods other methods aimed at reducing future flood risk has been discussed in section 8.1 at UoM scale. These methods will reduce the vulnerability of potential future receptors. Given that Leighlinbridge has large rural areas these methods could have a significant impact to overall area. As there is an 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. This is most relevant to options with methods with poor adaptability, such as option 1.
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 mostly adaptable to the MRFS and HEFS. Within flood cell 1 the hard defences are not adaptable however alternative FRM methods could be added to all options to provide an increased SoP. Option 1 could include individual property protection or resilience measures.
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, and the potential impacts of climate change. Based on this future change adaptability assessment the table below summarises how well each option achieves this objective.

Summary of Options Availability		
Option	Description	Score
Option 1 – Hard Defences	Flood Cell 1 is not adaptable however this only affects 1 property out of the 57 at risk properties. The rest of the option is adaptable at moderate to significant cost, difficulty and impact.	2

#### 8.7.1.3 Local Authority Comments

The existing flood defences identified as effective by Carlow County Council and confirmed by the OPW downstream of Main Street Bridge on both banks require further survey and analysis to ensure these walls are sufficient to protect property during the 1% AEP event.

#### 8.7.1.4 Summary

There is good confidence in both the hydrology and hydraulics of the Leighlinbridge AFA due to the presence of a gauging station and flood extent verification events.

The following potential options, with a BCR  $\geq 0.5$  have been identified:

- Option 1 – Hard Defences (FC 1 & 2)

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 Castledermot 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

Communities are located upstream and downstream of the Leighlinbridge AFA that could be affected by the potential option identified. The flows at the model boundaries were reviewed for the 1% AEP current scenario versus the 1% AEP with the option in place scenario. There is a negligible flow difference between the hydraulic model simulations. In addition any interactions with the drainage system in the urbanised area may need to be addressed during the development of the preferred option.

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.

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

### 8.10 Monasterevin Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Monasterevin	Kildare	140167	AFA	Final	15/06/2016

#### 8.8.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.8.2 Flood Cells

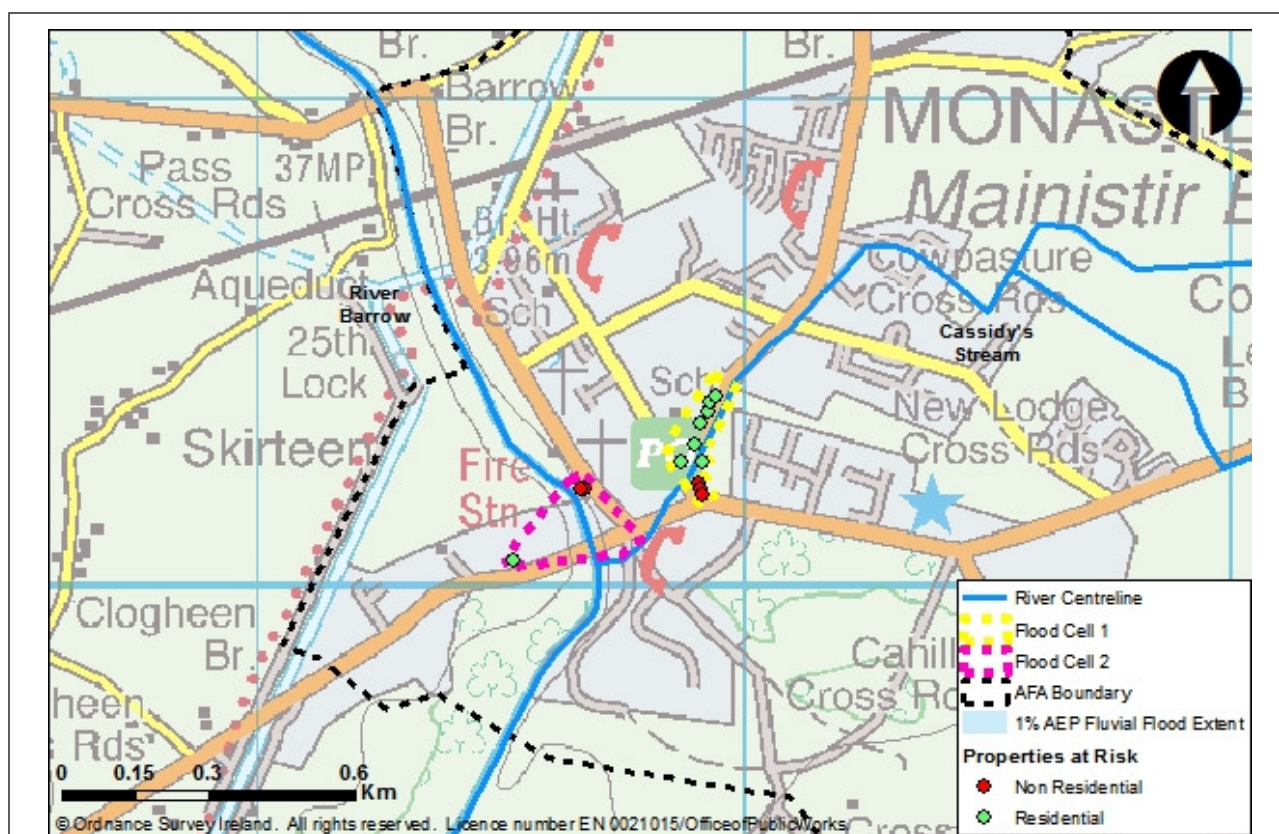


Figure 8.8.2.1.1.1.1.1 Monasterevin AFA Flood Cells within a 1% Fluvial Flood Extent

#### Flood Cell 1:

Properties on both banks of the Cassidy Stream are affected during the 1% AEP flood event due to restrictive culverts raising water levels and insufficient channel capacity. A small number of properties are affected by a single flood mechanism, therefore this flood cell is considered local.

**Flood Cell 2:**

Properties in flood cell 2 are affected by the River Barrow having insufficient channel capacity to convey the 1% AEP flows. As a small number of properties are affected by a single flood mechanism, this flood cell is considered local.

**Summary of Flood Cells:**

As shown in Figure 8.8.2.1.1.1.1.1 there are two flood cells within the Monasterevin AFA which have no interaction. Flood cells 1 & 2 are discrete areas with few properties at risk and single flood mechanisms each to consider. It is therefore appropriate to screen the cells as standalone areas.

On completion of the optioneering screening assessment all flood cells will be combined to form complete options for the Monasterevin AFA.

### 8.8.3 Existing Regime

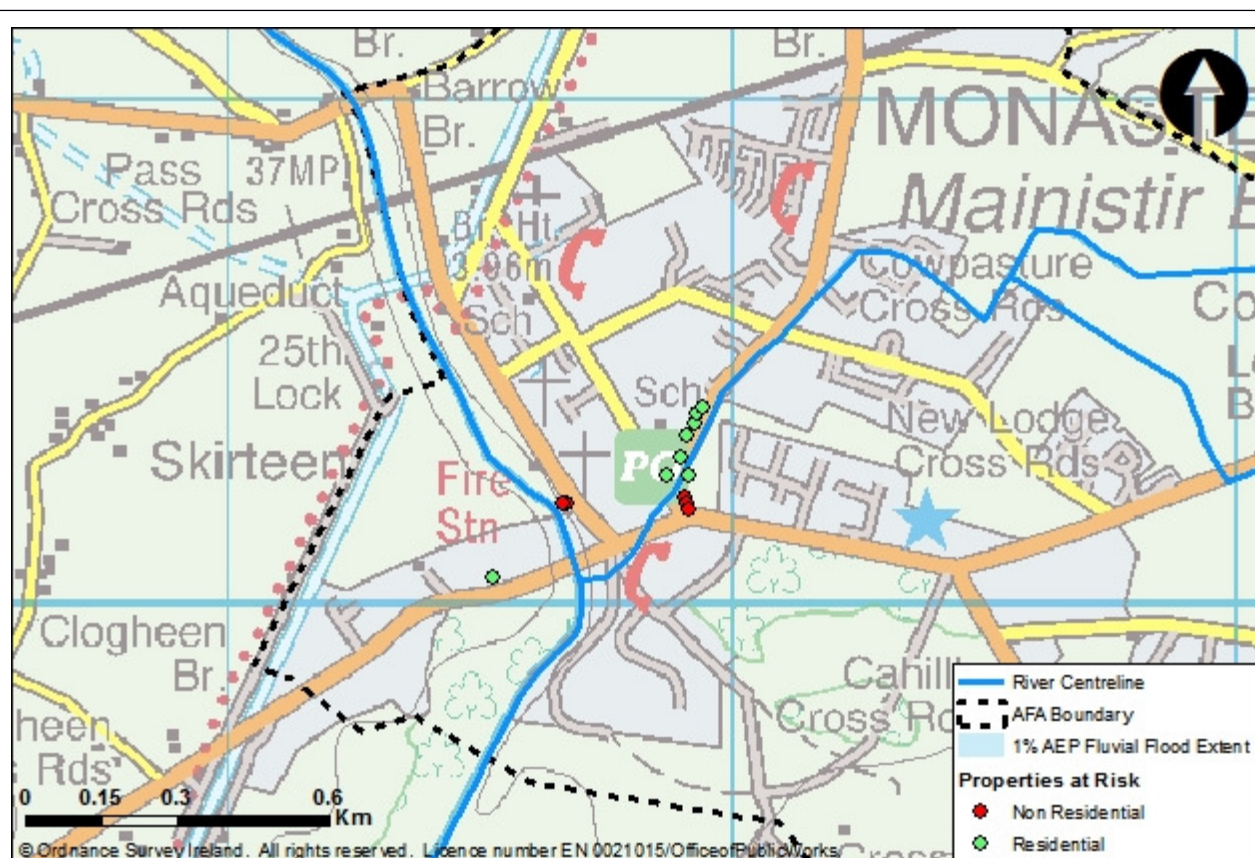
The existing regime considers all activities currently carried out which impact on the management of flood risk. The level and frequency of maintenance is considered, along with inspection, and any other specific activity (for example the operation of locks, barrages, sluice gates and valves).

A number of rivers within Monasterevin are located within a drainage scheme. Further details of this scheme are presented in section 6.3.

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

### 8.8.4

### 8.8.3 Summary of Flood Risk within SSA boundary



**Figure 8.8.4.1.1.1.1.1 Flood Risk in Monasterevin AFA within a 1% Fluvial Flood Extent**

In Monasterevin AFA the onset of residential properties occurs in the 5% AEP event in flood cell one; and in the 50% AEP event in flood cell two. Flooding commences at non-residential properties in flood cell one in the 2% AEP event and in flood cell two in the 50% AEP event.

### 8.8.5 Monetary Damage and Benefit

	Flood Cell 1	Flood Cell 2	Total in AFA
Annual Average Damage (AAD)	€15,288	€1,499	€19,729
Present Value Damage (pvD)	€328,421	€32,212	€423,815
Preferred Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	10	3	13
Minimum Present Value Benefit	€264,370	€20,223	€ 284,593
Capped Minimum Present Value Benefit	€264,370	€20,223	€ 284,593

\*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.



**8.8.6 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	✓	✓

8.8.6.1 Feasibility Review Summary of FRM Methods for Local Flood Cell 1				
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	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    ! - Progress, potential for significant impacts identified				
8.8.6.2 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 the 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.  A review of the current condition of the watercourse showed that additional maintenance would likely reduce the flood risk. For example rebuilding parts of the wall along the right bank of the Cassidy Stream where low points are allow spilling onto the R414 road. However this method would not significantly				

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

Method	Tech	Econ	Env	Soc
Do Minimum	x			

This method can include clearance of channels and is also 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 are no obvious locations where the do minimum method would greatly reduce flood risk. Additional channel clearance would have minimal impact on the overall flood risk due to the distributed nature the receptors. This is an unacceptable outcome in terms of contributing to achieving a 1% AEP standard of flood protection and this method was therefore rejected from the screening process.

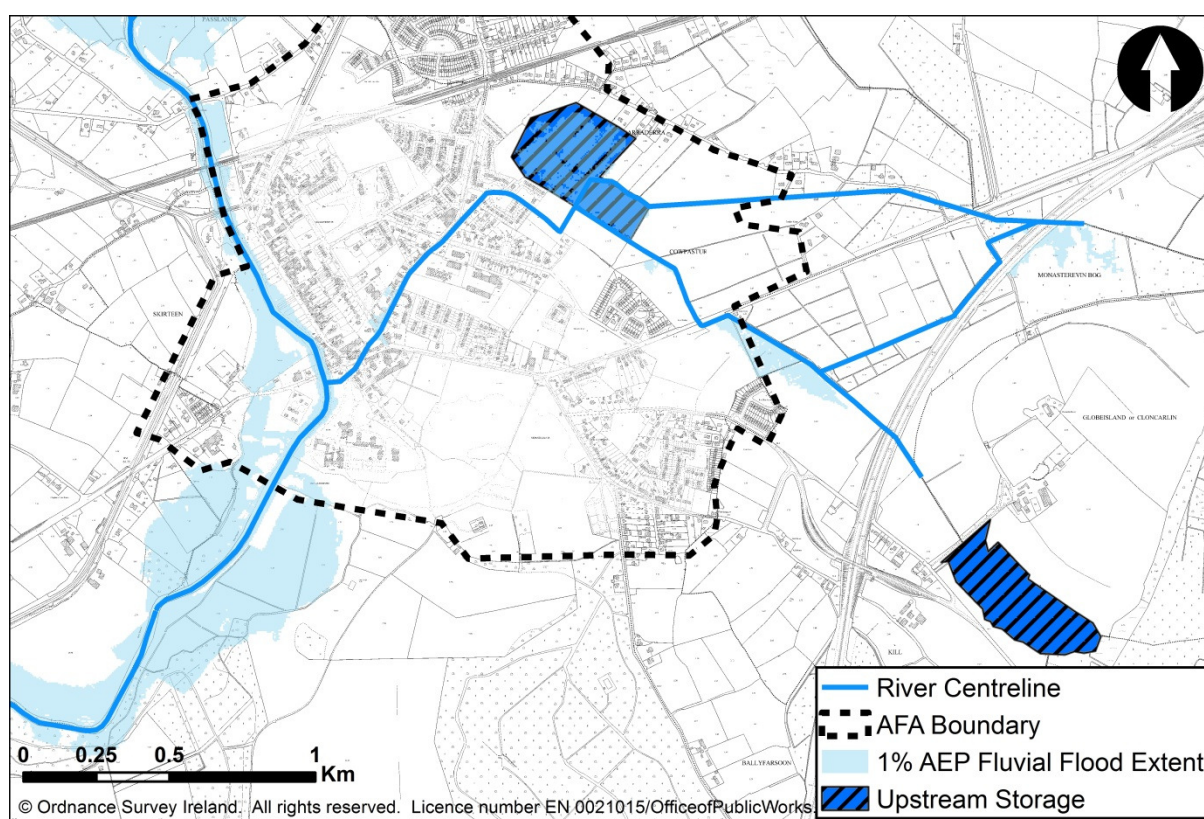
Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the large size of the catchment and current land use the method is considered unsuitable to benefit flood cell 1. This method is technically unfeasible.

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 reducing 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.

The properties affected in flood cell 1 would be protected if the storage areas shown in Figure 8.8.1.1.1.1.1.1 were utilised. To create the storage areas, embankments would be required with culverts to restrict the flow progressing down Cassidy's Stream along with overspill weirs. A pipe culvert allowing 0.1m<sup>3</sup>/s to leave the Storage area would be a 0.45m diameter and approximately 8.4m long. A pipe culvert allowing 1m<sup>3</sup>/s to leave the downstream storage area would be a 1.05m diameter and approximately 9.6m long.



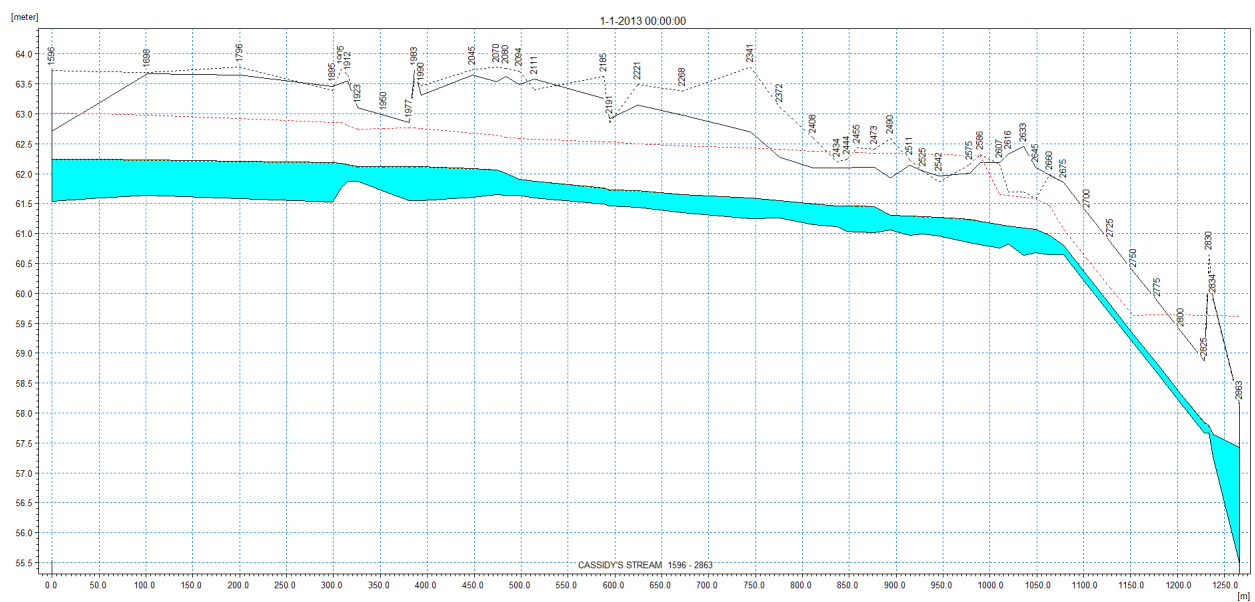
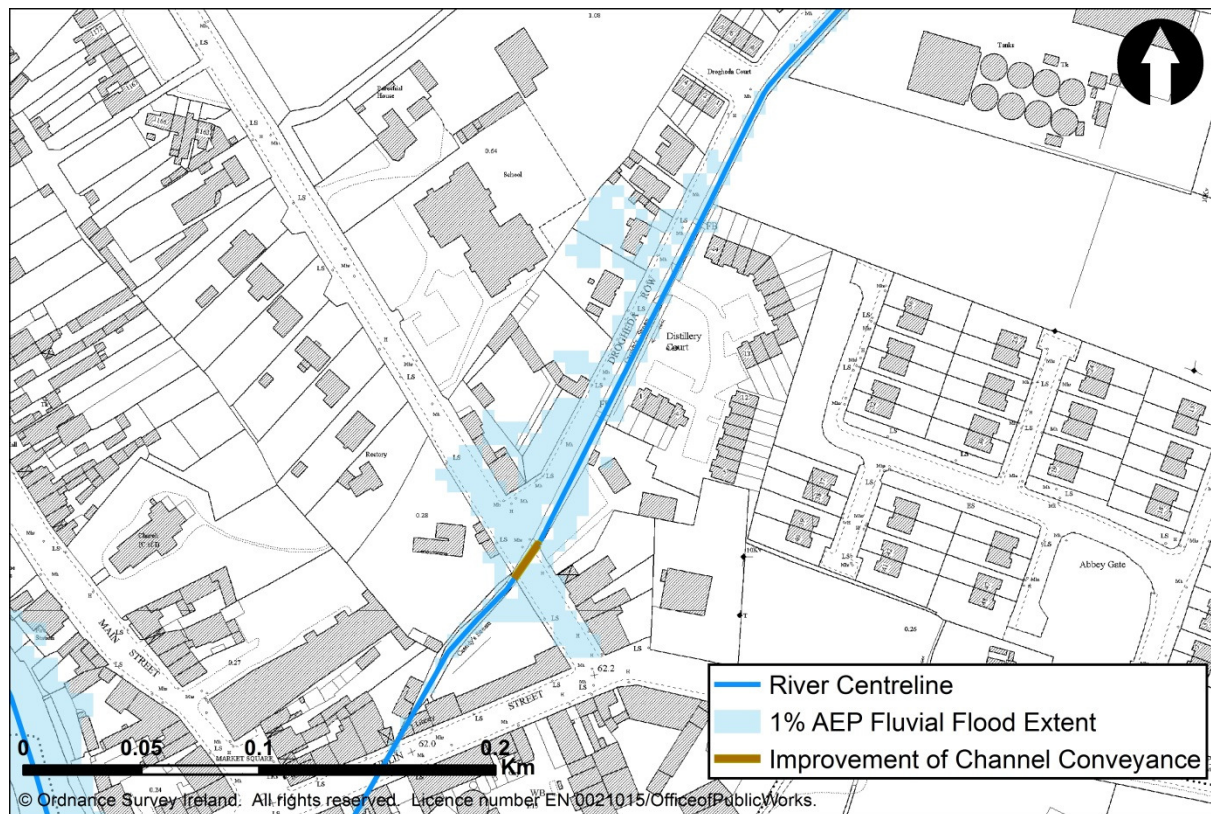
**Figure 8.8.1.1.1.1.1.1 Potential Storage Location for Storage to Benefit Flood Cell 1**

The estimated cost to carry these works out would be €662,734 making this method economically unviable.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

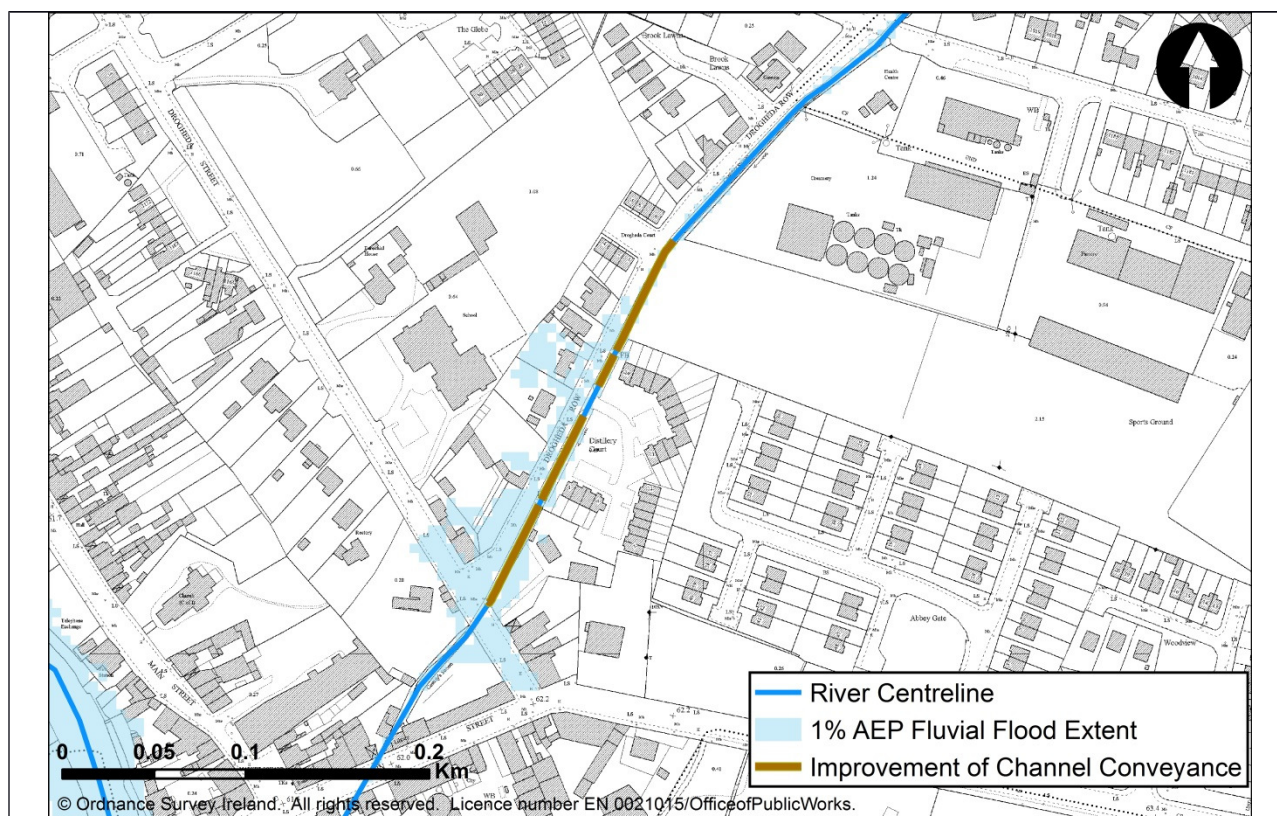
This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed levels, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse, reducing roughness of the channel and sealing manholes. A review of the various FRM method techniques, as listed above, was carried out for flood cell 1 and the following techniques were found to be the most appropriate way to implement this method.

Conveyance could be improved by upgrading the bridge (ID 14CASS00026D, location shown in Figure 8.8.6.2.1.1.1.1.1). The bridge is restricting flow and raising water levels in the open channel upstream of the inlet, as shown in Figure 8.8.6.2.1.1.1.1.2. Replacing the existing single arch bridge with a 2m wide by 0.8m box culvert will allow flow to continue unrestricted and lower water levels in the open stretch of channel therefore reducing flood risk to the properties. The estimated cost to carry these works out would be €608,651 making this method economically unviable.



An alternative improvement of channel conveyance in flood cell 1 could include culverting the open sections of the watercourse, location shown in Figure 8.8.6.2.1.1.1.3. An economic review estimated this to cost €1,069,312 which is also economically unviable.



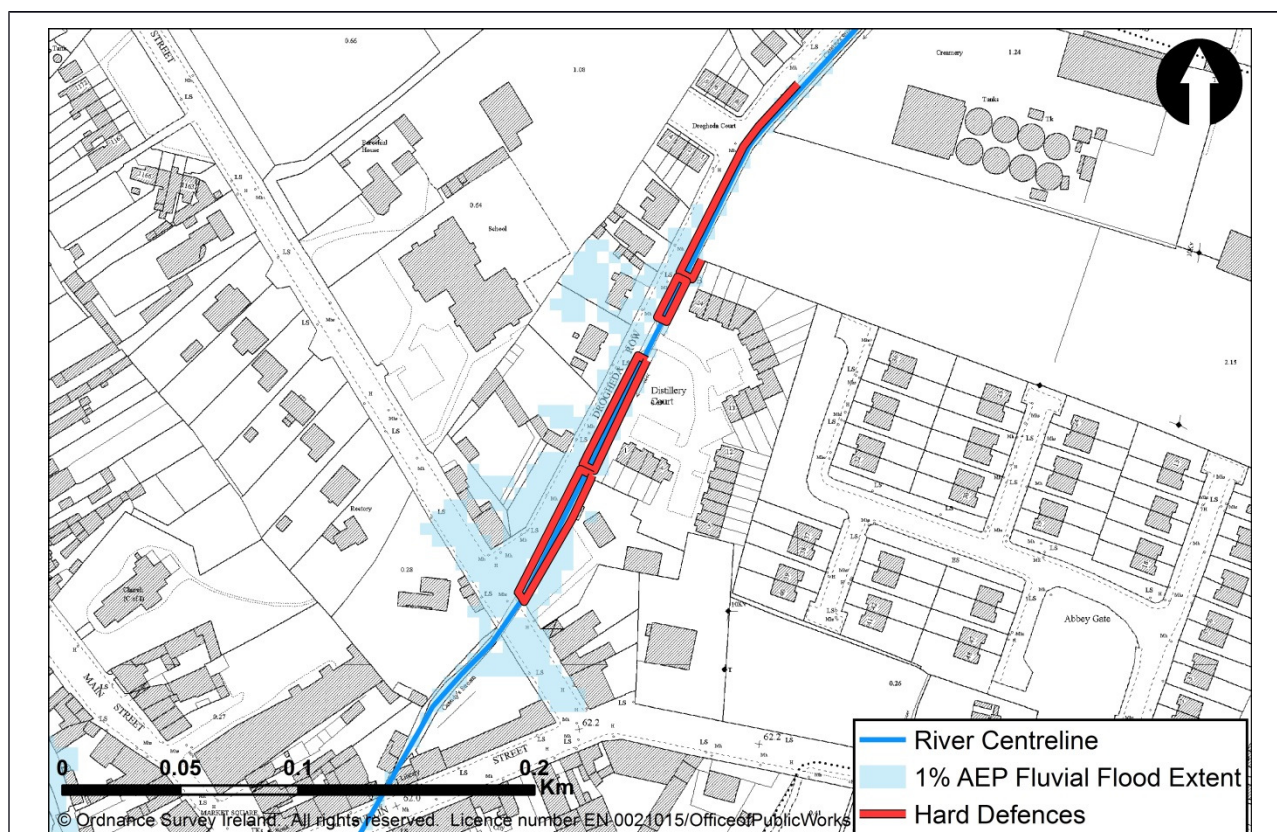


**Figure 8.8.6.2.1.1.1.3 Potential Location to Improve Channel Conveyance by Closing Open Watercourse for Flood Cell 1**

Method	Tech	Econ	Env	Soc
Hard Defences	x	✓		

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 8.8.6.2.1.1.1.4 shows the location of the Hard Defences required to protect properties during the 1% AEP event.



**Figure 8.8.6.2.1.1.1.4 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 0.6m and a total length of 400m. An economic review estimated the cost of the hard defences to be approximately €1,103,391 making this method economically unviable.

Method	Tech	Econ	Env	Soc
Relocation of properties	x	✓		

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 clusters of properties are located.

In practice it is always technically possible to relocate properties, however considering the socially negative impacts it should only be considered should no other method be found suitable. The cost to relocate the ten properties in flood cell 1, based on the market value, is €4,341,457 which is economically unviable.

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			

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.

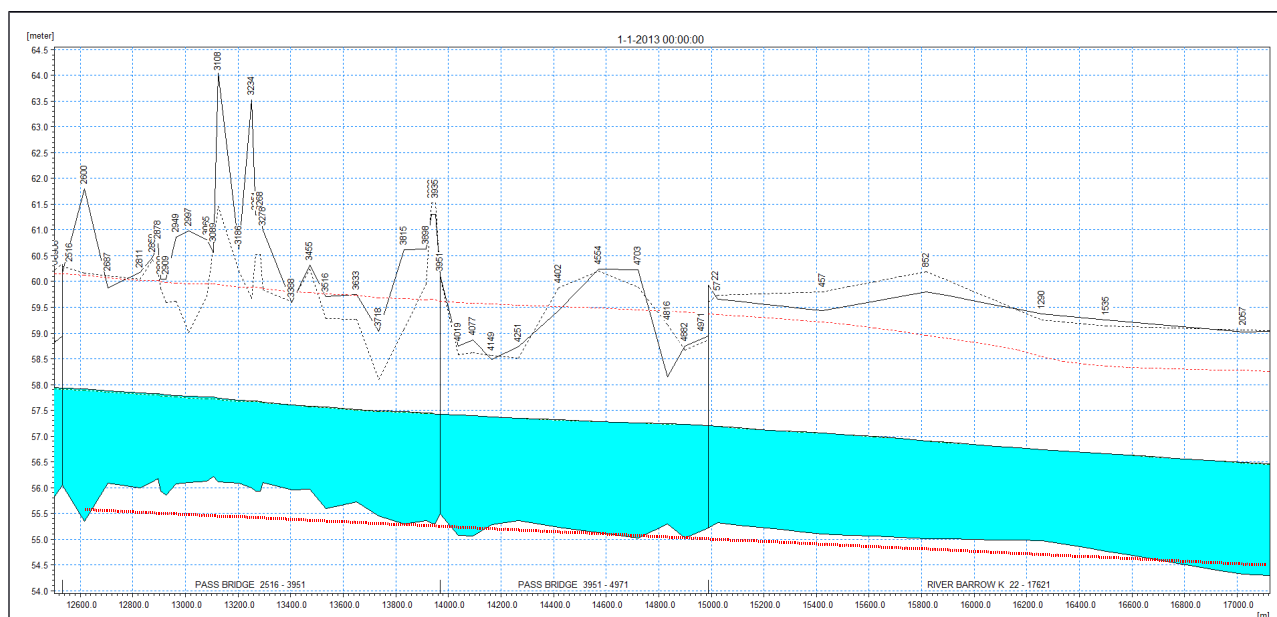
Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			
<p>This method involves directing some of the floodwater via a new route thereby reducing flow and associated flood risk along the original route. This would be carried out upstream of where floodwaters reach the area of at risk properties. The new flow 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 1. No location was found where this method could be carried out is therefore considered 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 areas 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>While this method would not provide the required design 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 the pass through the screening process. An economic review estimated that the cost of providing manual protection to the 10 properties to be approximately €174,691. This method is therefore economically viable.</p> <p>It is unlikely that individual property protection would have any impact to designated sites in the vicinity of the Monasterevin AFA.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for these flood cells				
8.8.6.3 Summary of Feasibility Review – Flood Cell 1				
<p>The following FRM methods have been carried forward to address the flood risk arising from flood cell 1;</p> <ul style="list-style-type: none"> <li>Individual Property Protection</li> </ul> <p>Individual Property Protection can only provide partial protection to properties however in the absence of any other viable solutions this method will continue as the only option for Flood Cell 1.</p>				

### 8.8.7

8.8.7.1 Feasibility Review Summary of FRM Methods for Local flood cell 2				
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	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 significant impacts identified    ! - Progress, potential for significant impacts identified				
8.8.7.2 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. As the River Barrow is part of an Arterial Drainage scheme the expected outcome would be increased vegetation on the river but would likely have little impact with regards to the current flood risk. This is an unacceptable outcome in terms of contributing to design SoP and this method was therefore rejected from the screening process.				

Method	Tech	Econ	Env	Soc
Additional Maintenance	x			
<p>Historical flood data and channel survey data indicated that the present day flood risk in flood cell 2 is not attributable to vegetation, debris or blockages.</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	x			
<p>It is unlikely that any adjustment to the Barrow Arterial Drainage scheme would have a noticeable impact on to the level of flood risk. There is little opportunity to improve the conditions on the Barrow River and little scope to reduce the overall flood risk due. This is an unacceptable outcome in terms of contributing to achieving a design SoP and this method was therefore rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	x			
<p>The application of land use management measures was tested at UoM scale. Due to the large size of the catchment and current land use the method is considered unsuitable to benefit flood cell 2. This method is technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Storage	x			
<p>A review of the surrounding land was carried out but no suitable location was found. This method is therefore considered technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		
<p>A review of the various techniques, was carried out for flood cell 2 and the following techniques were found to be the most appropriate way to implement this method.</p> <p>Flood cell 2 is affected by high water levels in the River Barrow. A review of the river was carried out identifying all high points in the river bed which would require lowering (River Barrow Long Section is shown in Figure 8.8.7.2.1.1.1.1.1). The Monasterevin hydraulic model was used to identify the required cross sectional area of the River Barrow channel at the desired locations to convey the 1% AEP flow, this indicated that a channel depth of 4.1m and width of 35m would be required. This would require 4.5km of the River Barrow to be dredged and widened (or sheet piling used where banks could not be battered), requiring approximately 122,500m<sup>3</sup> to be excavated. An economic review estimated the cost of excavation to be approximately €12m including the cost to underpin 4 bridges, this method is therefore economically unviable.</p>				

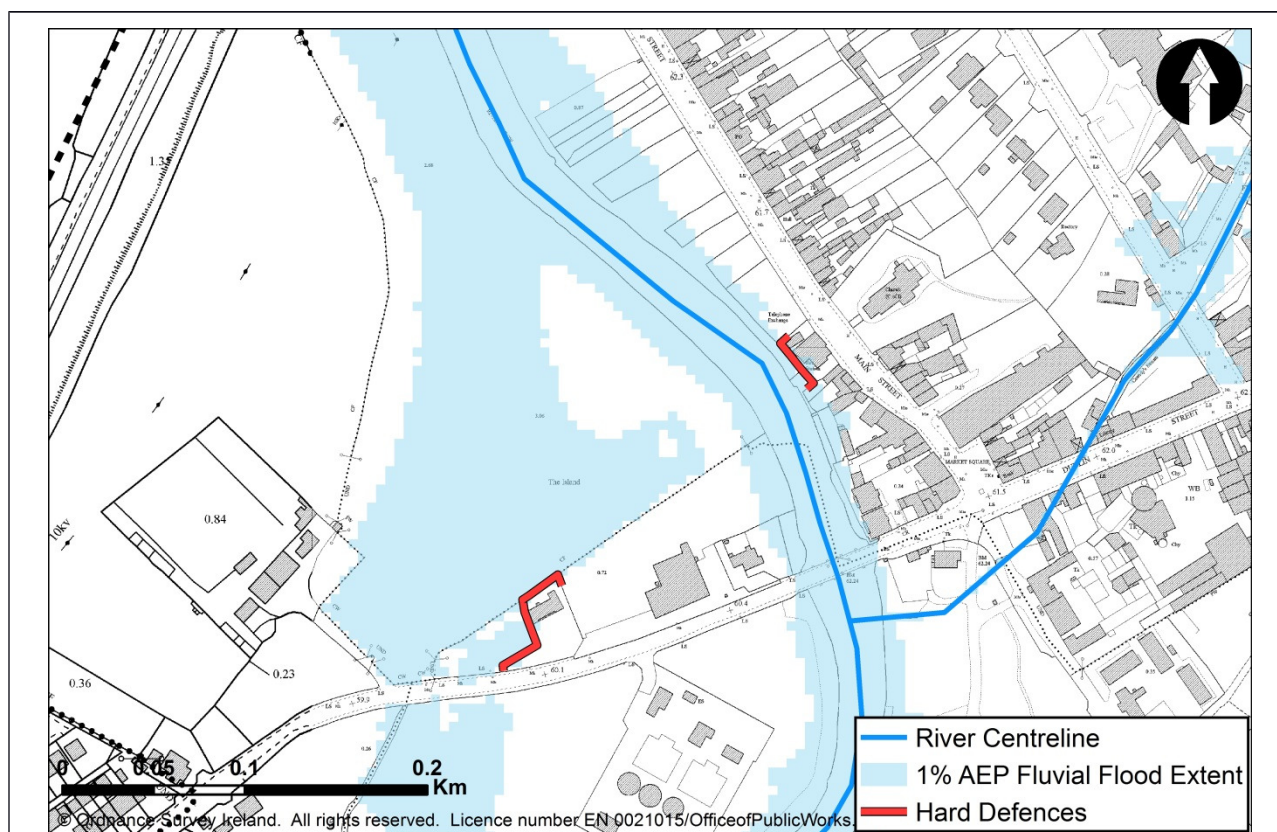




**Figure 8.8.7.2.1.1.1.1 Long Section of River Barrow**

Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	?	?

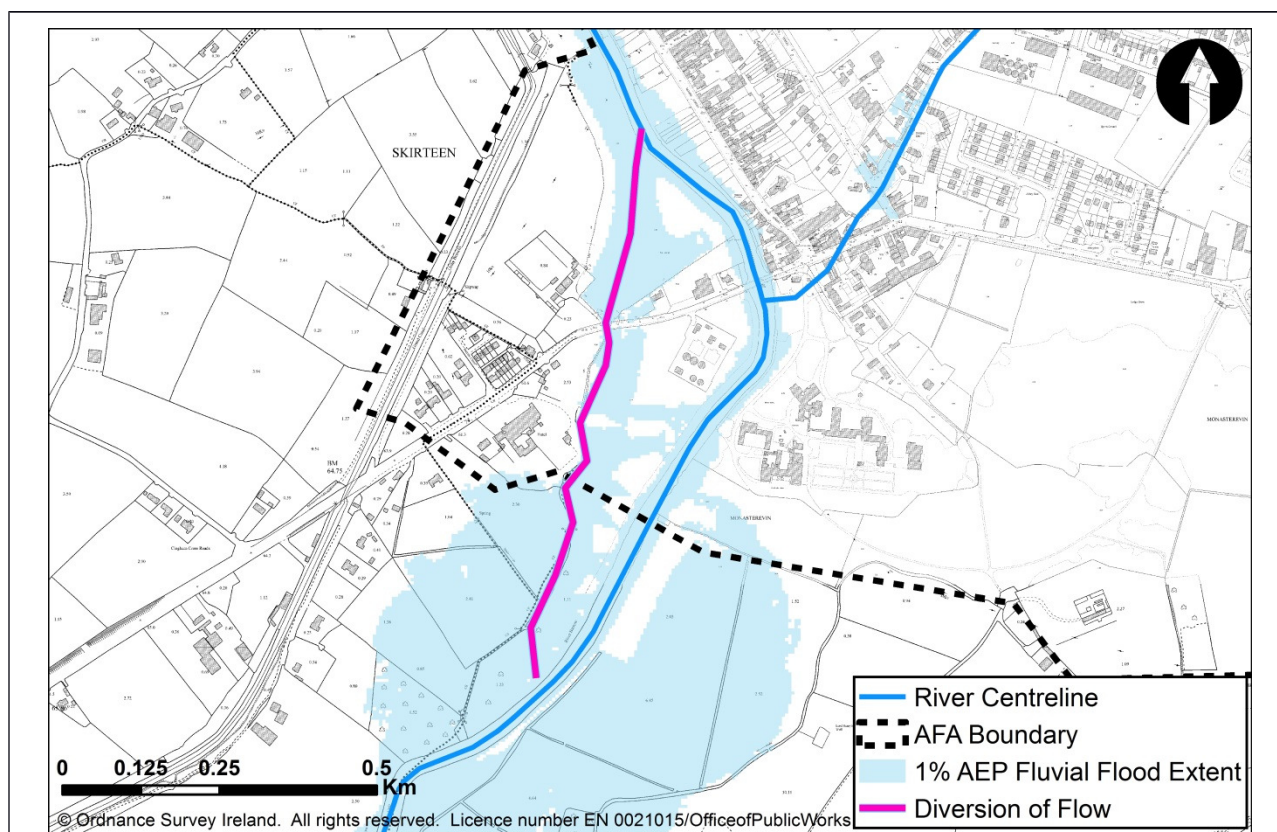
A review was carried out to ascertain where Hard Defences would be required to protect the existing properties in flood cell 2. Figure 8.8.7.2.1.1.1.2 shows the location of the Hard Defences required to protect properties during the 1% AEP event. In order to ascertain the effectiveness of Hard Defences 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 1.1m and a total length of 259m. The estimated cost to carry these works out would be €169,130, which is economically viable.



**Figure 8.8.7.2.1.1.1.2 Location of Hard Defence in Flood Cell 2**

The River Barrow and River Nore SAC is within, upstream and downstream of Monasterevin. However FRM Methods have been placed outside the designated areas where possible.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓		
The properties at risk during the design event in flood cell 2 are single properties. The cost to relocate all the properties, based on the market value, is €688,845 which is economically unviable.				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x	-	?	?
This method is considered in section 8.1 at UoM scale. The screening found flood warning/forecasting to be technically feasible for Monasterevin and could provide approximately 11.5hrs warning. With this warning time available it is estimated that some flood damage would be avoided; however as this method can only provide partial protection it should only be reviewed if all other methods are deemed unsuitable later in the optioneering process.				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✓	✓		
A review of the topography was carried out to identify possible flow diversion routes. Analysis of the flow paths shows a potential diversion from a location upstream of flood cell 2 on River Barrow could be formalised to reduce risk to properties as shown in Figure 8.8.7.2.1.1.1.3.				



**Figure 8.8.7.2.1.1.1.3 Potential Flow Diversion Route**

Some properties in flood cell 2 are at risk as frequently as the 50% AEP event. The Flow Diversion FRM Method is not technically feasible as a standalone method for flood cell 2 but a partial Flow Diversion FRM could be used in conjunction with another method to create a complete option for flood cell 2.

A channel capacity assessment was used to estimate the required dimensions of the channel needed to convey the 1% AEP flood flow. It was found that a trapezoidal channel of 10m width, 3.5m depth with sloping sides was sufficient to convey the required flow between the existing invert levels. The total length of the channel would be approximately 900m and a new bridge would be required for the R445 road. The economic review showed the estimated cost to carry these works out would be approximately €4.1m making this method economically unviable.

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

While this method would not provide the required design 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 the pass through the screening process. An economic review estimated that the cost of providing manual protection to 2 properties and automatic protection to the fire station would be approximately €87,104. This method is therefore economically viable.

It is unlikely that individual property protection would have any impact to designated sites in the vicinity of the Monasterevin AFA.

Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for this flood cell				
<b>8.8.7.3 Summary of Feasibility Review – Flood Cell 2</b>				
<p>The following FRM method has been carried forward to address the flood risk arising from flood cell 2;</p> <ul style="list-style-type: none"> <li>• Hard Defences</li> </ul> <p>Neither Flood Warning/Forecasting or Individual Property Protection provide the required SoP and should therefore only be used if other methods are deemed unsuitable later in the optioneering process. Consequently, hard defences is the preferred method and is carried forward to address the flood risk arising from flood cell 2.</p>				

### 8.8.8 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4
Individual Property Protection	x			
Hard Defences is a viable option for flood cell 2 however only Individual Property Protection is viable for flood cell 1, providing a different SoP across the AFA is deemed socially unacceptable. Therefore the only FRM Method viable for both flood cells is Individual Property Protection.				
8.8.8.1 Option 1 Details – Individual Property Protection				
However as the Individual Property Protection FRM method assumes that only 20% of the flood damage will be avoided the Capped Minimum Present Value Benefit available is only €56,919 giving a BCR of less than 0.5. Therefore no FRM options are available for Monasterevin.				
There are no FRM methods identified at AFA scale for Monasterevin; therefore the existing regime should continue in order to maintain the current SoP. However methods were identified at UoM level (see section 8.1) that are applicable to Monasterevin AFA, that if implemented, will serve to avoid increasing flood risk in the future:				
<ul style="list-style-type: none"><li>• Planning and Development Control</li><li>• Building Regulations</li><li>• Sub-catchment Wide SuDs</li><li>• Strategic Development Management</li><li>• Public Awareness Campaign</li></ul>				
Total MCA-Benefit Score	Option Cost (€millions)		MCA-Benefit Score / Cost Ratio	
-	-		-	
Economic Appraisal (Cost-Benefit Analysis) Outcomes				
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio	
€423.815	€261.796	€56.919	0.22	



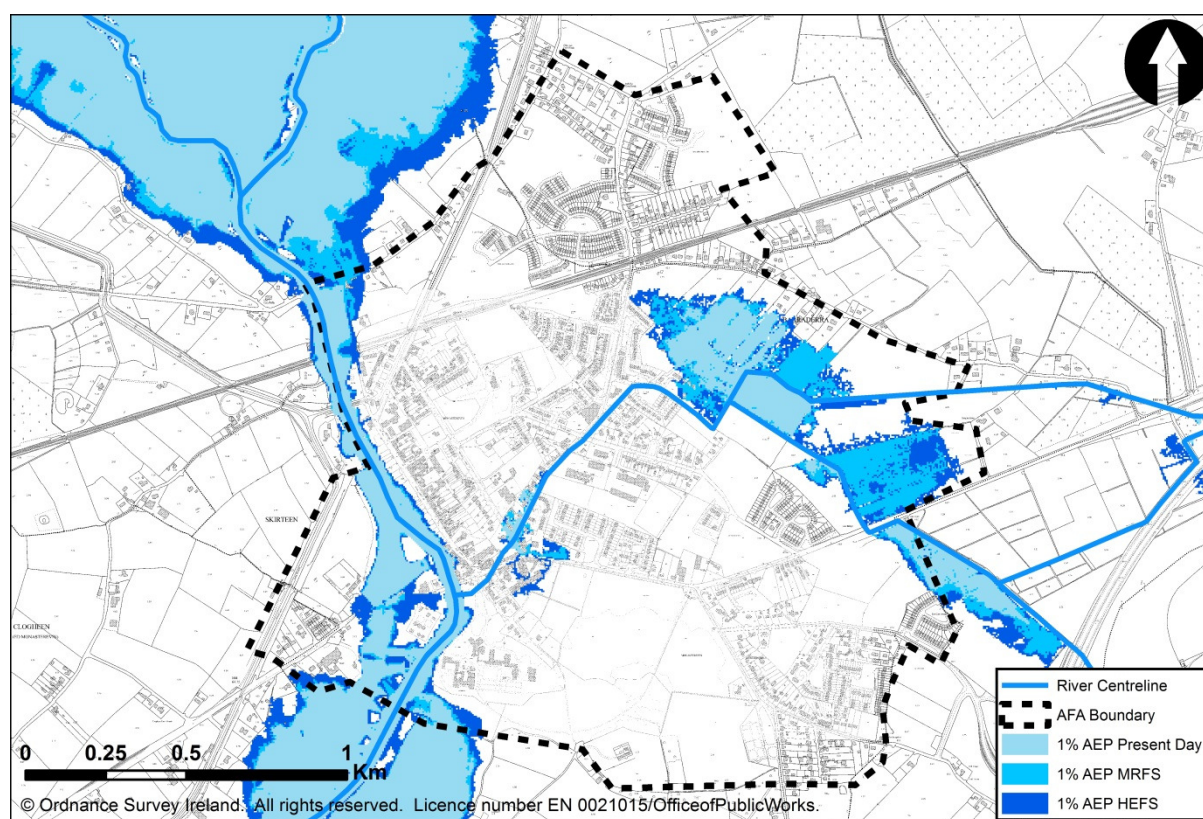
### 8.8.8.2 AFA Sensitivity to Future Change

As shown in Figure 8.8.8.2.1.1.1.1.1, during a MRFS 1% AEP flood event there is significant change to the flood extents due to the topography of the surrounding area. An additional 18 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €19,729 to €117,792. As a result Monasterevin AFA would be considered to be at moderate vulnerability from the MRFS.

During the HEFS 1% AEP flood event the flood extent, while larger than the MRFS, is significant also. An additional 50 properties are estimated to be at flood risk when compared to the present day flood risk. The AAD would increase from €19,729 to €577,520. As a result Monasterevin AFA would be considered to be at moderate vulnerability from the HEFS.

The main area of additional flood risk is at the confluence of the Barraderra and Cassidy Stream confluence and at Drogheda Street.

The number of additional properties affected by future scenarios indicates a significant increase to the annual average damage and the Monasterevin area of assessment would be considered to be at moderate vulnerability. Options should be assessed to their adaptability to climate change.



**Figure 8.8.8.2.1.1.1.1.1 Future Change Flood Extents**

### 8.8.8.3 Local Authority Comments

Local Authority representatives reviewed the conclusions in December 2015 and requested that further consideration be given to developing a workable option, however no viable options were identified.

**8.8.8.4 Summary**

There is good confidence in both the hydrology and hydraulics of the Monasterevin AFA due to the presence of a gauging station and flood extent verification events.

Low risk was identified in Monasterevin AFA. No options were identified; therefore the existing regime should continue in order to maintain the current SoP. The existing and future flood extents should be considered for any proposed planning and development.

Methods also were identified at UoM level (see section 8.1) that are applicable to Castledermot 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

Communities are located upstream and downstream of the Monasterevin AFA that could be affected by the potential option identified. The flows at the model boundary were reviewed for the 1% AEP current scenario versus the 1% AEP with the options in place scenarios. There are negligible flow differences between the hydraulic model simulations. In addition any interactions with the drainage system in the urbanised area may need to be addressed during the development of the preferred option.

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

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

A relatively low risk was identified in Monasterevin AFA although no a suitable low cost options have been identified that can provide a consistent SoP across the AFA.

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

## 8. OPTIONEERING OF SSA'S

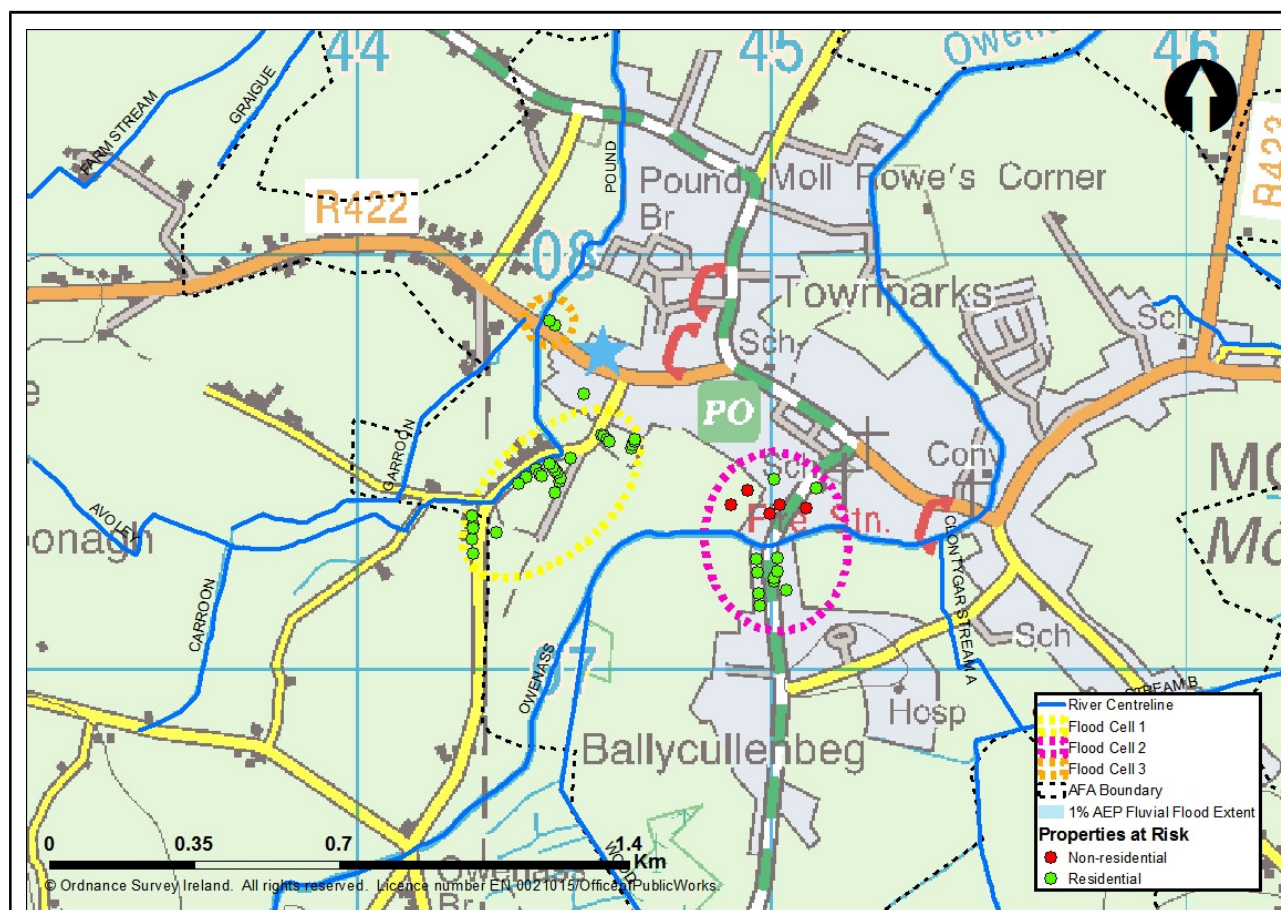
### 8.11 Mountmellick Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Mountmellick	Laois	140168	AFA	Final	15/06/2016

#### 8.11.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.9.6 Flood Cells



#### 8.11.1 Mountmellick AFA Flood Cells within a 1% AEP Fluvial Flood Extent

##### Flood Cell 1:

There is flooding in flood cell 1 during the 1% AEP fluvial event due to a combination of high water levels in the Pound River and overland flow originating from the Owenass River. Flood cell 1, is located at the south-west extent of Mountmellick AFA (see Figure 8.11.1); there are a total of 27 residential properties included in flood cell 1 (5 of these are just located outside of but contiguous with the AFA perimeter).

Flood cell 3 is located downstream of flood cell 1.

This flood cell is defined as complex since the fluvial flooding mechanism is associated with the behaviour of interconnected river channels such as the Avooley, Caroon and Garoon Rivers that feed into the Pound River channel, as well as flooding and overland flow originating from the Owenass River. Downstream these tributaries connect to the River Barrow, and the level of the River Barrow determines how efficiently this catchment can drain. During high flow events, high water levels in the River Barrow will cause up these tributaries to back-up.

#### **Flood Cell 2:**

Flood cell 2, is located at the centre of Mountmellick AFA, and is associated with insufficient channel capacity and overland flow originating from the Owenass and Wood Rivers. The affected properties are located in close proximity to where the N80 crosses over the Owenass River. A total of 11 residential and 5 non-residential properties are affected by flooding within this flood cell. Flood cell 2 is a complex flood cell since flooding is associated with the interconnectivity of the Wood and Owenass Rivers.

#### **Flood Cell 3:**

Flood cell 3, is located close to the point where the River Garroon joins with the Pound River. The flooding mechanisms associated with flood cell 3 are similar to flood cells 1 & 2, where the main causative flooding mechanisms are insufficient channel capacity and overland flow. 2 residential properties are affected by flooding during a 1% AEP fluvial event. Flood cell 3 is a discrete flood cell and therefore considered as local.

#### **Summary of Flood Cells:**

As shown in Figure 8.11.1 there are three flood cells associated with Mountmellick AFA. Flood cells 1 and 2 have been defined as complex flood cells, due to the complexity and interaction of the flooding mechanisms associated with these flood cells, it is considered appropriate that they are screened together in the optioneering process (see Section 8.9.8).

Flood cell 3 is a discrete area with only two residential properties at risk. It is therefore appropriate to screen this flood cell as a standalone area assessing options applicable to localised works (Section 8.9.9).

On completion of the optioneering screening assessment, measures for all flood cells will be combined to form complete options for the Mountmellick AFA as detailed in Section 8.9.10.

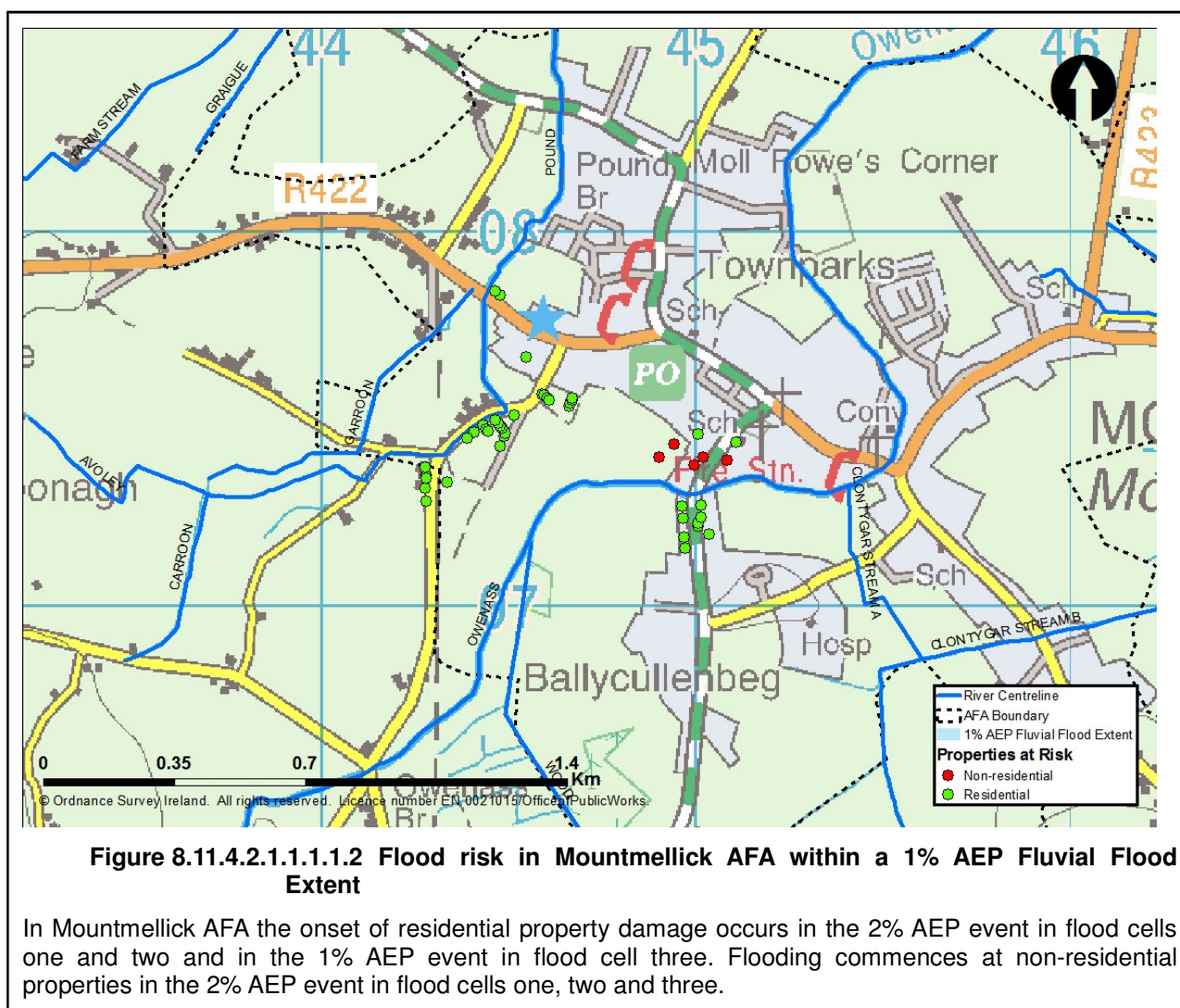
### **8.11.3 Existing Regime**

The 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 Mountmellick AFA watercourses are located within the Barrow Drainage District. Further details of operations in this district are presented in section 6.3



### 8.9.7 Summary of Flood Risk within SSA boundary



### 8.11.5 Monetary Damage and Benefit

	Flood Cell 1 & 2	Flood Cell 3	Total in AFA
Annual Average Damage (AAD)	€894,932	€4,097	€899,092
Present Value Damage (pvD)	€19,224,920	€88,006	€19,096,465
Preferred Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	43	2	45
Minimum Present Value Benefit	€15,964,435	€61,271	€16,025,706
Capped Minimum Present Value Benefit	€4,656,126	€61,271	€4,717,397

\*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.

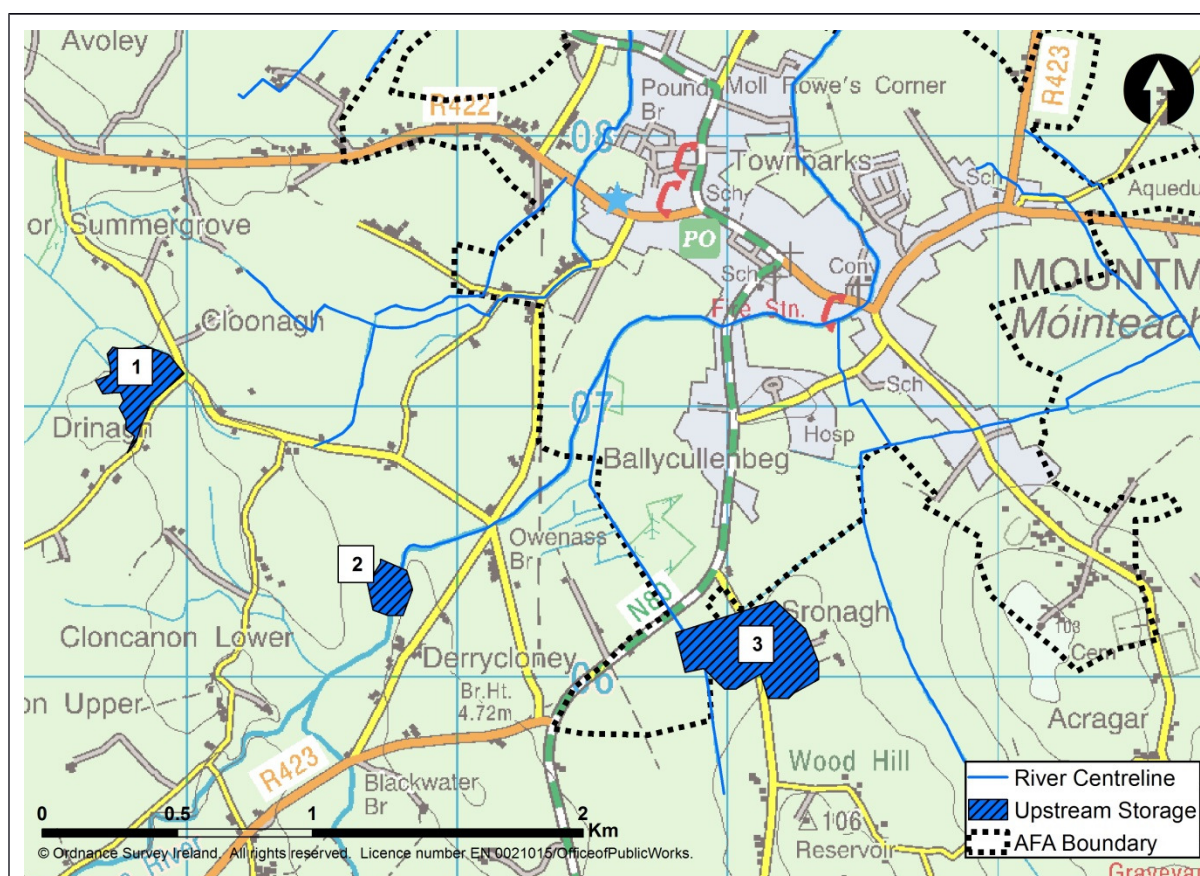


**8.9.8 Short Listing FRM Methods – Complex Cells**

Method	Review Comment	Continue Screening
		Flood Cell 1 & 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	✓

8.11.7.1 Feasibility Review Summary for Complex Cell (flood cell 1 & 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	✓	✓		
Flood Warning/Forecasting	✗	✓	✓	✓
Diversion of Flow	✓			
Individual Property Protection	✗	✓	✓	✓
Other Works	✓			
✗ - Reject      ✗ - Progress      ? - Progress, potential for impacts identified      ! - Progress, potential for significant impacts identified				
8.9.8.2 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	x			
<p>Do Minimum, applies to the FRM that may include clearance of channels and is also 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>Considering that flooding associated with flood cells 1 &amp; 2 is influenced by fluvial flow originating from a network of rivers and subsequent overland flow, this flood risk cannot be easily addressed with a discrete low cost activity. This method is therefore considered technically unfeasible for flood cells 1 &amp; 2.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	x	-	✓	✓
<p>The application of land use management measures was tested at UoM scale. Flood cells 1 and 2 are 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 reducing 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> <p>A technical review of the surrounding topography was carried out to identify possible storage areas. Three potential storage locations have been investigated as shown in Figure 7.11.3.</p>				



**Figure 8.9.8.2.1.1.1.8 Mountmellick Potential Flood Storage**

For storage area 1, investigation showed that the surrounding topography is unsuitable for creating sufficient storage volume. Similarly for potential storage areas 2 and 3, the topography surrounding the watercourse at AFA level was unsuitable for creating sufficient storage without affecting existing properties. This is primarily due to the relatively flat and slightly undulating terrain. Consequently storage has been deemed technically unfeasible.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

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.

Properties located within flood cells 1 and 2 are at risk from flooding during a 1% AEP event, due to flooding originating from the Owenass River, water spills out of bank due to insufficient channel capacity and generally flows in a northerly direction, contributing to flooding in both flood cells 1 and 2. The Owenass River has been examined to locate areas where channel conveyance might be improved. This exercise concluded that the bed level along a selected length of the Owenass River could be lowered by an average of 0.5m to reduce the flood risk. This would involve dredging 2.2km of the river and underpinning two bridges.

The Pound and Carroon Rivers have also been examined but no suitable locations for improving channel conveyance were identified. The Pound River joins to River Barrow downstream of flood

cell 2, which causes the Pound River to back-up during periods of high flow. The bed level along the River Barrow could be lowered by an average of 0.55m. This would involve dredging approximately 4.9km of channel and underpinning 3 bridges. Figure 8.9.8.2.1.1.1.9, Figure 8.9.8.2.1.1.1.10 and Figure 8.9.8.2.1.1.1.11 show the proposed positions of Improved Channel Conveyance.

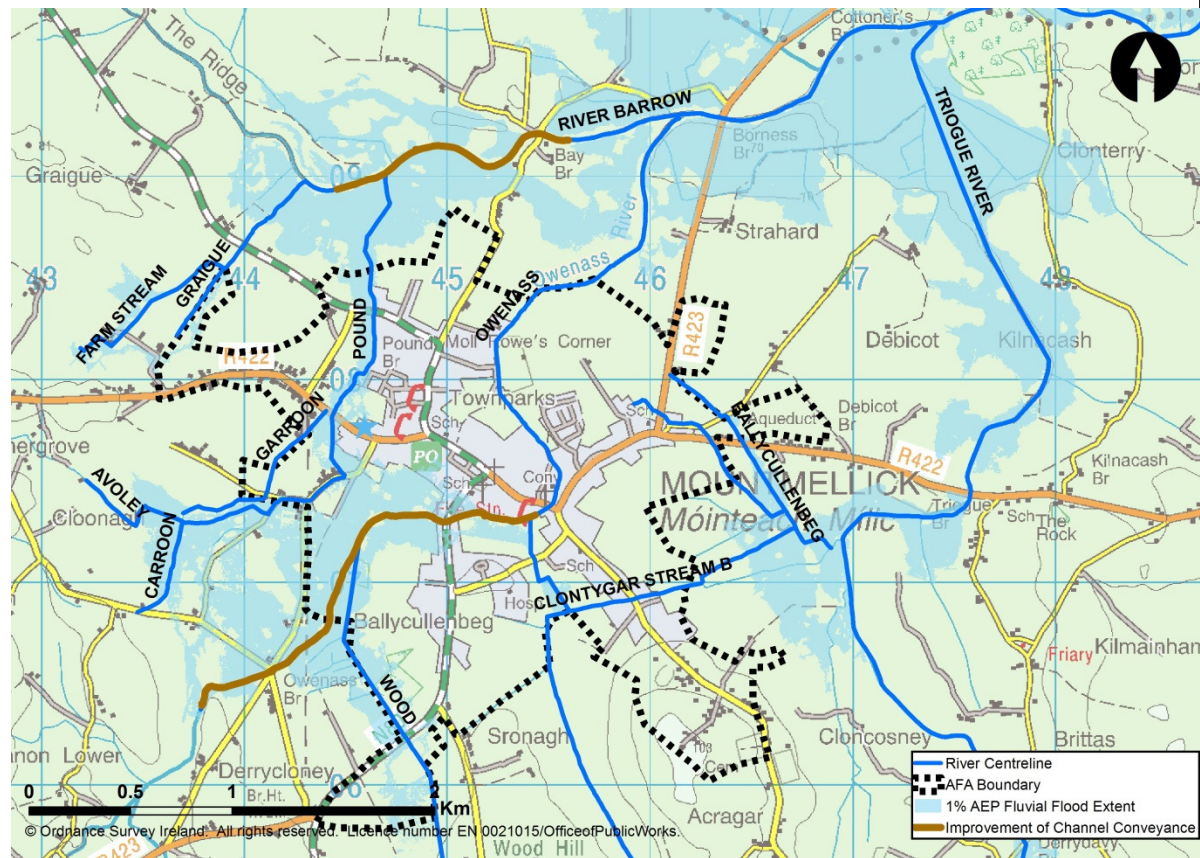
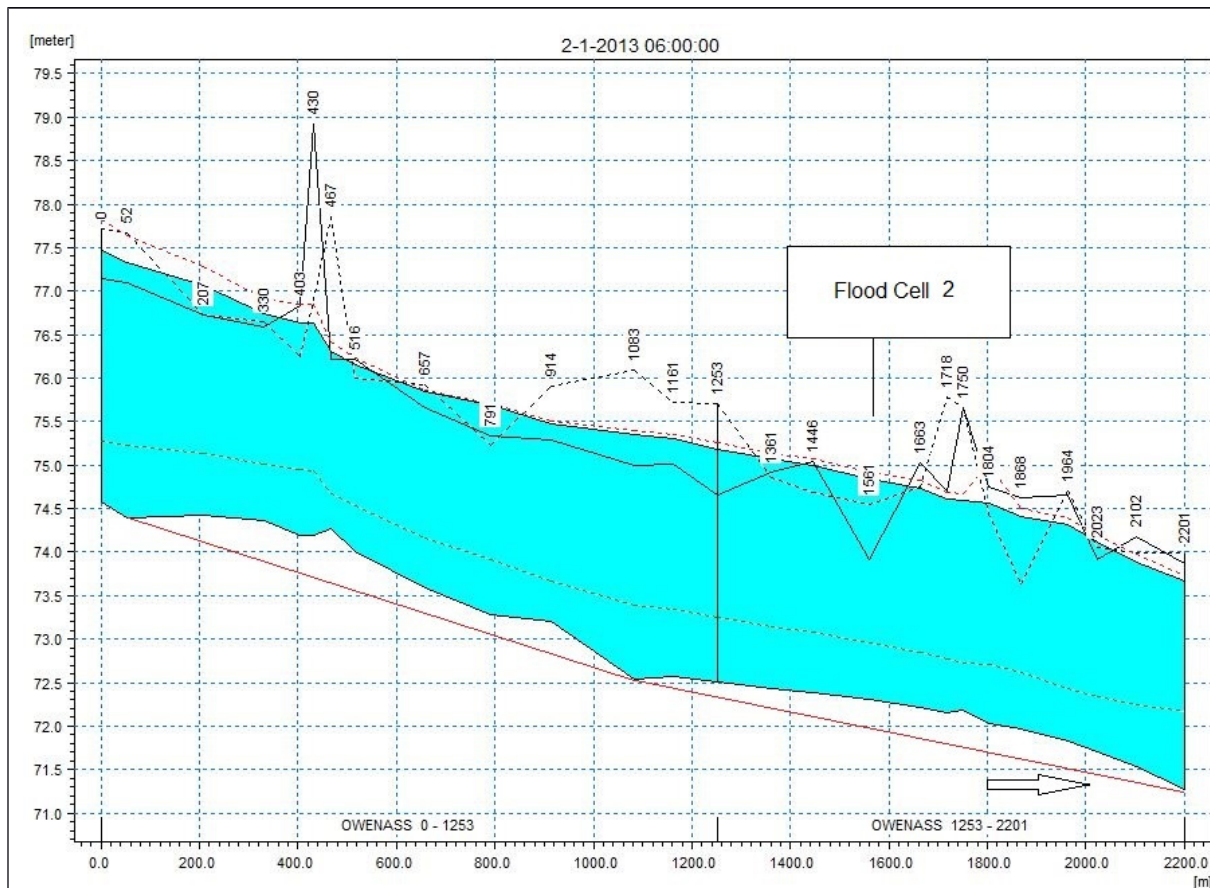
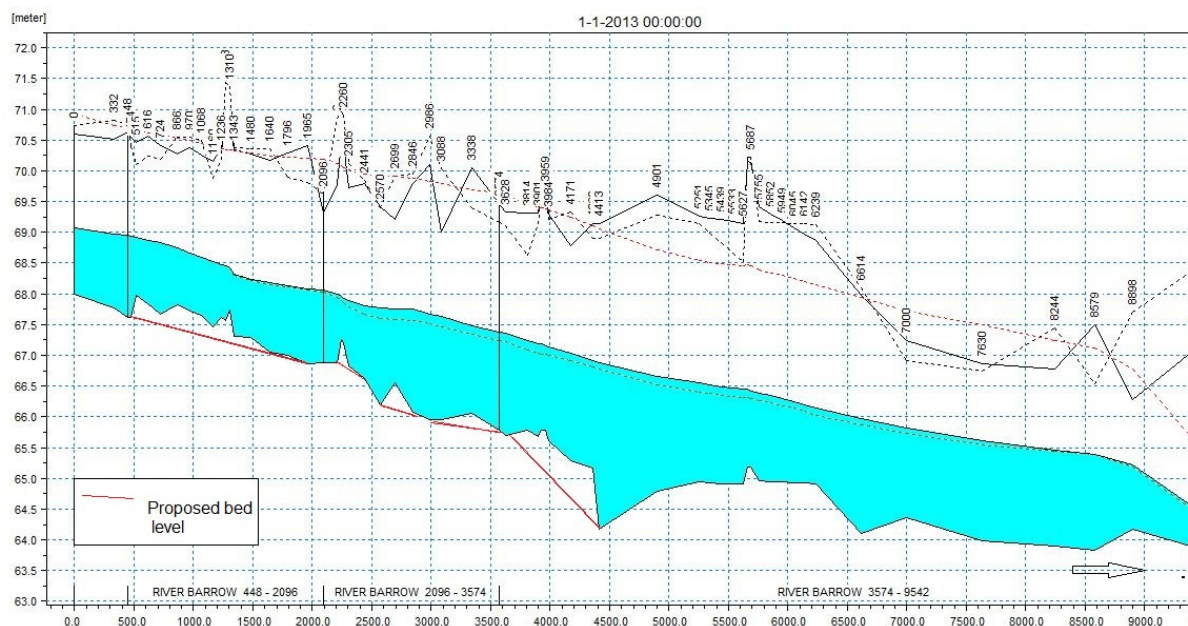


Figure 8.9.8.2.1.1.1.9 Location of Channel Improvement





**Figure 8.9.8.2.1.1.1.10 Owenass River showing Improved Conveyance**



**Figure 8.9.8.2.1.1.1.11 Long Section of the Barrow River showing Improved Conveyance**

Model simulations have shown that the application of Improved Channel Conveyance would not sufficiently alleviate flooding within flood cells 1 and 2 to enable the design 1% SoP to be achieved. As a standalone method Improved Channel Conveyance is therefore viewed as

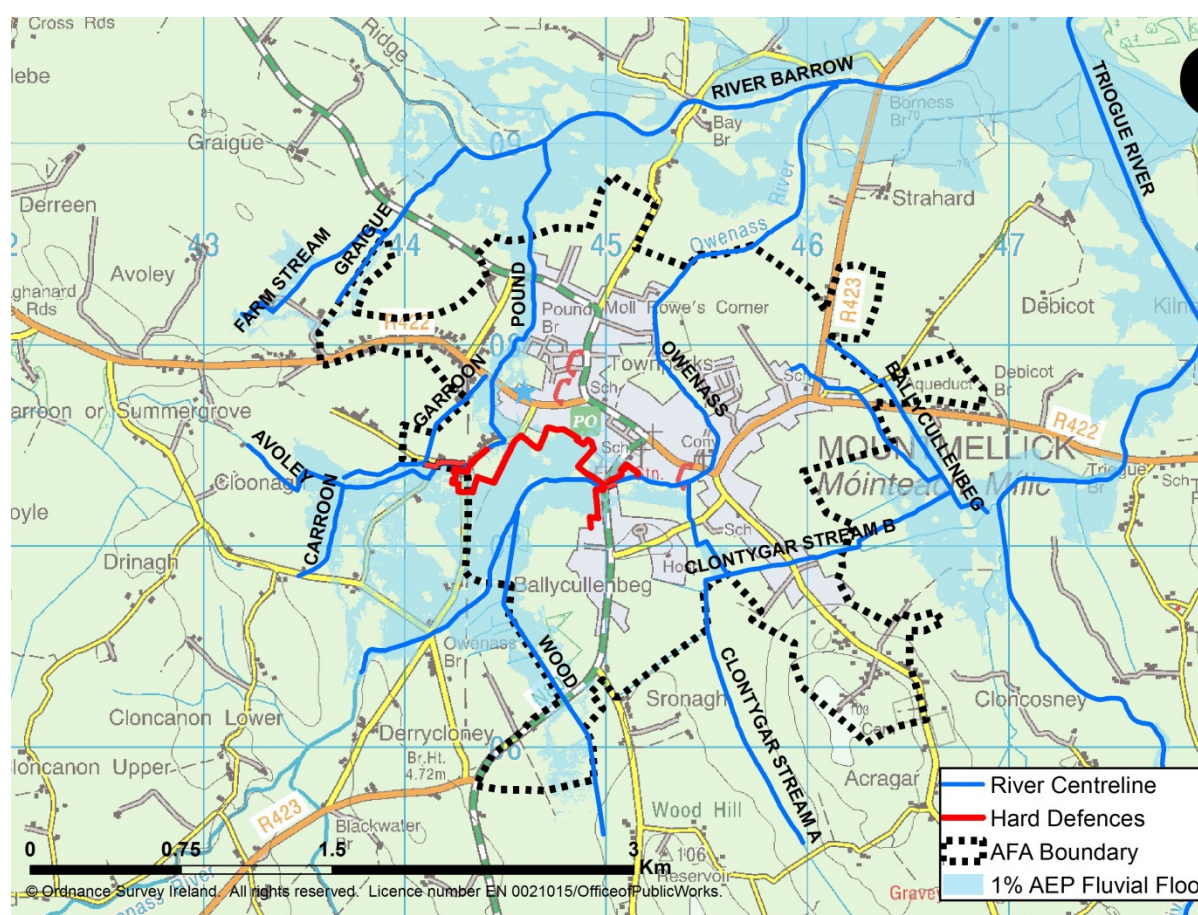
technically unfeasible. If combined with walls, this method would be rendered economically unviable.

It is estimated that the combined cost of improved channel conveyance within the Owenass and Barrow River would be €3,408,436. When considered in combination with walls, the capital costs rises to €7.5 million.

Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	!	✓

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.

For Mountmellick, a technical review was conducted to ascertain the optimum location for Hard Defences, benefitting the greatest number of properties. Figure 8.9.5.4.1.1.1.7 shows the location of the proposed Hard Defences for a SoP of 1% AEP.



**Figure 8.9.5.4.1.1.1.7 Location of Potential Hard Defence within Mountmellick Flood Cell 1 & 2**

In order to ascertain the effectiveness of Hard Defences a hydraulic model was constructed to simulate the proposed measures. The model showed these hard defences would protect to the 1% AEP flood event with an average height of 1m and a total length of 2.4 km. Hard defences include

sections of walls, embankments and sections of raised road.

An economic review estimated the cost of the hard defences to be approximately €3,135,680 making this method economically viable.

The River Barrow and River Nore SAC is within, upstream and downstream of Mountmellick. The Slieve Bloom Mountains SAC, SPA and Ramsar Site are over 7km up catchment of the AFA. The Mountmellick SAC is 3km to the east of Mountmellick, however is not hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Flood Warning / Forecasting	✓	✓	✓	✓

The application of flood warning / forecasting was tested at UoM scale. Several suitable positions, located far enough upstream of flood cells 1 and 2 is available to provide sufficient warning time. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.

An economic review estimated that the cost of providing up to 6 hydrometric gauging stations with simple forecasting systems would be approximately €284,953. This method is therefore economically viable.

The proposed gauging station is not within any environmental designations and it is unlikely that flood forecasting would have any impact to designated sites in the vicinity of the Mountmellick 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 clusters of properties are located.

In practice it is always technically possible to relocate properties, however considering the socially negative impacts it should only be considered should no other method be found suitable. There are 43 properties at risk within flood cell 1 and 2, during the occurrence of a 1% AEP fluvial event. Although it is technically feasible to relocate these properties elsewhere, it is estimated that this would cost €23,413,035, therefore making this method uneconomical.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			



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.

A technical review was conducted to identify any possible Flow Diversion routes, which would alleviate the flood impact within flood cells 1 and 2. One possible route was identified, whereby flow from the Owenass River would be diverted across to the Pound River, following an existing flood flow route. This would involve diverting flooding from the Owenass into an already flooded Pound River. Whilst this method alleviated flooding within flood cell 2 it was at a cost of increased flooding within flood cell 1. This method was therefore seen as technically unfeasible and has been rejected from the screening process.

Method	Tech	Econ	Env	Soc
Individual Property Protection	x	✓	✓	✓
<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>While this method would not provide the required design 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 these properties is €449,799 This method is therefore 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 these flood cells.				
<b>8.9.8.3 Summary of Feasibility Review – Flood Cells 1 &amp; 2</b>				
<p>The following FRM method has been carried forward to address the flood risk arising from flood cell 1 and 2 are</p> <ul style="list-style-type: none"> <li>• Hard Defences</li> </ul> <p>Hard Defences can provide the full protection to all the commercial properties during the occurrence of a 1% AEP flood event. The emplacement of such Hard Defences would be the most efficient and economic method available. Individual Property Protection, Flood forecasting and Land Use Management whilst also feasible should therefore only be adopted should hard defences be deemed unsuitable later in the optioneering process.</p>				



**8.9.9 Short Listing FRM Methods – Local Cells**

Method	Review Comment	Continue Screening
		Flood Cell 3
Do Nothing	Consider Further	✗
Additional Maintenance	Consider Further	✓
Do Minimum	Consider Further	✓
Land Use Management	Consider Further	✓
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	✓

## 8.11.7.1 Feasibility Review Summary of FRM Methods for flood cell 3

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

## 8.9.9.2 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do nothing	✓			
The do nothing FRM method for flood cell 3 would involve stopping the current maintenance regime. The expected outcome would be increased vegetation on the Pound River, therefore raising water levels. This is an unacceptable outcome in terms of contributing to design SoP. This method is therefore rejected from the screening process.				

Method	Tech	Econ	Env	Soc
Additional Maintenance	x			
<p>Historical flood data and channel survey data indicated that the present day flood risk from the Mountmellick Rivers is not attributable to vegetation, debris or blockages. While maintenance should continue on these Rivers, increased activities will not significantly relieve the current flood risk.</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	x			
<p>Within flood cell 3 there is little opportunity to improve the conditions in the Pound River and therefore little scope to reduce the overall flood risk. This is an unacceptable outcome in terms of contributing to achieving a design SoP and this method was therefore rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Storage	x			
<p>A technical review of the surrounding topography was carried out to identify possible storage areas. Three potential storage locations have been investigated as shown in Figure 8.11.3. In summary, the siting of potential storage areas has been restricted by the lack of favourable terrain and the presence of existing properties. Based on these grounds, Storage has been deemed technically unfeasible for flood cell 3 and Mountmellick.</p>				
Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x			
<p>Properties within flood cell 3 are at risk from flooding originating from the Pound River as the result of insufficient channel capacity during the occurrence of a 1% AEP fluvial event. Model results have shown that improving the channel capacity along the Owenass &amp; Pound Rivers would not alleviate flooding within flood cell 3.</p>				
Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	!	✓
<p>Model results have shown that the properties within flood cell 3 are fully protected by the application of hard defences as shown in Figure 8.11.7. There is no requirement to emplace Hard Defences within flood cell 3.</p>				

Method	Tech	Econ	Env	Soc
Flood Warning / Forecasting	✓	✓	✓	✓
<p>The application of flood warning / forecasting was tested at UoM scale. Several suitable positions, located far enough upstream of flood cell 3 are available to provide sufficient warning time. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.</p> <p>An economic review estimated that the cost of providing up to 6 hydrometric gauging stations with simple forecasting systems would be approximately €284,953. This method is therefore economically viable.</p> <p>The proposed gauging station is not within any environmental designations and it is unlikely that flood forecasting would have any impact to designated sites in the vicinity of the Mountmellick AFA.</p>				
Method	Tech	Econ	Env	Soc
Relocation of Properties	✓	✓	✓	?
<p>The two residential properties at risk during the design event within flood cell 3 may be suitable for relocation. The cost to relocate these properties based on the market value is €1,029,848. This method may therefore be economically viable. This method should only be considered as a last resort if no other viable methods are available due to the potentially significant social impacts of relocating properties.</p>				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✓			
<p>A review was carried to identify locations where a Flow Diversion route could be constructed in the vicinity of flood cell 3. In simplistic terms, this would mean diverting the Pound River away from flood cell 3. Due to the presence of urban infrastructure, no suitable route was identified. Even if a suitable route was identified and constructed, this would not eliminate the effects of flooding originating from the overland flood flow path originating from the Owenass River. Consequently, this FRM would have a negligible effect in reducing the flood risk within flood cell 3 and this method is considered technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Individual Property Protection	x	✓	✓	✓
<p>While this method would not provide the required design 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 the pass through the screening process. It is estimated that 'Individual Property Protection' of flood cell 3 would cost €65,561 and there would be no anticipated impact to environmental or social receptors.</p>				

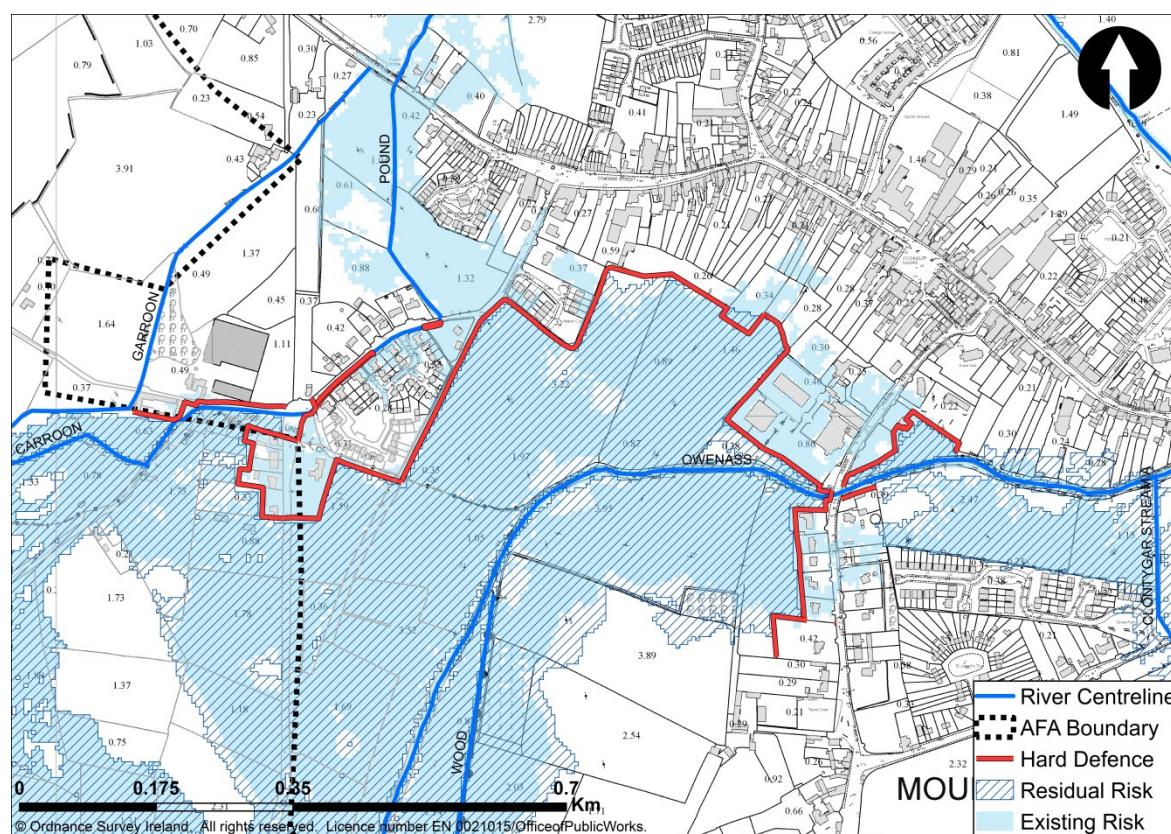
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for this flood cell				
<b>8.9.9.3 Summary of Feasibility Review – Flood Cell 3</b>				
<p>The following FRM method has been carried forward to address the flood risk arising from flood cell 3;</p> <ul style="list-style-type: none"> <li>• Hard Defences</li> </ul> <p>Within flood cell 3 Hard Defences provide the full SoP to all properties during a 1% AEP flood event. Relocation of Properties is not considered any further, since Hard Defence provides full protection. This method should only be considered as a last resort if no other viable methods are available due to the potentially significant social impacts of relocating properties.</p> <p>Considering that Individual Property Protection can only provide partial protection, this FRM should only be used only if no other suitable options are identified towards the end of the optioneering process.</p> <p>Land Use Management and Flood Forecasting is no longer considered since other FRM have been identified that provide the preferred level of SoP.</p>				

#### 8.9.10 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Hard Defences	x				
<p>For flood cells 1, 2 and 3 Hard Defences are identified as a suitable FRM method. Hydraulic model simulations have shown that the emplacement of walls to protect properties within flood cell 1 &amp; 2 has the added benefit of sufficiently preventing flooding within flood cell 3.</p>					



## 8.11.8.1 Option 1 details - Hard Defences



**Figure 8.9.10.2.1.1.1.8 Mountmellick Option 1**

At risk properties would be protected by a series of 'Hard Defences' consisting of flood embankments, walls and sections of raised roads as shown in Figure 8.9.10.2.1.1.1.8. These hard defences would protect to the 1% AEP fluvial flood event with an average height of 1m and a total length of 2.4 km.

Figure 8.9.10.2.1.1.1.8 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).

The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Flood Wall	256.54 m length, 0.66m high (average)	€327,325	
Embankment	2.3km length, 1.1m high (average)	€518,764	
Raised Road	54m length, 0.9m high (average)	€388,544	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
1456	3.1	464.38	
Economic Appraisal (Cost-Benefit Analysis) Outcomes - All figures €millions			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€19,096,465	€3,135,680	€4,717,397	1.5

### 8.9.10.3 AFA Sensitivity to Future Change

As shown in Figure 8.9.10.3.1.1.1.8, during a MRFS 1% AEP flood event there is a significant increase in flood extent that is most obvious along Moore Street and Emmett Street, within the town centre. The main area of additional flood risk is in the Mountmellick Town Centre, and in particular in properties located along O'Moore Street and Emmett Street. Other areas include increased flooding within Wolfe Tone Court, Manor Court and Manor Grove. Other properties at risk as the result of climate change are located close to the Clontygar Stream, within Brock View and close to Ballycullenbeg Stream, within the Bayview Estate. The extent of flooding is limited by the fluvial basal and fluvial floodplain topography.

An additional 171 properties are estimated to be at risk of flooding during the MRFS when compared to the present day flood risk. The AAD would increase from €899,092 to € 2,050,108. As a result Mountmellick AFA would be considered to be at high vulnerability from the MRFS.

During the HEFS 1% AEP flood event the flood extent an additional 385 properties are estimated to be at risk. The AAD would increase from €899,092 to €5,644,723. As a result Mountmellick AFA would be considered to be at high vulnerability from the HEFS.

The relatively large number of additional properties affected by future scenarios indicates a significant increased to the annual average damage and the Mountmellick area of assessment would be considered to be at high vulnerability. Options should therefore be assessed to their adaptability to climate change.

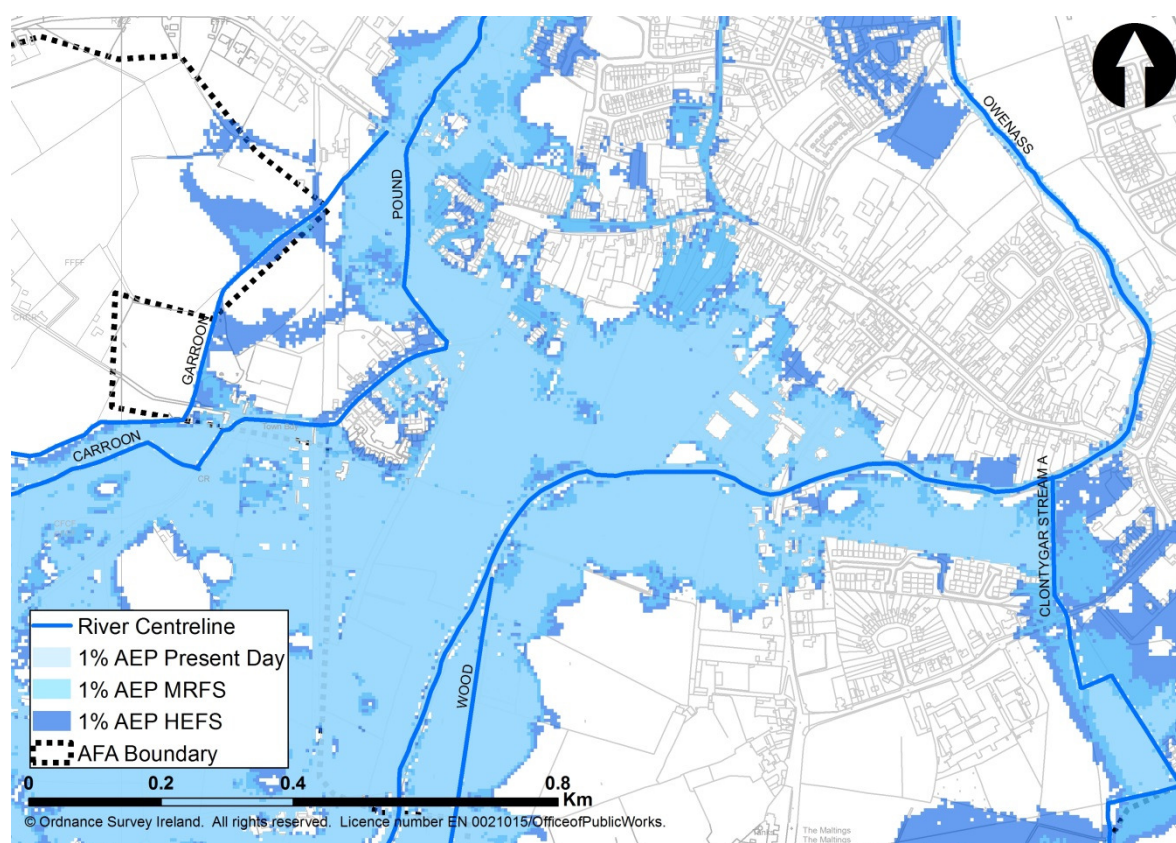


Figure 8.9.10.3.1.1.1.8  
1)

Future Change Flood Extents (Flood Cell



#### 8.9.10.4 Future Change Adaptability

The following discusses the adaptability of the potential FRM methods proposed in Mountmellick /AFA

**Hard Defences Flood Cell 1** - This method could be adapted by increasing the height of the wall and extending its length, particularly the section along the Pound River, this will add further protection to flood cell 3 and Mountmellick Town Centre. A review of the effect of the MRFS and the HEFS showed that the hard defences might need to be increased from 1m to 1.7m and 2m, respectively. The review also showed that the additional length of Hard Defence required would be minimal. To ensure that this wall would be adaptable the design would need to account for the potential increase on Hard Defence height. This method is considered to have a **moderate to poor** adaptability.

**Hard Defences Flood Cell 2** – Similar to the assessment conducted above, increasing the height of the Hard Defences that would protect properties within flood cell 2, will add further protection. A review of the effect of the MRFS and the HEFS showed that the hard defences might need to be increased from 1m to 1.7m and 2m, respectively. This addition could be accommodated. The review also showed that the additional length of Hard Defence required would be minimal

To ensure that this wall would be adaptable the design would need to account for the potential increase on Hard Defence height. This method is considered to have a **moderate to poor** adaptability.

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 these methods other methods aimed at reducing future flood risk has been discussed in section 8.1 at UoM scale. These methods will reduce the vulnerability of potential future receptors. These methods, such as building regulations and planning & development control will reduce the impact to potential future receptors. Given that Mountmellick is developed currently this would have little impact to overall area. Given that 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 campaign. This is most relevant to options with methods with poor adaptability.
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. The emplacement of Hard Defence will affect the direction of overland flow paths.
3. **Does the option deliver co-benefits?** No co-benefits were identified
4. **Does the option provide flexibility?** Hard Defence is generally the most adaptable measure to the MRFS and HEFS. However alternative FRM methods could be added to all options 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 without increasing the level of vulnerability to Mountmellick receptors.

An objective for each potential option is to ensure that flood risk can be managed effectively and sustainably into the future, and the potential impacts of climate change. Based on this future change adaptability assessment the 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)	Option is adaptable at significant cost, difficulty and impact	2
<b>8.9.10.5 Local Authority Comments</b>		
LA representatives reviewed preliminary options in November 2015.		
<b>8.9.10.6 Summary</b>		
<p>There is good confidence in both the hydrology and hydraulics of the Mountmellick AFA due to the presence of several gauging stations and flood extent verification events.</p> <p>The following potential options, with a BCR <math>\geq 0.5</math> have been identified:</p> <ul style="list-style-type: none"> <li>Option 1 – Hard Defence (FC 1 &amp; 2).</li> </ul> <p>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 also form part of the ongoing regime once in place.</p> <p>Methods also were identified at UoM level (see section 8.1) that are applicable to Mountmellick AFA, that if implemented, will serve to avoid increasing flood risk in the future :</p> <ul style="list-style-type: none"> <li>Planning and Development Control</li> <li>Building Regulations</li> <li>Sub-catchment Wide SuDs</li> <li>Strategic Development Management</li> <li>Public Awareness Campaign</li> </ul> <p>Portarlinton AFA is located downstream of Mountmellick AFA and should be taken into consideration for any future works carried out. The flow at the downstream model boundary was reviewed for the 1% AEP current scenario versus the 1% AEP with the option in place scenario. There was a negligible flow difference between the hydraulic model simulations. In addition any interactions with the drainage system within Mountmellick may need to be addressed during the development of the preferred option.</p> <p>No critical environmental, cultural heritage or social issues have been identified.</p> <p>It should be noted that this area is sensitive to climate change however no physical provision can be incorporated into detailed design.</p> <p>These recommendations should be taken forward with a view to identification of a preferred option for the flood risk management plan.</p>		



## 8. OPTIONEERING OF SSA'S

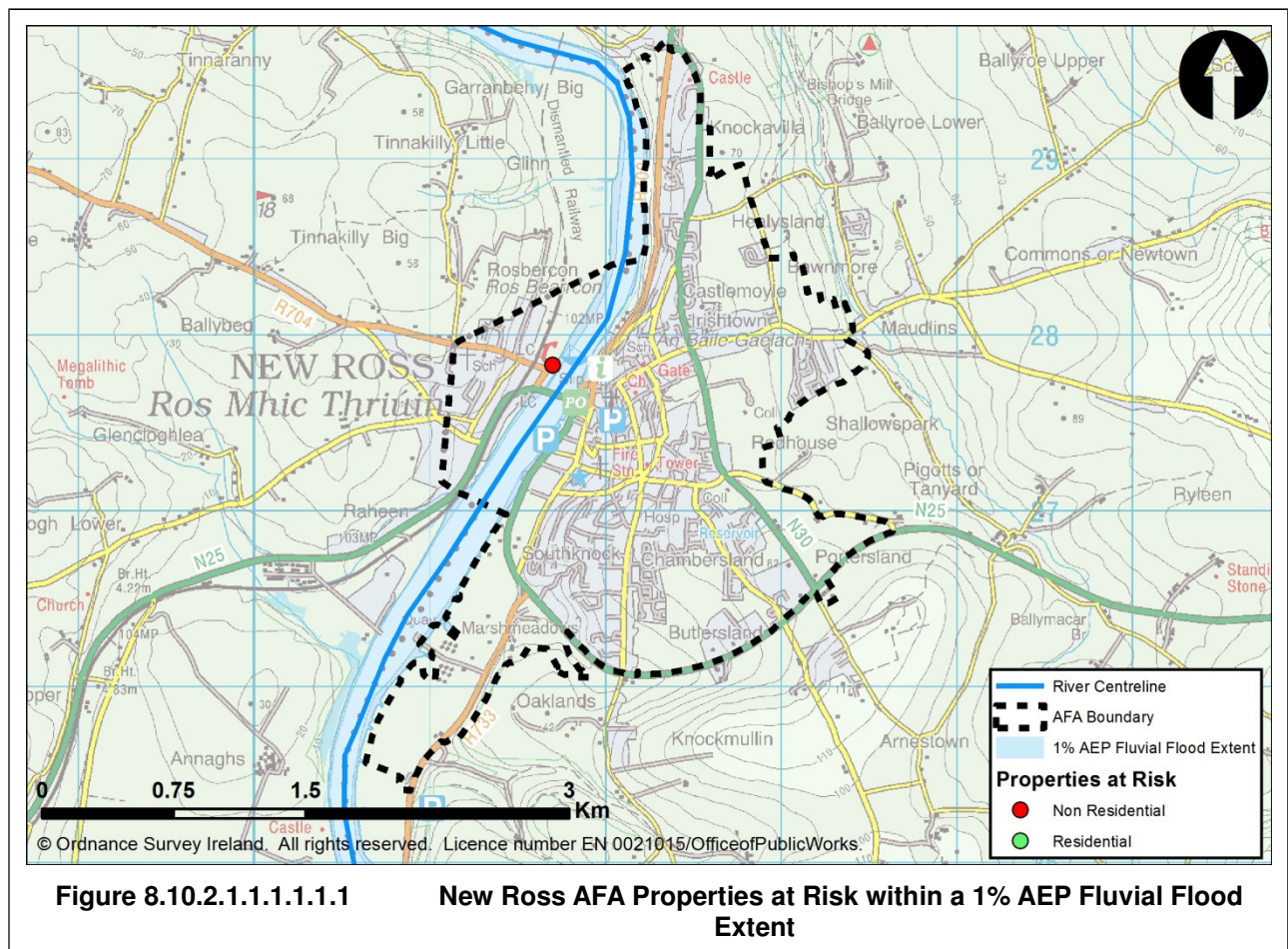
### 8.12 New Ross optioneering of FRM Options

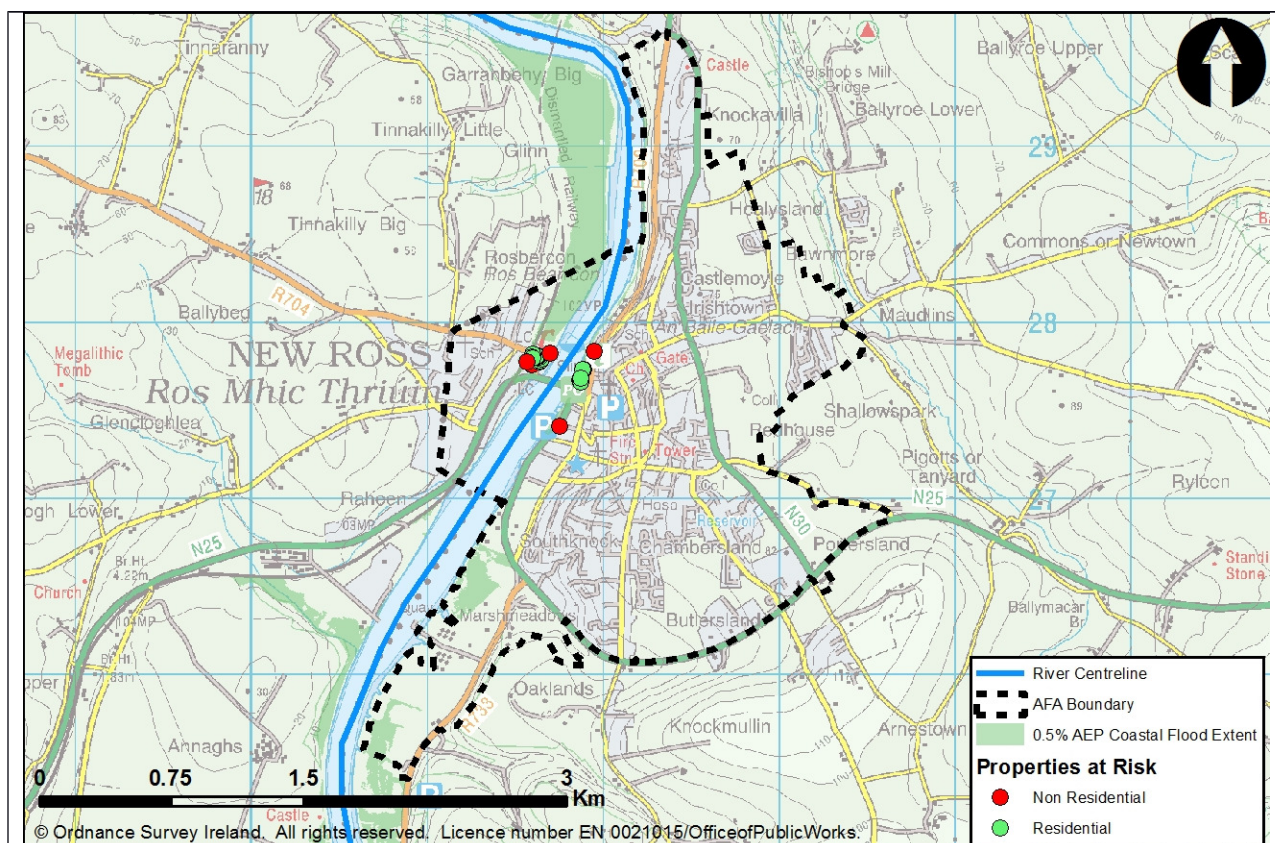
Name	Local Authority	Unique ID	SSA	Status	Date
New Ross	Wexford/Kilkenny	141599	AFA	Final	15/06/2016

#### 8.10.1 Source of Flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.10.2 Flood Cells





**Figure 8.10.2.1.1.1.1.1.2 New Ross AFA Properties at Risk within a 0.5% Coastal Mechanism 1 Flood Extent**

#### Summary of Flood Cells:

As shown in Figure 8.10.2.1.1.1.1.1 and Figure 8.10.2.1.1.1.1.2 there are a number of properties at risk during the 1% AEP fluvial and 0.5% AEP coastal mechanism 1 events within New Ross AFA. Wexford County Council have confirmed there is an existing FRM scheme approved for the New Ross AFA and no optioneering is required, therefore no flood cells have been created.

### 8.10.3 Existing Regime

The 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 section of the River Barrow which flows through New Ross is maintained by Wexford County Council. Inspections and maintenance works in these areas are carried as and when necessitated. There is also an approved flood protection scheme currently progressing in New Ross. These works have been designed to manage the flood risk in New Ross therefore this maintenance regime provides the preferred SoP.

#### 8.10.4 Monetary Damage and Benefit

	Total in AFA
Annual Average Damage (AAD)	€72,771
Present Value Damage (pvD)	€1,563,273
Standard of Protection (SoP)	1% AEP/0.5% AEP
Number of Properties Benefiting from Design SoP	0 <sup>4</sup>
Minimum Present Value Benefit	€0
Capped Minimum Present Value Benefit	€0

<sup>4</sup>There is an existing and approved flood defence scheme progressing in New Ross to protect properties within the town centre and hinterland. The properties benefitting from the scheme do not contribute to the economic assessment in the 0.5% AEP tidal event or 1% AEP fluvial event.

#### 8.10.5 Selection of Options

Wexford County Council have confirmed there is an existing FRM scheme approved for the New Ross AFA and therefore no further optioneering is required. While there is a structural option in progress other FRM methods were identified at UoM level (see section 8.1) to be included, along with maintaining the existing regime:

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



### 8.10.1.1 AFA Sensitivity to Future Change

During a MRFS 0.5% AEP tidal flood event in New Ross the increase in flood extent is significant as flood waters overtop existing defences where low crest levels are present. This would result in an additional 128 properties being at risk. The flood risk identified is located along both banks to the River Barrow throughout the AFA as shown in Figure 8.10.1.1.1.1.1.1.

During a MRFS 1% AEP fluvial flood event the increase in flood extent is significant as the River Barrow widens and flows through the flood plains in and around the New Ross AFA. This would result in an additional 91 properties being at risk. The main area of additional flood risk is shown in Figure 8.10.1.1.1.1.1.2.

The AAD would increase from €72,771 to €2,244,762.

During a HEFS 0.5% AEP tidal flood event in New Ross the increase in flood extent is significant as flood waters overtop existing defences where low crest levels are present. This would result in an additional 169 properties being at risk. The flood risk identified is located along both banks to the River Barrow throughout the AFA as shown in Figure 8.10.1.1.1.1.1.1.

During a HEFS 1% AEP flood event the increase in flood extent is significant as the River Barrow widens and flows through the flood plains in and around the New Ross AFA. This would result in an additional 165 properties being at risk. The main area of additional flood risk is shown in Figure 8.10.1.1.1.1.1.2.

The AAD would increase from €72,771 to €27,090,956.

There is a significant increase in the number of properties and hence the AAD therefore the New Ross AFA would be considered to be at high vulnerability.

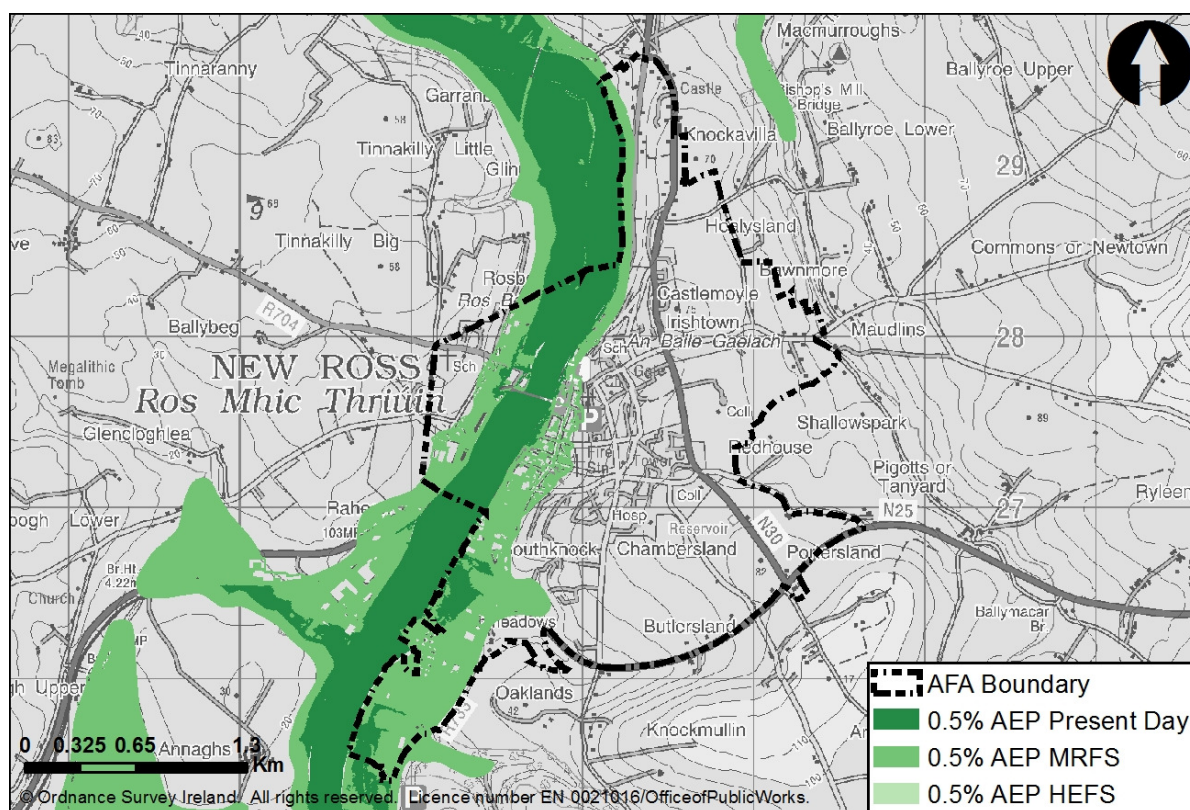


Figure 8.10.1.1.1.1.1.1

New Ross Coastal Future Change Flood Extents

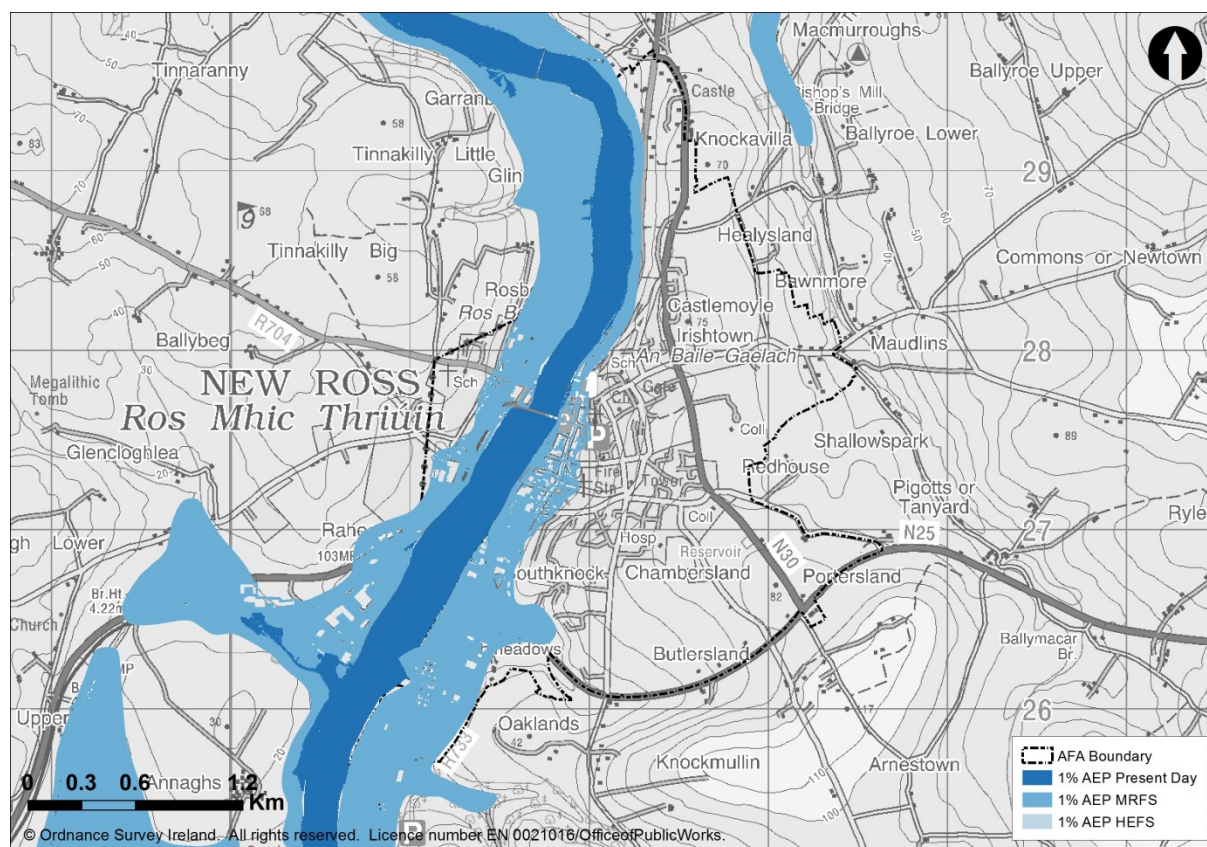


Figure 8.10.1.1.1.1.1.2

New Ross Fluvial Future Change Flood Extents

### 8.10.1.2 Local Authority Comments

Wexford County Council provided details on the planned flood defence scheme for New Ross in November 2015 in order to ensure all properties identified under CFRAMs would be protected by New Ross.

### 8.10.1.3 Summary

There is moderate confidence in both the hydrology and hydraulics of the New Ross AFA as there are no gauges within the model domain. A limited verification exercise has been undertaken based on the data available, however due to the lack of data full calibration is not possible. Despite the lack of calibration and verification data, the model is considered to be performing satisfactorily for design event simulation.

Due to the approved flood defence scheme there is no unmanaged present day flood risk associated with the New Ross AFA during the preferred SoP event, however, future change assessment identified that New Ross AFA is sensitive to climate change and other potential future changes to the hydrological regime.

As no risk was identified in the New Ross AFA the existing and future flood extents should be considered for any proposed planning and development.

Methods also were identified at UoM level (see section 8.1) that are applicable to New Ross 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

There are no AFAs located downstream which should be taken into consideration for any future works carried out in New Ross. Graiguenamanagh is located upstream of New Ross however any changes in water levels from option in New Ross would be negligible.

No unmanaged flood risk was identified in New Ross AFA due to an approved flood relief scheme currently being implemented however the existing regime should be maintained to retain the required SoP.

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

## 8. OPTIONEERING OF SSA'S

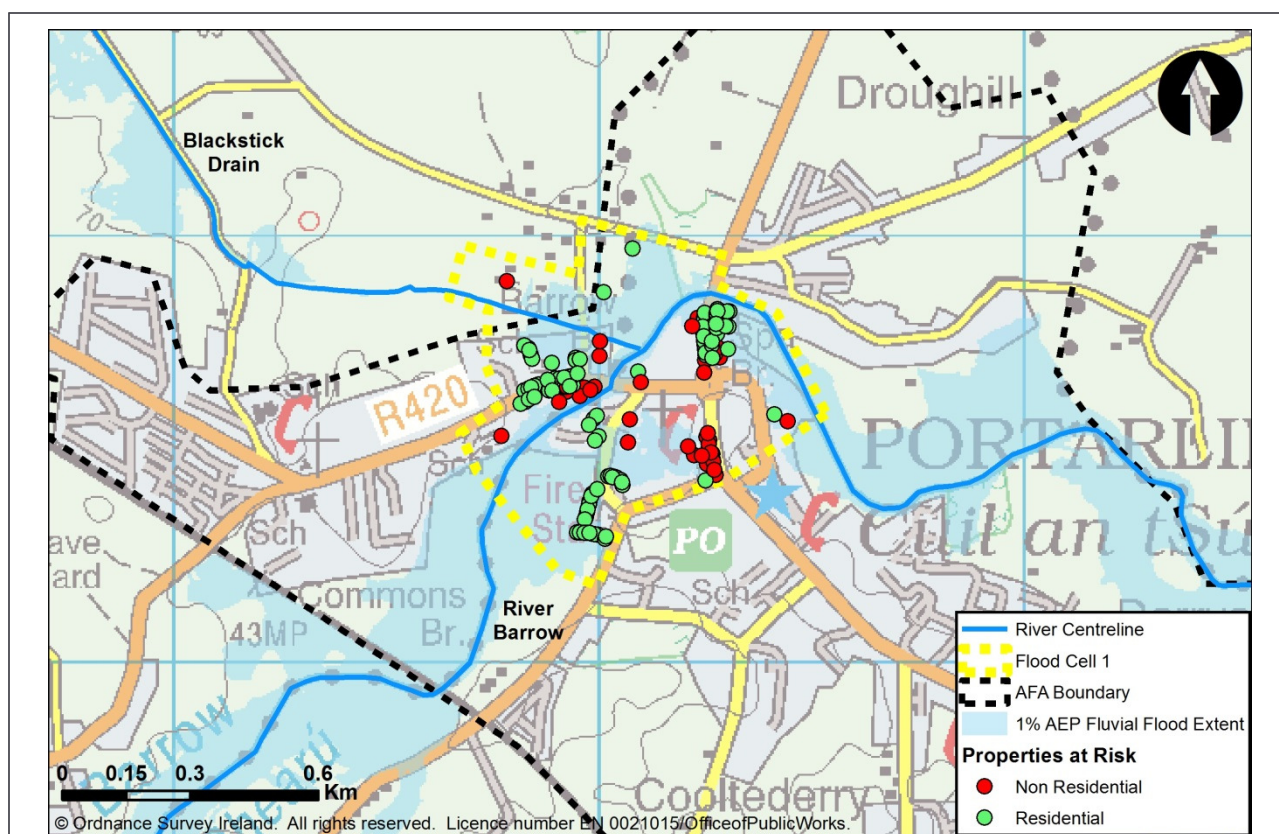
### 8.13 Portarlinton Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Portarlinton	Laois	140173	AFA	Final	15/06//2016

#### 8.11.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.11.2 Flood Cells



**Figure 8.11.2.1.1.1.1.1 Portarlinton AFA Flood Cells within a 1% AEP Fluvial Flood Extent**

#### Flood Cell 1:

Out of bank flooding occurs during the 1%AEP fluvial flood event, on both banks of the River Barrow as it passes through Portarlinton. A number of properties are affected as the channel has insufficient capacity to convey the 1% AEP flow. Properties are also affected at the downstream extent of the Blackstick Drain due to a back water effect from the River Barrow. Given that 145 properties are affected flood cell 1 is considered complex.

### 8.11.3 Existing Regime

The 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 within Portarlington are located within a Drainage District. Further details of operations in this district are presented in section 6.3

Other watercourses are, for the most part, in private lands and are not the responsibility of Laois County Council although they carry out ad-hoc maintenance to the river where resources allow. The existing regime does not provide the preferred SoP.

### 8.11.4 Summary of Flood Risk within SSA boundary

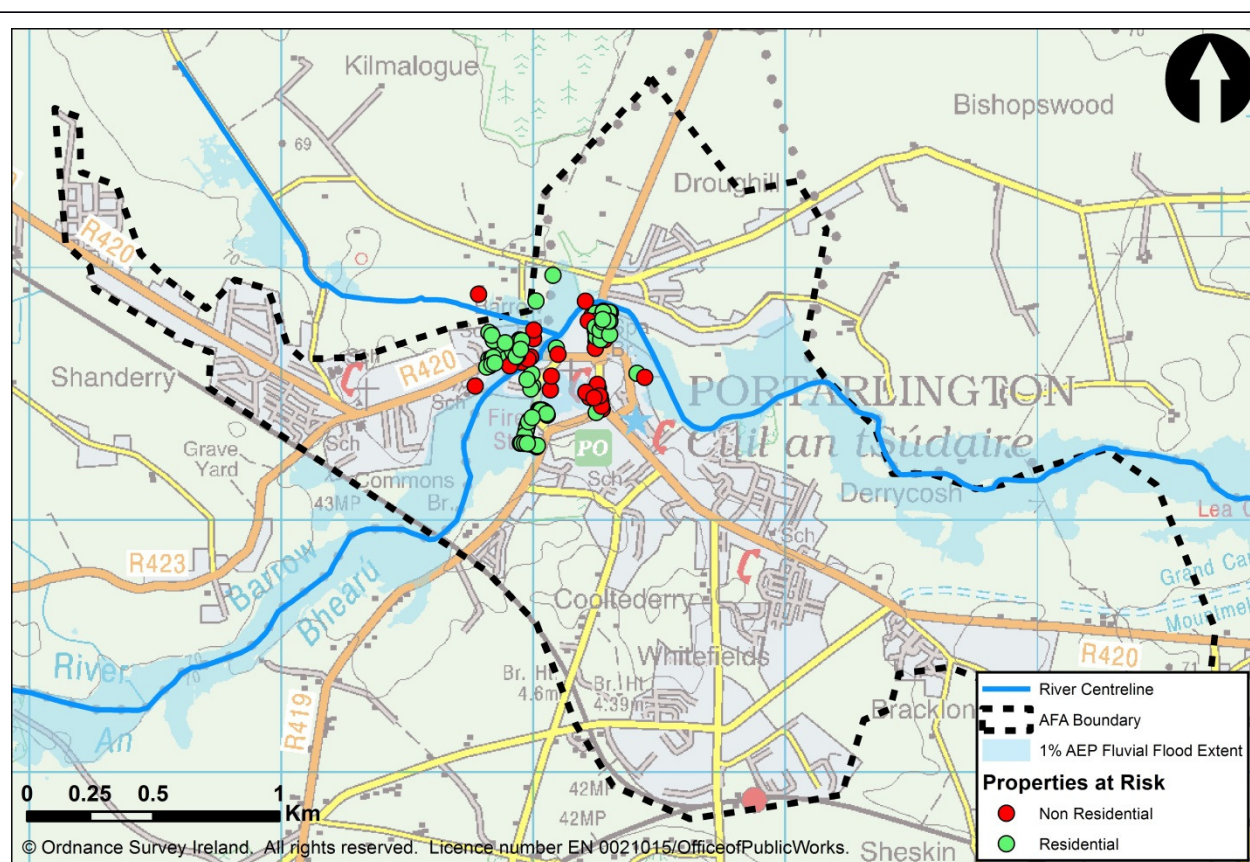


Figure 8.11.4.1.1.1.1.1

Flood risk in Portarlington AFA within a 1% AEP Fluvial Flood Extent

In Portarlington AFA the onset of residential and non-residential property damage occurs in the 50% AEP event.

### 8.11.5

**8.11.6 Monetary Damage and Benefit**

	Flood Cell 1	Total in AFA
Annual Average Damage (AAD)	€1,198,496	€1,213,295
Present Value Damage (pvD)	€25,746,082	€26,063,992
Preferred Standard of Protection (SoP)	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	144	144
Minimum Present Value Benefit	€22,109,882	€22,109,882
Capped Minimum Present Value Benefit	€13,624,398	€13,624,398

\*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.

**8.11.7 Short Listing FRM Methods – Complex Cell**

Method	Review Comment	Continue Screening
		Flood Cells 1
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	✓



8.11.7.1 Feasibility Review Summary for Complex Cell (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				
8.11.7.2 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 therefore was rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional Maintenance	✗			
This method considers whether improvements can be made to augment the 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	x			

This method can include clearance of channels and is also 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 are no obvious locations where the do minimum method would greatly reduce flood risk. Additional channel clearance would have minimal impact on the overall flood risk due to the distributed location of receptors. This is an unacceptable outcome in terms of contributing to achieving a 1% AEP standard of flood protection and this method was therefore rejected from the screening process.

Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the large size of the catchments the method is considered unsuitable to benefit flood cell 1. This method is technically unfeasible.

Method	Tech	Econ	Env	Soc
Storage	x			

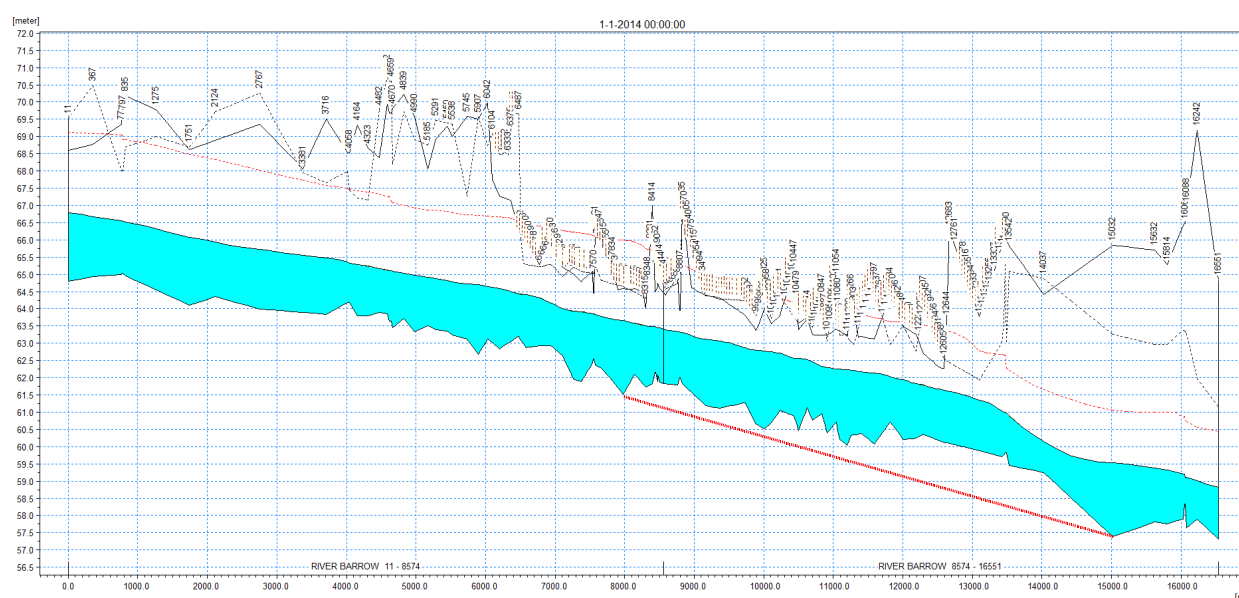
This method considers areas where flood water can be stored and then released at a controlled rate therefore reducing the flow rate through the AFA and reducing the level of flood risk. This can be achieved by using existing depressions to create online or offline storage areas or by identifying pinch 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 to identify potential flood storage areas however the volume of water required to be stored on the River Barrow before reaching flood cell 1 is too large to be attenuated upstream. A storage area could be located on the Blackstick Drain to reduce the flow on this tributary however the River Barrow backs up into the watercourse and is the flooding source which is putting properties at risk. This method is therefore considered technically unfeasible.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed levels, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse, reducing roughness of the channel and sealing manholes. A review of the various FRM method techniques, as listed above, was carried out for flood cell 1 and the following techniques were found to be the most appropriate way to implement this method.

Flood cell 1 covers Portarlinton town centre which is affected by high water levels in the River Barrow. A review of the river profile was carried out identifying all high points in the river bed which would require lowering (River Barrow Long Section is shown in Figure 8.11.7.2.1.1.1.1.1). The Portarlinton hydraulic model was used to identify the required cross sectional area of the River Barrow channel needed to convey the 1% AEP flow, and indicated that in some places this would require the bed level to be lowered by 1.4m. This method would require 6.8km of the River Barrow to be dredged and widened (or sheet piling used where banks could not be sloped), requiring approximately 214,106m<sup>3</sup> to be excavated. An economic review estimated the cost of excavation to be approximately €19.7m with additional cost to underpin three bridges, this method is therefore economically unviable.

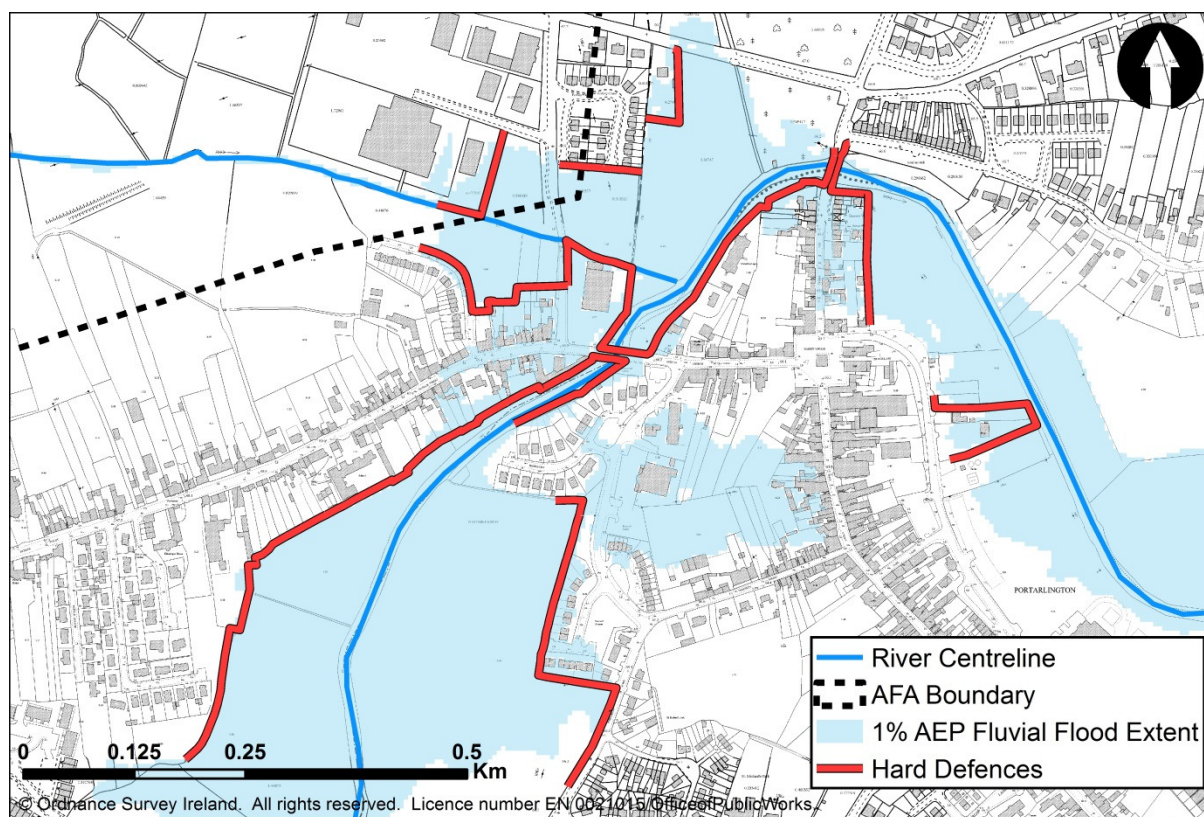


**Figure 8.11.7.2.1.1.1.1 Long section of River Barrow**

Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	?	✓

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 properties within flood cell 1. Figure 8.11.7.2.1.1.1.2 shows the location of the Hard Defences required to protect properties during the 1% AEP event.



**Figure 8.11.7.2.1.1.1.2 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 properties to the 1% AEP flood event with an average height of 1.6m and a total length of 3.3km. An economic review estimated the cost of the hard defences to be approximately €5.7m making this method economically viable.

The River Barrow and Nore SAC is within, upstream and downstream of Portarlington. The Mountmellick SAC is 5km to the south west of Portarlington, however it is not hydraulically linked to the AFA. FRM Methods have been placed outside the designated areas where possible.

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 clusters of properties are located.

The cost to relocate the affected properties in flood cell 1 to an area of lower risk would be €68m making this method economically unviable.

Method	Tech	Econ	Env	Soc
Diversion of Flow	x			
<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 is therefore considered technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x	✓	✓	✓
<p>This method is considered in section 8.1 at UoM scale. The screening found flood warning/forecasting to be technically feasible on the River Barrow for Portarlinton and could provide approximately 6hrs warning. With this warning time available it is estimated that some flood damage would be avoided; however as this method can only provide partial protection it should only be reviewed if all other methods are deemed unsuitable later in the optioneering process.</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>A review was carried out of the possibility of Individual Property Protection for flood cell 1. The cost of applying this method would be €2.1m making it economically viable. However, this method would not provide the required SoP so would not be technically the best method to use.</p> <p>This method is unlikely to have any negative environmental or social impacts. Individual Property Protection should only be considered if no other FRM method passes through the optioneering process.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for these flood cells				



### 8.11.7.3 Summary of Feasibility Review – Flood Cell 1

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

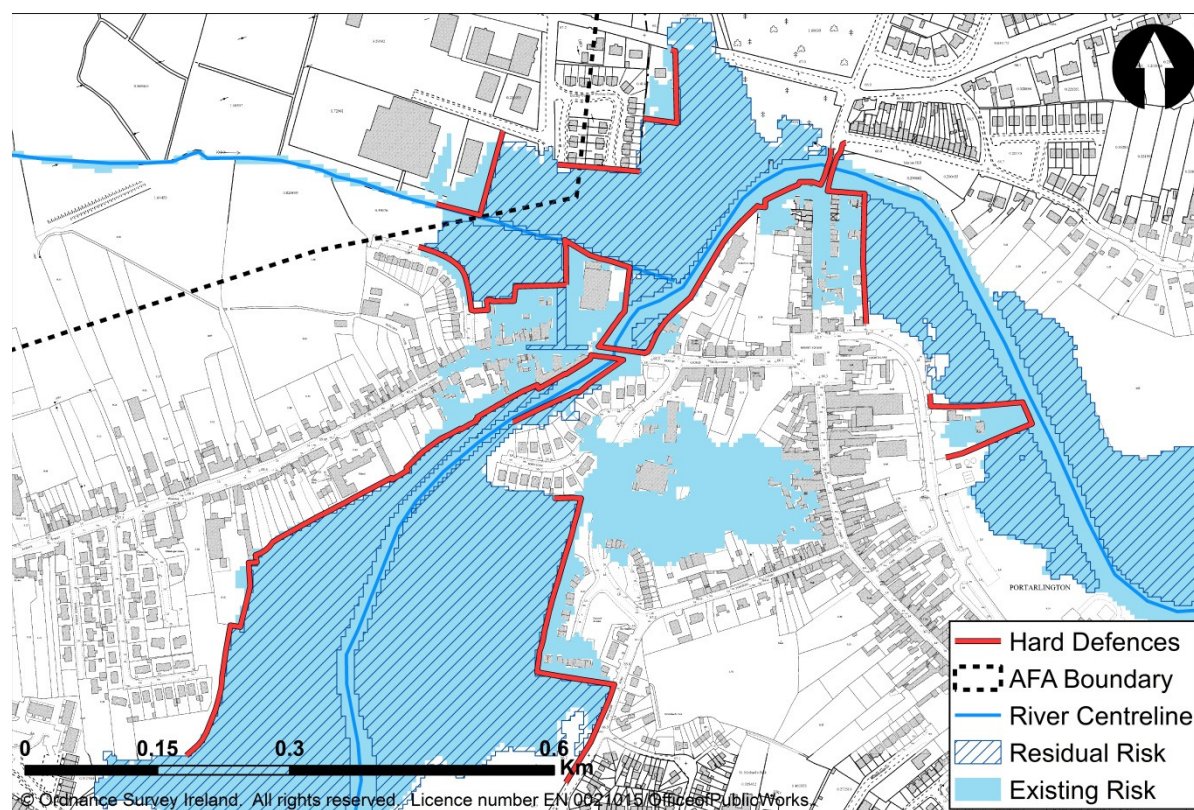
- Hard Defences

Neither Flood Warning/Forecasting or Individual Property Protection provide the required SoP and should therefore only be used if other methods are deemed unsuitable later in the optioneering process. Consequently, hard defences are the preferred method and are carried forward to address the flood risk arising from flood cell 1.

### 8.11.8 Selection of Options

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

#### 8.11.8.1 Option 1 Details - Hard Defences



**Figure 8.11.8.1.1.1.1.1 Portarlington AFA Option 1**

At risk properties would be protected by a series of flood embankments, walls and one section of road raising. These hard defences would protect to the 1% AEP flood event with an average height of 1.6m and a total length of 3.23km.

Figure 8.11.8.1.1.1.1.1.1 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).

The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Wall	702m length, 1.9m high (average)	€1,477,139	
Embankment	2377m length, 1.6m high (average)	€763,803	
Road Raise	151m length, 1.4m high (average)	€141,034	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
664	5.56	119.49	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€26.063.992	€5.560.037	€13.624.398	2.45

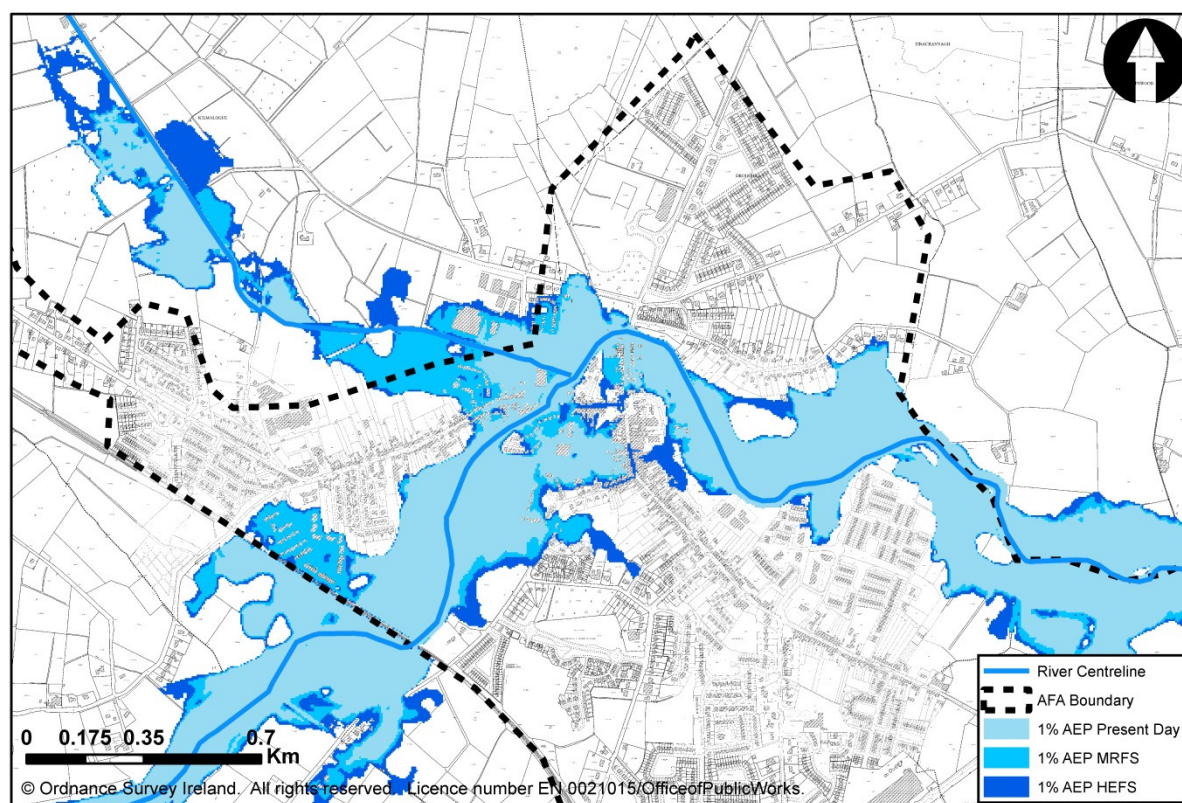
### 8.11.1.2 AFA Sensitivity to Future Change

As shown in Figure 8.11.1.2.1.1.1.1.1, during a MRFS 1% AEP flood event the increase in flood extent is substantial due to the surrounding topography. Approximately an additional 186 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €1,213,295 to €12,853,496. As a result Portarlington AFA would be considered to be at high vulnerability from the MRFS.

During the HEFS 1% AEP flood event the flood extent, substantial also. An additional 277 properties are estimated to be at flood risk when compared to the present day flood risk. The AAD would increase from €1,213,295 to €25,016,743. As a result Portarlington AFA would be considered to be at high vulnerability from the HEFS.

The main area of additional flood risk is in the town centre and at the Riverside Housing Estate.

The large number of additional properties affected by future scenarios indicates a significant increased to the annual average damage and the Portarlington area of assessment would be considered to be at high vulnerability. Options should therefore be assessed to their adaptability to climate change.



**Figure 8.11.1.2.1.1.1.1.1 Future Change Flood Extents (Flood Cell 1)**

#### 8.11.1.4 Future Change Adaptability

The following discusses the adaptability of the potential FRM **methods** proposed in Portarlinton SSA:

**Hard Defences Flood Cell 1** - This method could be adapted by increasing the height of the hard defences and extending their length. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from an average of 1.6m to a max of 3m and 3.4m respectively. Given that the proposed average height of the wall would be over 3m in some cases this addition could not be accommodated. The review also showed that the additional length of wall preferred would be minimal. To ensure that this wall would be adaptable the design would need to account for the potential increase on wall height. This method is considered to have a **not adaptable**.

The potential **option** identified has 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 these methods other methods aimed at reducing future flood risk has been discussed in section 8.1 at UoM scale. These methods will reduce the vulnerability of potential future receptors. Given that Portarlinton has some rural areas these methods could have an impact to overall area. Given that 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. This is most relevant to options with methods with poor adaptability, such as option 1.
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 adaptable to the MRFS and HEFS. However alternative FRM methods could be added to the option 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, and the potential impacts of climate change. Based on this future change adaptability assessment the table below summarises how well each option achieves this objective.

#### Summary of Option Adaptability

Option	Description	Score
Option 1 – Hard Defences (FC 1)	Hard defences has been screened for Flood Cell 1 as not adaptable however only 100m of hard defences would be over the required 3m height. The rest of the hard defences (3km) within the option are adaptable at moderate to significant cost, difficulty and impact.	2



#### 8.11.1.5 Local Authority Comments

A report by JBA consulting (Portarlinton Flood Risk and Management Strategy Jan 2007) has provided an option for combined hard defences with conveyance (both in channel and on floodplain) aimed at providing protection to zoned but undeveloped land. This report has been reviewed but as it is not the aim of CFRAMs to protect zoned areas the optioneering differs from the JBA report.

#### 8.11.1.6 Summary

There is good confidence in both the hydrology and hydraulics of the Portarlinton AFA due to the presence of a gauging station and flood extent verification events.

The following potential options, with a BCR  $\geq 0.5$  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 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 Portarlinton 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

Communities are located upstream and downstream of the Leighlinbridge AFA that could be affected by the potential option identified. The flows at the model boundaries were reviewed for the 1% AEP current scenario versus the 1% AEP with the option in place scenario. There is negligible flow differences between the hydraulic model simulations. In addition any interactions with the drainage system in the urbanised area may need to be addressed during the development of the preferred option.

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 assumptive 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

### 8.14 Portlaoise Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Portlaoise	Laois	140174	AFA	Final	15/06/2016

#### 8.12.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.12.2 Flood Cells

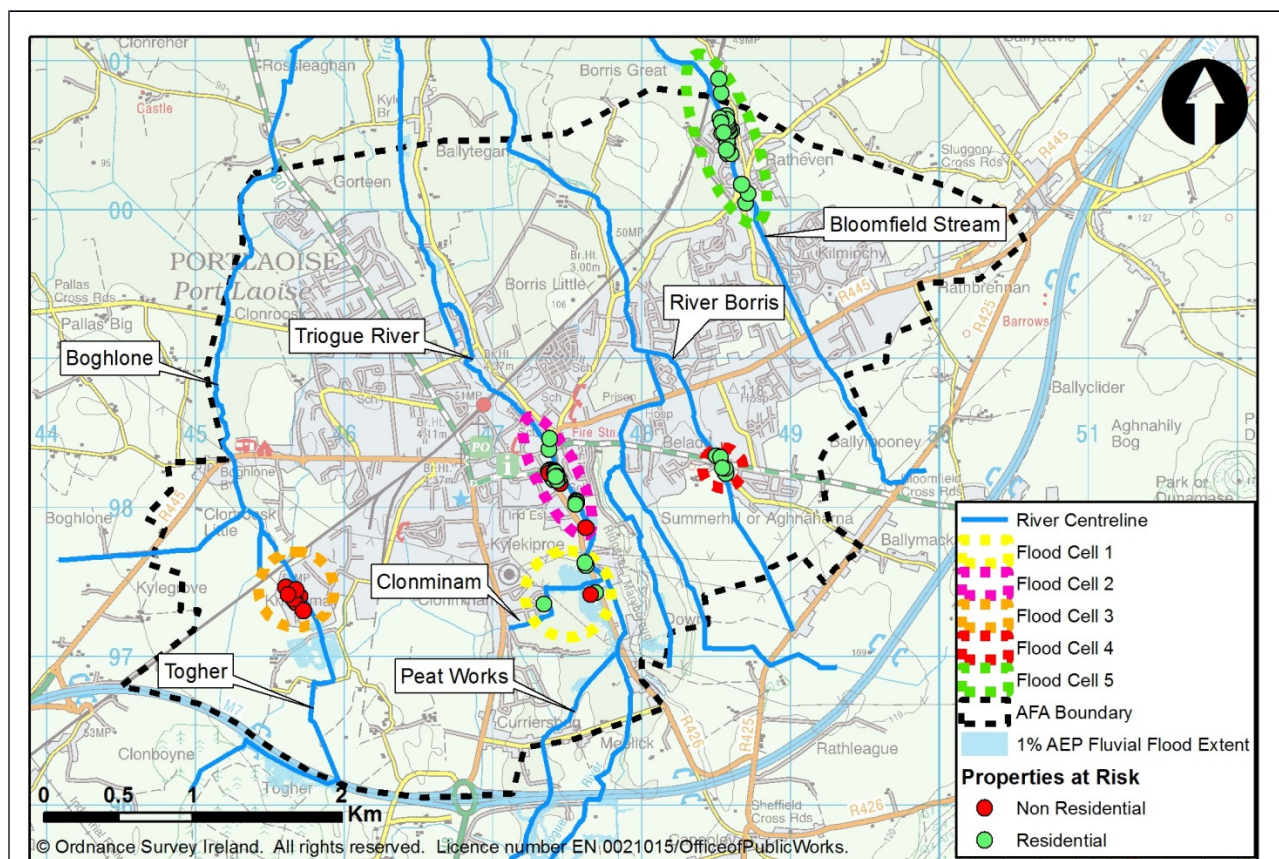


Figure 8.12.2.1.1.1.1.1

Portlaoise AFA Flood Cells within a 1% AEP Fluvial Flood Extent

#### Flood Cell 1:

Out of bank flooding would occur around the confluence of the Clonminam watercourse and the Triogue River during a 1% AEP flood event. The cause of the flooding is fluvial flow in both the Triogue River and the Clonmanin watercourse exceeding channel capacity, particularly due to the capacity of a number of culverts and bridges along both watercourses being exceeded. 5 properties would be affected by flooding during a 1% AEP flood event. Given that flood cell 1 is affected by out of bank flooding from two different watercourses with interaction between the floodplain flows, and as the flood risk in flood cell 2 just downstream is likely to be dependent, flood risk in flood cell 1 is considered complex.

**Flood Cell 2:**

On the Triogue River downstream of flood cell 1 a number of properties along New Road / Well Road would be affected by out of bank flooding in the 1% AEP event. This out of bank flooding is exacerbated by a number of bridge structures the capacity of which is exceeded during the 1% AEP event. It is estimated that 30 properties would be affected by flooding during a 1% AEP flood event the majority of which are located at Rankin's Wood. Given that the flooding in flood cell 2 is likely to be dependent on the flood risk in flood cell 1, flood risk in flood cell 2 is considered to be complex.

**Flood Cell 3:**

Flood cell 3 represents the flood risk emanating from out of bank flooding on the Togher watercourse. It is estimated that seven properties within the Clonminam Industrial Estate would be affected in the 1% AEP event. Out of bank flooding would occur upstream of a culvert under the industrial estate and involves out of bank flooding on the left bank of the watercourse which affects properties within the industrial estate. As the mechanism is as a result of capacity at the culvert being exceeded and is not dependent on the flood risk at other cells, flood risk in flood cell 3 is considered local.

**Flood Cell 4:**

Flood cell 4 represents the flood risk from out of bank flooding on the River Borris. It is estimated that five properties located around the junction of Summerhill Lane / Beladd Lower and the Stradbally Road (N80) would be affected in the 1% AEP event. Out of bank flooding occurs at the upstream face of the culvert under Summerhill Lane where the capacity is exceeded by events larger than the 2% AEP event. As the mechanism is totally a consequence of the capacity at the culvert being exceeded and is not dependent on the flood risk at other cells, flood risk in flood cell 4 is considered local.

**Flood Cell 5:**

Flood cell 5 on the Bloomfield Stream represents the flood risk to the area around Colliers Lane, Rathevan View and Rathevan Heights. Up to 29 properties are affected at various locations along the watercourse. This out of bank flooding is exacerbated by a number of culvert structures the capacity of which is exceeded during the 1% AEP event. The flood risk is due to a number of restrictions along the watercourse but is not dependent on flooding at any other flood cells. Given the number of properties at risk in flood cell 5 it is considered a complex flood cell.

**Summary of Flood Cells:**

As shown in Figure 8.12.2.1.1.1.1.1 a large portion of the flood risk originates from the Triogue River and just upstream on one of its tributaries, the Clonminam watercourse. These areas of flood risk are covered by flood cells 1 & 2. 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 8.12.6).

Flood cells 3, 4 & 5 are discrete areas with a single flood mechanism at each to consider. It is therefore appropriate to screen these flood cells as standalone areas assessing options applicable to localised works. (section 8.12.7)

On completion of the optioneering screening assessment all flood cells will be combined to form complete options for the Portlaoise AFA as detailed in section 8.14.8.

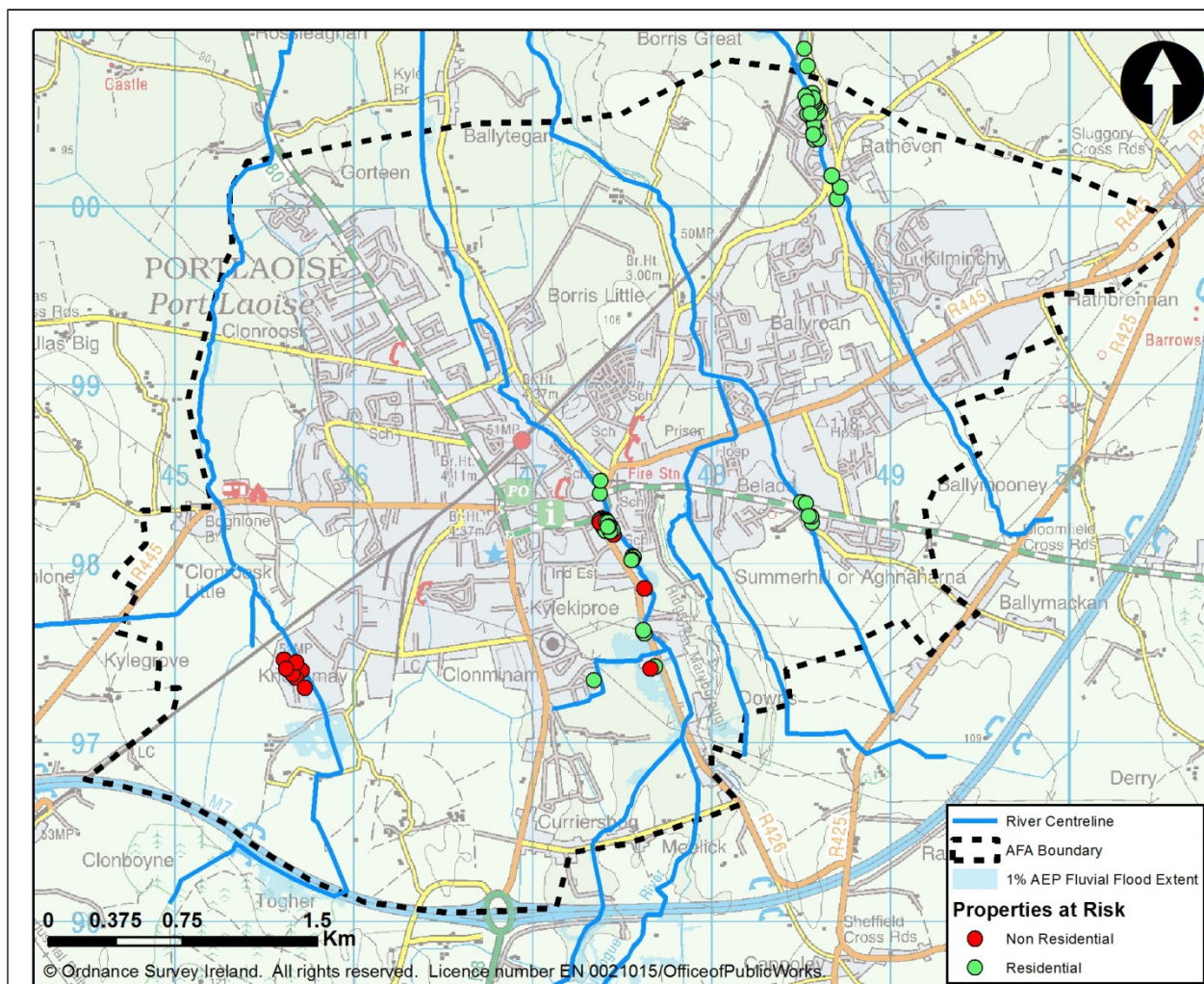
**8.12.3 Existing Regime**

The 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 Portlaoise watercourses are not located within a Drainage District or an Arterial Drainage scheme. They are, for the most part, in private land and are not the responsibility of Laois County Council. Nevertheless, inspections and maintenance are carried out as and when resources are available.

#### 8.12.4 Summary of Flood Risk within SSA boundary



**Figure 8.12.4.1.1.1.1.1 Flood risk in Portlaoise AFA within a 1% AEP Fluvial Flood Extent**

In Portlaoise AFA the onset of non-residential property damage occurs in the 10% AEP event in flood cells one and two, 1% AEP in flood cell three, 2% AEP in flood cell four and 5% AEP in flood cell five. Flooding commences at residential properties in flood cells one and two in the 50% AEP event. There are no residential properties in flood cells three, four and five within this AFA.

#### 8.12.5 Monetary Damage and Benefit

	Flood Cells 1 & 2	Flood Cell 3	Flood Cell 4	Flood Cell 5	Total in AFA
Annual Average Damage	€109,399	€40,519	€3,348	€116,380	€311,012

(AAD)					
Present Value Damage (pvD)	€2,350,111	€870,422	€71,924	€2,500,071	€6,681,152
Preferred Standard of Protection (SoP)	1% AEP	1% AEP	1% AEP	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	35	7	5	29	76
Minimum Present Value Benefit	€1,152,918	€248,689	€34,337	€2,004,729	€3,440,673
Capped Minimum Present Value Benefit	€1,047,577	€248,689	€34,337	€2,004,729	€3,335,332

\*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.

**8.12.6 Short Listing FRM Methods – Complex Cells (1 & 2, 5)**

Method	Review Comment	Continue Screening	
		Flood Cells 1 & 2	Flood Cell 5
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	✓	✓

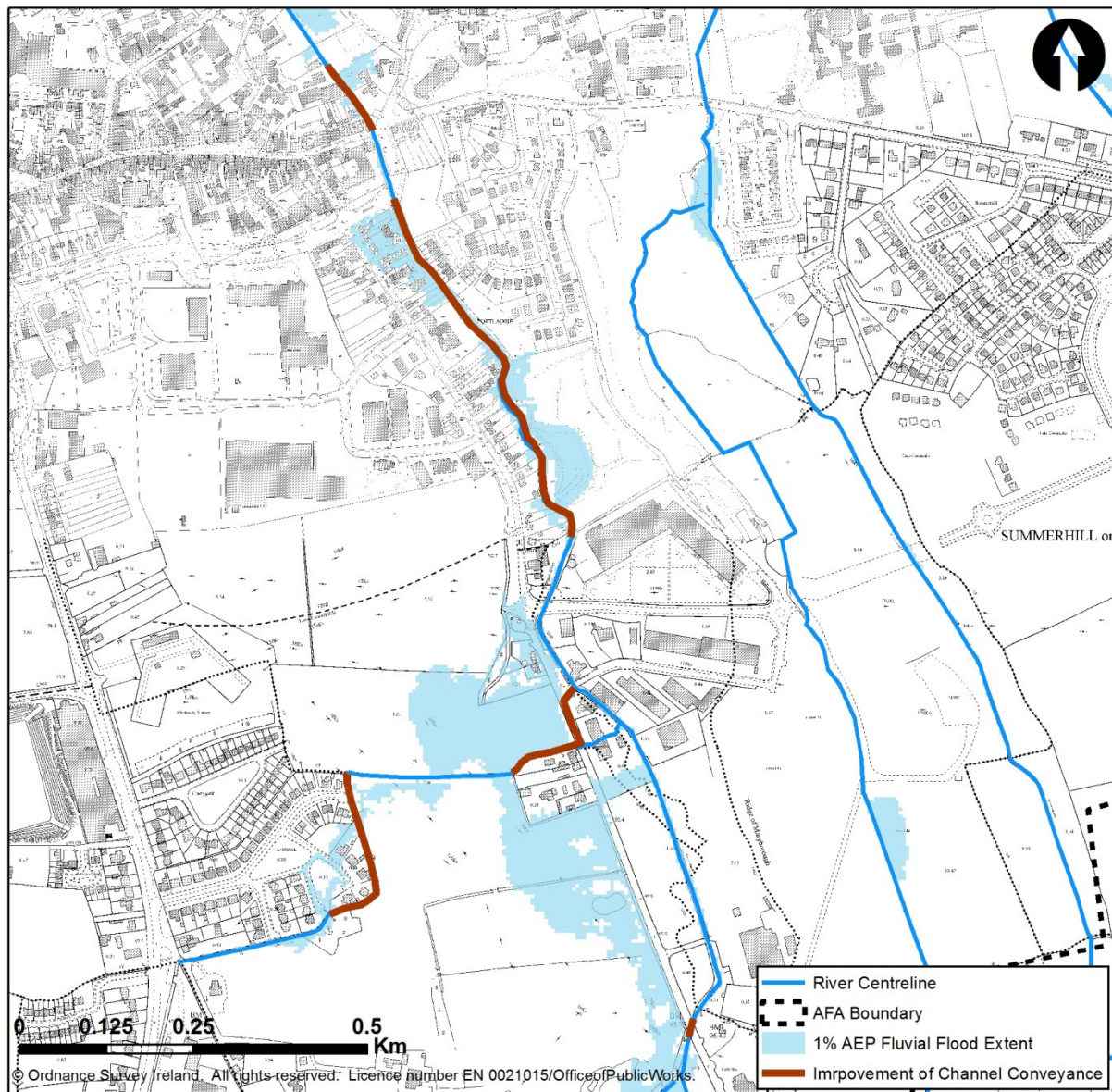


8.12.6.1 Feasibility Review Summary for Complex Cells (flood cells 1 & 2)				
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	Social Screening
Do nothing	✓			
Additional Maintenance	✗			
Do Minimum	✗			
Land Use Management	✗			
Storage	✗			
Improvement of Channel Conveyance	✗	✓		
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				
8.12.6.2 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 the 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	x			
<p>This method can include clearance of channels and is also 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 cells 1 &amp; 2 there are several locations where the watercourses flood out of bank due to a flow constriction. As such there is no opportunity to significantly alleviate the flood risk through minimal works. This is an unacceptable outcome in terms of contributing to achieving a 1%AEP standard of flood protection and this method was therefore rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	x			
<p>The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in catchments the method is considered unsuitable to benefit flood cells 1 &amp; 2. This method is technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Storage	x			
<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 reducing 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> <p>The volume of water required to be stored on the Triogue River before reaching flood cells 1 &amp; 2 has been estimated to be 217,840m<sup>3</sup>. A review of the topography of the catchment upstream of Portlaoise was undertaken to establish if this storage volume could be provided. The Triogue catchment is relatively steep upstream of the AFA and this volume of storage could not be found upstream unless it was provided behind a dam (a structure height above 4m on the Triogue River). The largest single area which could be found below an impoundment height of 3.4m (allowing for 600mm freeboard) was 71,227m<sup>3</sup>. A review of the topography upstream of flood cell 1 on the Clonminam watercourse was also undertaken to assess if storage was available to reduce the flood risk from this watercourse (i.e. partial protection). The topography was found not to lend itself to the creation of a storage area and the storage area could only be located at a point upstream where the total flow in the watercourse is less than the reduction in flow required downstream such that the Standard of Protection could not be provided. As such the Storage FRM method is deemed technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	x	✓		

This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed levels, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse, reducing roughness of the channel and sealing manholes. A review of the various FRM method techniques, as listed above, was carried out for flood cells 1 and 2 and the following techniques were found to be the most appropriate way to implement this method.

Flooding within flood cell 1 and 2 is caused by a number of constrictions and reduced channel capacity. The sections of watercourse which would require improved conveyance are shown in Figure 8.12.6.2.1.1.1.1.1.



**Figure 8.12.6.2.1.1.1.1 Location of Channel Improvement**

Improving the channel conveyance through flood cells 1 & 2 would be complex given the number of structures and the confined nature of the watercourse within an urban area. A review of the channel capacity was undertaken and it was estimated that the channel generally would need to be widened to approximately 4m wide. A summary of the works which would be required follows:

- 120m of channel widening / excavation on the Triogue from Bridge Street downstream.
- 580m of channel widening / excavation on the Triogue from Portlaoise Retail Park to James

Fintan Lalor Avenue (N80)

- Underpinning of four single span bridges, a total length of 58m
- A new 1.2m x 5.1m wide box culvert under James Fintan Lalor Avenue (N80)
- A new 6m clear span road bridge where the Triogue River passes under Well Road (R426) to the south of the town
- 454m of new 1.2m diameter culvert on the Clonminam watercourse

The total estimated cost of these works is €6.1m and as such this method is not considered economically viable.

Method	Tech	Econ	Env	Soc
Hard Defences	x	✓	!	✓

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 cells 1 & 2. Figure 8.12.6.2.1.1.1.2 shows the location of the Hard Defences required to protect properties during the 1% AEP event.

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 0.8m and a total length of 1.6km. An economic review estimated the cost of the hard defences to be approximately €2.6m making this method economically viable.

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.



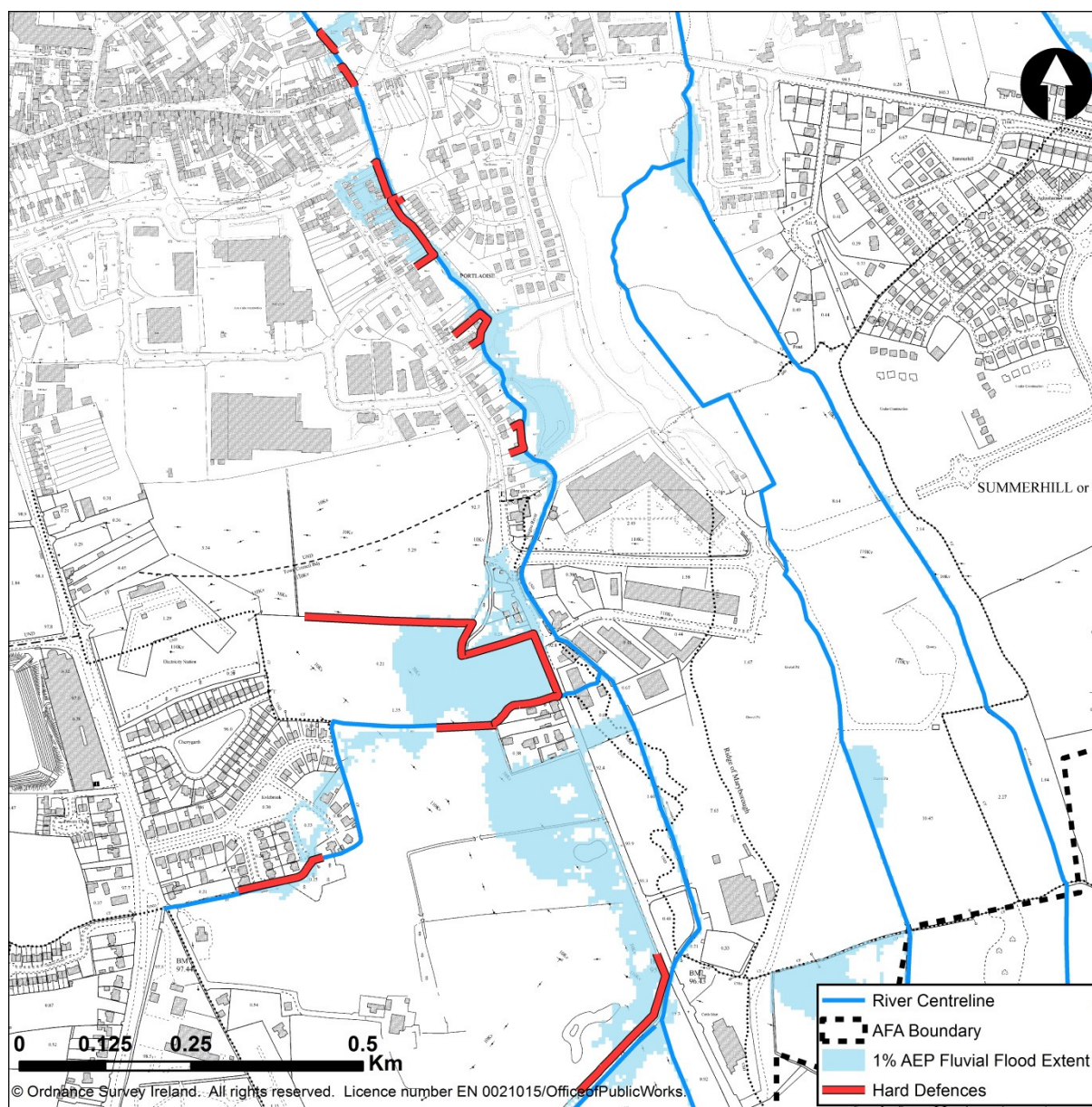


Figure 8.12.6.2.1.1.1.2

Location of Hard Defences in flood cells 1 &amp; 2

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 clusters of properties are located.

There are 35 properties at risk during the 1% AEP event in flood cells 1 and 2, which could be relocated. The cost to relocate all properties, based on the market value, is €15,356,843 which is uneconomically viable and therefore this method was removed from the screening process.



Method	Tech	Econ	Env	Soc
Diversion of Flow	x			
<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 cells 1 &amp; 2. The Triogue River takes a relatively direct path through the AFA. To divert the watercourse away from properties would require diversion of this large watercourse around the AFA, crossing the paths of a number of different watercourses, major roads and railway lines and requiring massive cut and fill to facilitate the new channel. This is not considered technically feasible given the complexity of the works required.</p>				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			
<p>The application of flood warning/forecasting was tested at UoM scale. A suitable location far enough upstream of flood cell 2 is available to provide sufficient warning. However there is no suitable location far enough upstream of flood cell 1 to provide sufficient warning. Therefore this method is technically unviable.</p>				
Method	Tech	Econ	Env	Soc
Individual Property Protection	x	✓	✓	✓
<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>While this method would not provide the required design 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 the pass through the screening process. An economic review estimated that the cost of providing individual property protection for 35 properties (33 requiring manual protection and 3 requiring automatic protection) would be approximately €581,788. This method is therefore economically viable.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✓			
<p>No other works were identified for flood cells 1 and 2.</p>				
8.12.6.3 Summary of Feasibility Review – Flood Cells 1 & 2				
<p>The following FRM method has been carried forward to address the flood risk arising from flood cells 1 &amp;</p>				

2;

- 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.

Neither Flood Warning/Forecasting or Individual Property Protection provide the required SoP and should therefore only be used if other methods are deemed unsuitable later in the optioneering process. Consequently, hard defences are the preferred method and are carried forward to address the flood risk arising from flood cells 1 & 2.

8.12.6.4 Feasibility Review Summary for flood cell 5				
Method	Technical Screening	Economic Screening	Environmental and Cultural	Social Screening
Do nothing	x			
Additional Maintenance	x			
Do Minimum	x			
Land Use Management	x			
Storage	x	✓	!	✓
Improvement of Channel Conveyance	✓	✓	!	✓
Hard Defences	✓	✓	!	✓
Relocation of properties	✓	✓		
Diversion of Flow	x			
Flood Warning/Forecasting	x			
Individual Property Protection	x	✓	✓	✓
Other Works	✓			
x - Reject    x - Progress    ? - Progress, potential for impacts identified    ! - Progress, potential for significant impacts identified				
8.12.6.5 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	x			
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	x			

Within flood cell 5 there is little opportunity to improve the conditions in the Bloomfield Stream and therefore little scope to reduce the overall flood risk due. This is an unacceptable outcome in terms of contributing to achieving a design SoP and this method was therefore rejected from the screening process.

Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in catchment the method is considered unsuitable to benefit flood cell 5. This method is technically unfeasible.

Method	Tech	Econ	Env	Soc
Storage	x	✓	!	✓

The volume of water required to be stored on the Bloomfield Stream before reaching the at risk properties in flood cell 5 has been estimated to be 97,543m<sup>3</sup> based on a reduction of the 1% AEP flow at the flood cell to the equivalent of a 10% AEP peak flow, the largest event at which properties are not impacted. A review of the surrounding land was carried out and two potential storage areas were identified upstream of the town to the south east of the Carrick Hill area. These potential storage areas have useable storage volumes behind a maximum impoundment height of 4m (3.4m useable height plus 0.6m freeboard) of 20,008m<sup>3</sup> and 39,277m<sup>3</sup> respectively. Neither of these storage areas could provide the required storage however a review of the first storage area indicated that the area may be suitable for providing increased storage if the area was excavated. This storage area is located just upstream of Carrick Hill and has a narrow mouth set within a defined valley in the topography consequently any impoundment structure would be relatively short. The location of this potential storage area is shown in Figure 8.12.6.5.1.1.1.1.1.

In order to provide the required storage approximately 80,000m<sup>3</sup> of material would need to be excavated and a 140m embankment up to 4m in height constructed to retain the required storage volume. A flow control culvert and an overtopping weir would also be required bringing the estimated cost to provide this method at flood cell 5 to €1.28m which is economically viable.

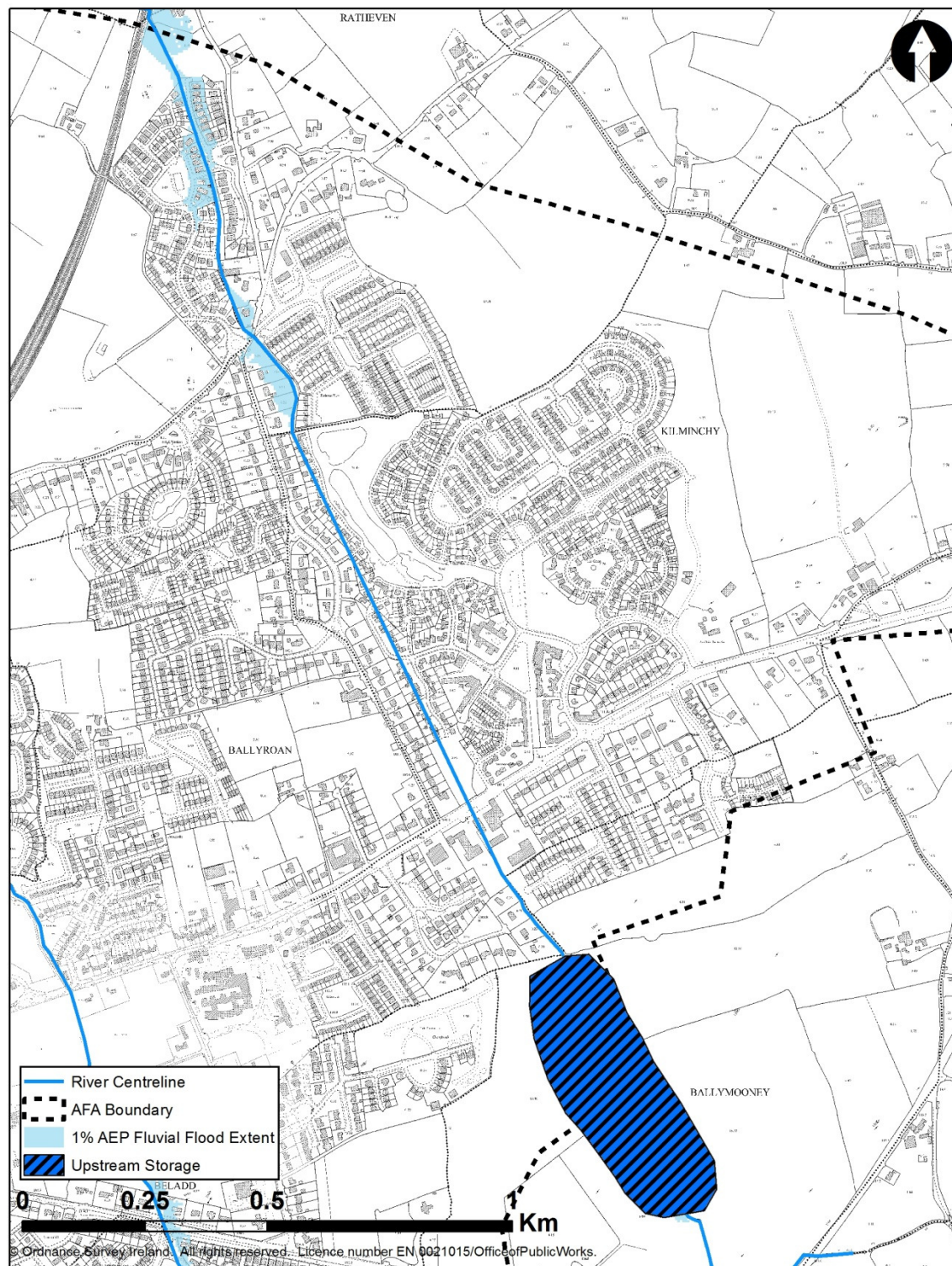


Figure 8.12.6.5.1.1.1.1

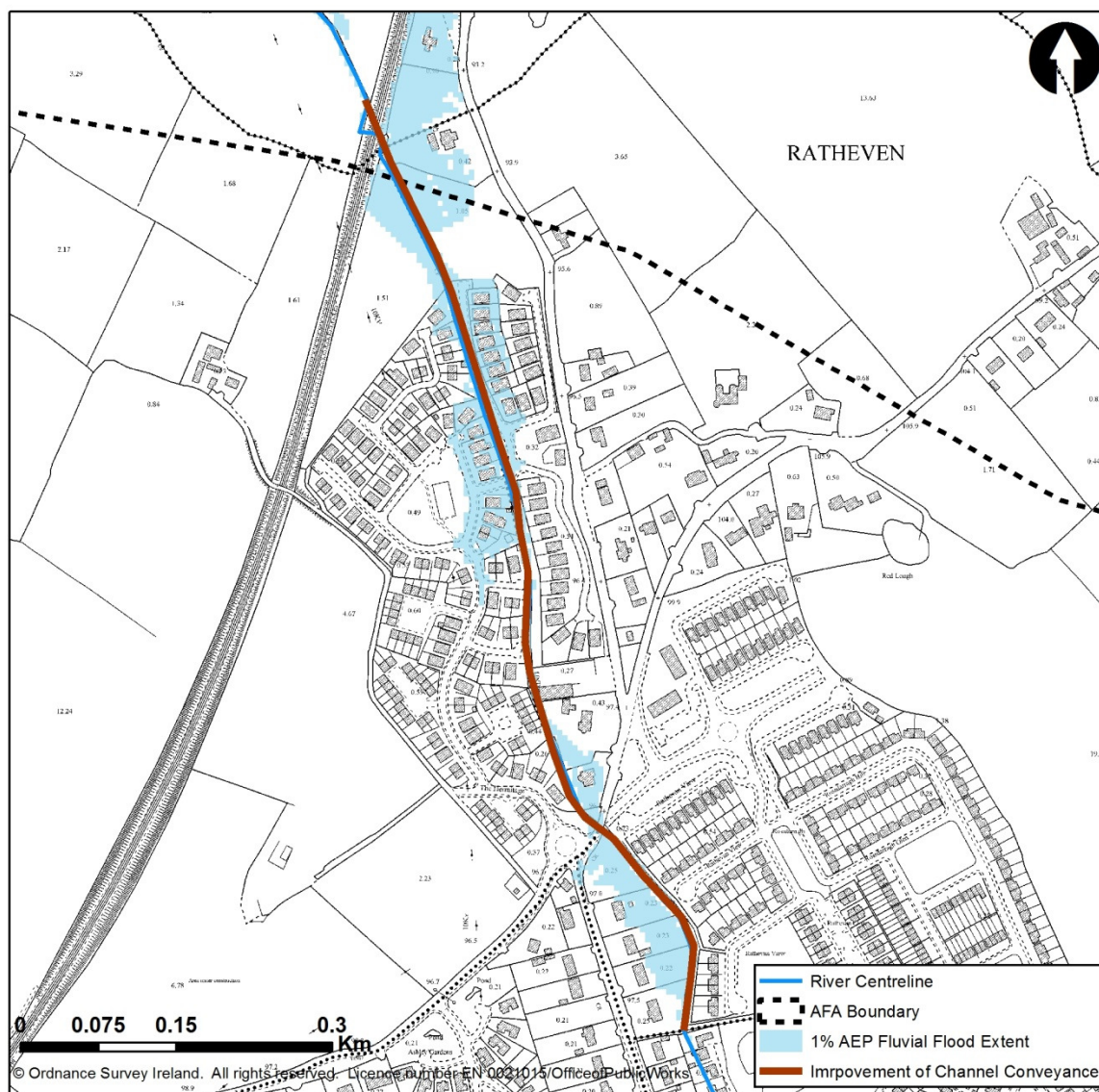
Location of Storage for flood cell 5

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.



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

A review of various techniques to improve channel conveyance was carried out for flood cell 5 and the following techniques were found to be the most appropriate way to implement this method. Flooding is caused by a number of constrictions and reduced channel capacity through flood cell 5. The sections of watercourse which would require improved conveyance is shown in Figure 8.12.6.5.1.1.1.2.



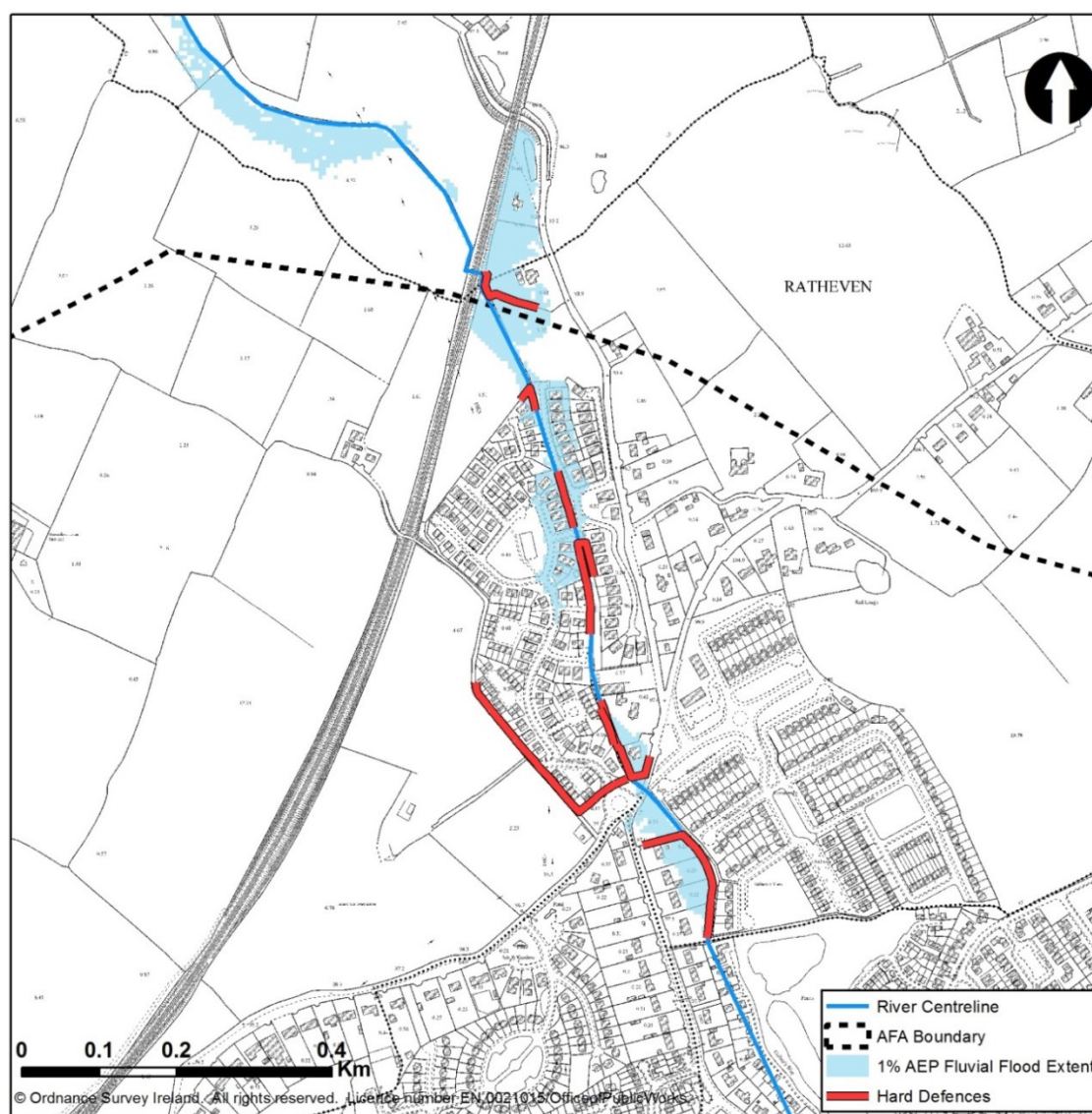
**Figure 8.12.6.5.1.1.1.2 Location of Improved Channel Conveyance for flood cell 5**

Improving the channel conveyance through flood cell 5 would be complex given the number of structures and the confined nature of the watercourse within a built up area. An assessment of channel capacity indicates that the channel generally would need to be widened over a length of approximately 200m. In addition three culverts which currently have diameters of 1-1.1m would need to be upgraded to a diameter of 2.1m (or equivalent rectangular cross-section). A 1.1m box culvert under the railway line would also need to be upgraded. In total over 406m of culvert would require upgrading. The total estimated cost of these works is €3.3m, which is economically viable.

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	!	✓

A review was carried out to ascertain where Hard Defences would be required to protect the existing property in flood cell 5. Figure 8.12.6.5.1.1.1.3 shows the location of the Hard Defences required to protect properties during the 1% AEP event. 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 0.8m and a total length of 1.1km. The model also showed that a significant portion of Hard Defence is required along The Hermitage Road along the western side of the flood cell as flood waters are forced out of bank along Colliers Lane and Ashley Gardens when the defences upstream are in place. The estimated cost to carry these works out would be €2.9m, which is economically viable.



**Figure 8.12.6.5.1.1.1.3**

**Location of Hard Defence in flood cell 5**



The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓		

The number of properties at risk during the design event in flood cell 5, 29, is such that relocation is considered not appropriate. Furthermore the cost to relocate all of the properties, based on the market value, is €14.9m, resulting in this method being economically unviable.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			

A review was carried out to assess the suitability of a flow diversion. A route for a proposed diversion channel / culverts was identified as shown in Figure 8.12.6.5.1.1.1.4.

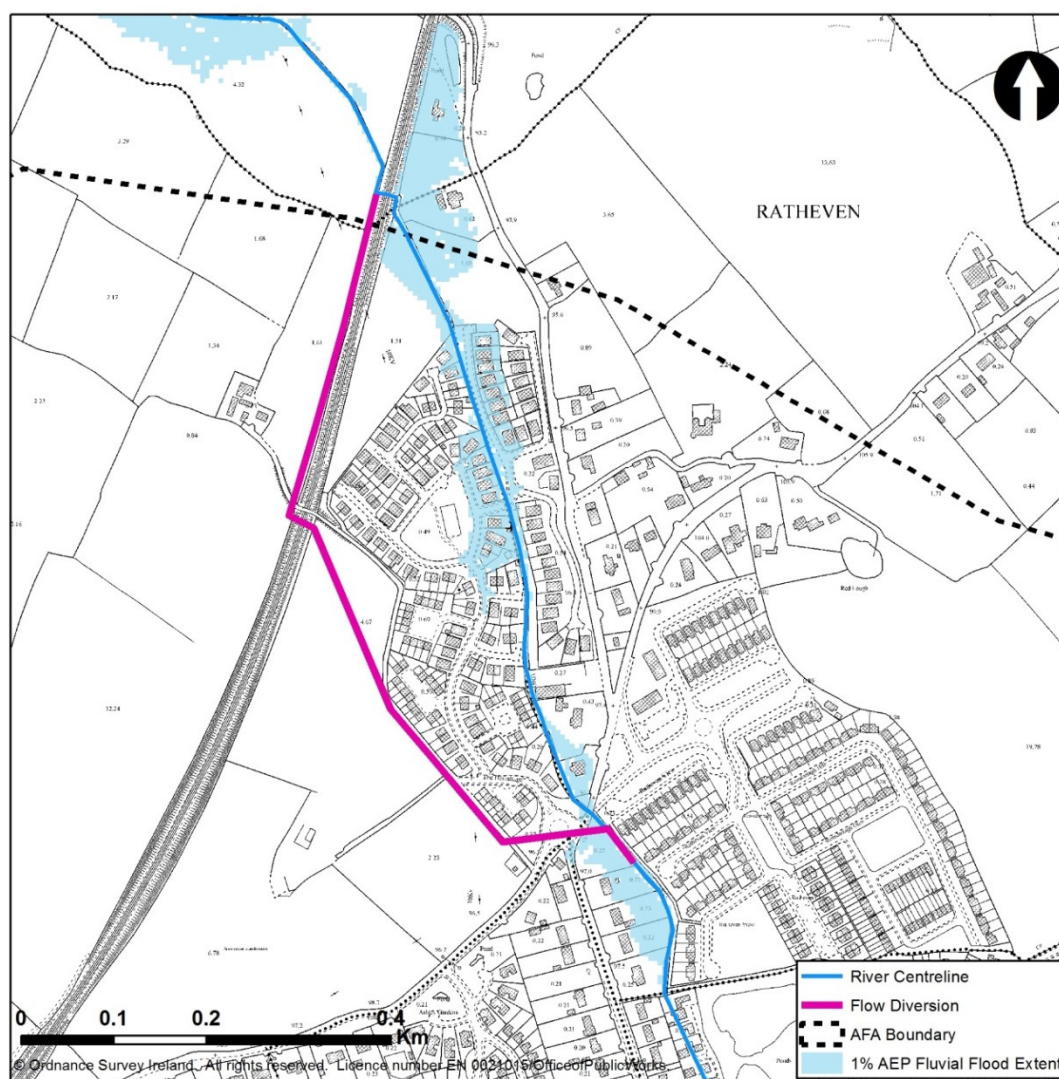


Figure 8.12.6.5.1.1.1.4

Location of Flow Diversion in flood cell 5

The route is approximately 950m long however there is approximately 450m of deep dig (over 4m) to facilitate the proposed falls in the channel. At the deepest point the invert of the culvert / channel would be up to 6.5m below the railway line / Hermitage Road. Given the health and safety implications of carrying out such works, and the likely cost, it was considered that this method is technically not feasible for flood cell 5.

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			

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 5. This method is technically unfeasible.

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

While this method would not provide the required design 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 the pass through the screening process. An economic review estimated that the cost of providing manual individual property protection for all 29 properties within flood cell 5 would be approximately €375,155. This method is therefore economically viable.

Method	Tech	Econ	Env	Soc
Other Works	✓			

No other works were identified for this flood cell.

#### 8.12.6.6 Summary of Feasibility Review – Flood Cell 5

The following FRM methods have been carried forward to address the flood risk arising from flood cell 5;

- Storage
- Improvement of Channel Conveyance
- Hard Defences

There are three options which can provide 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 no other method be deemed suitable later in the optioneering process.

**8.12.7 Short Listing FRM Methods – Local Cells 3 & 4**

Method	Review Comment	Continue Screening	
		Flood Cell 3	Flood Cell 4
Do Nothing	Consider Further	x	✓
Additional Maintenance	Consider Further	✓	✓
Do Minimum	Consider Further	✓	✓
Planning and Development Control	Consider at UoM SSA - Reject	✓	x
Building Regulations	Consider at UoM SSA - Reject	x	x
Catchment Wide SuDs	Consider at UoM SSA - Reject	x	x
Land Use Management	Consider Further	x	✓
Strategic Development Management	Consider at UoM SSA - Reject	✓	x
Storage	Consider Further	x	✓
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	✓	x
Individual Property Protection	Consider Further	x	✓
Other Works	Consider Further	✓	✓



## 8.12.6.1 Feasibility Review Summary of FRM Methods for flood cell 3

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	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				

## 8.12.7.1 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	✗			
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	✗			

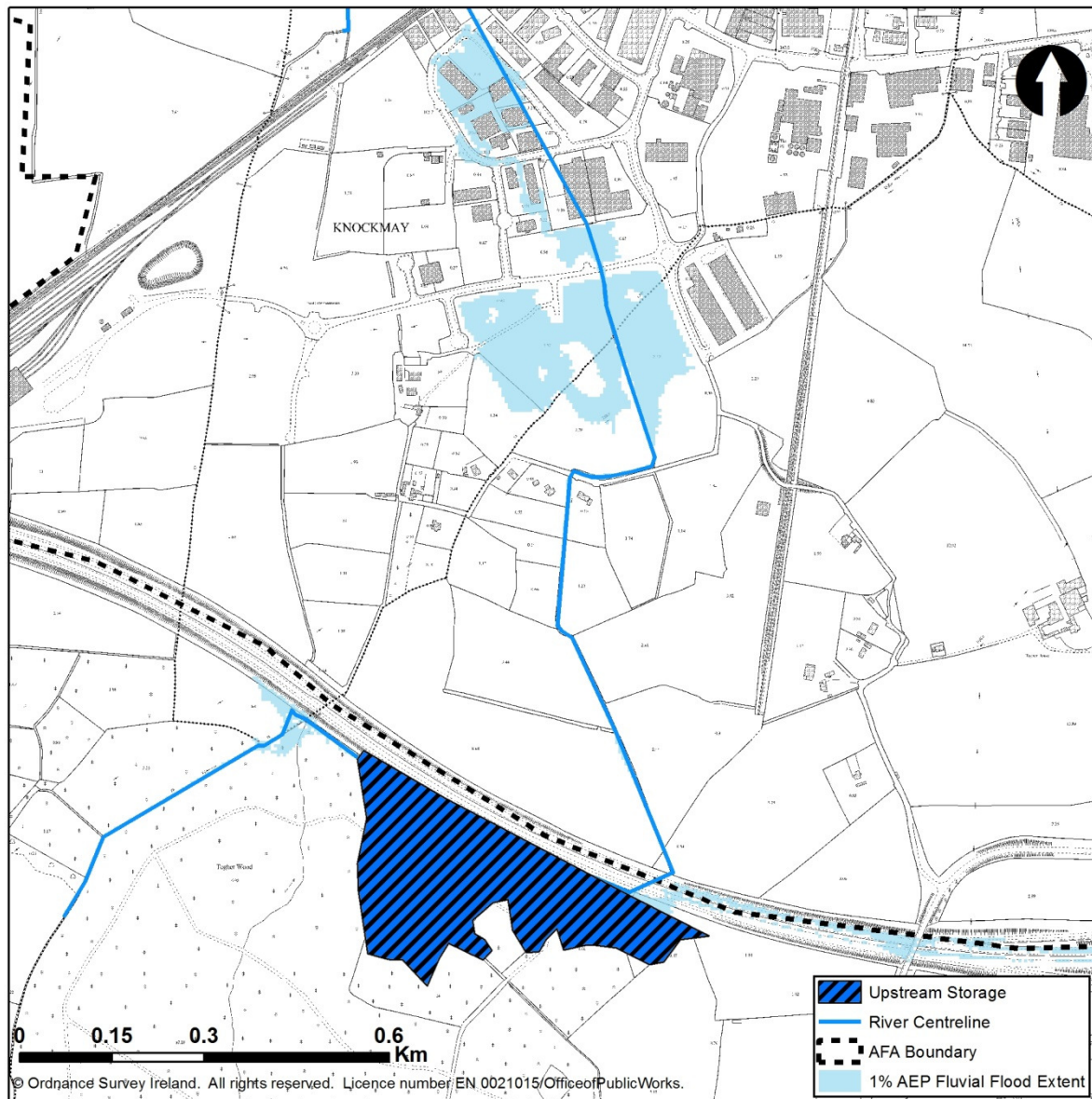
Within the flood cell 3 there is little opportunity to improve the constriction at the inlet of the culvert on the Togher watercourse at which the flooding develops through minimal works. There is therefore little scope to reduce the overall flood risk in flood cell 3 using this method. This is an unacceptable outcome in terms of contributing to achieving a design SoP and this method was therefore rejected from the screening process.

Method	Tech	Econ	Env	Soc
Land Use Management	x			

The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in the catchment the method is considered unsuitable to benefit flood cell 3. This method is technically unfeasible.

Method	Tech	Econ	Env	Soc
Storage	x	✓	?	✓

The volume of water required to be stored on the Togher watercourse before reaching flood cell 3 has been estimated to be 11,512m<sup>3</sup>. A review of the surrounding land was carried out and a location was found just upstream of the M7 where this volume of storage was available. To prevent flooding at flood cell 3 requires the reduction of flow upstream of the M7 from a 1% AEP event to a 5% AEP event. This method is therefore considered technically feasible and the location of the proposed storage is shown in Figure 8.12.7.1.1.1.1.1.1.



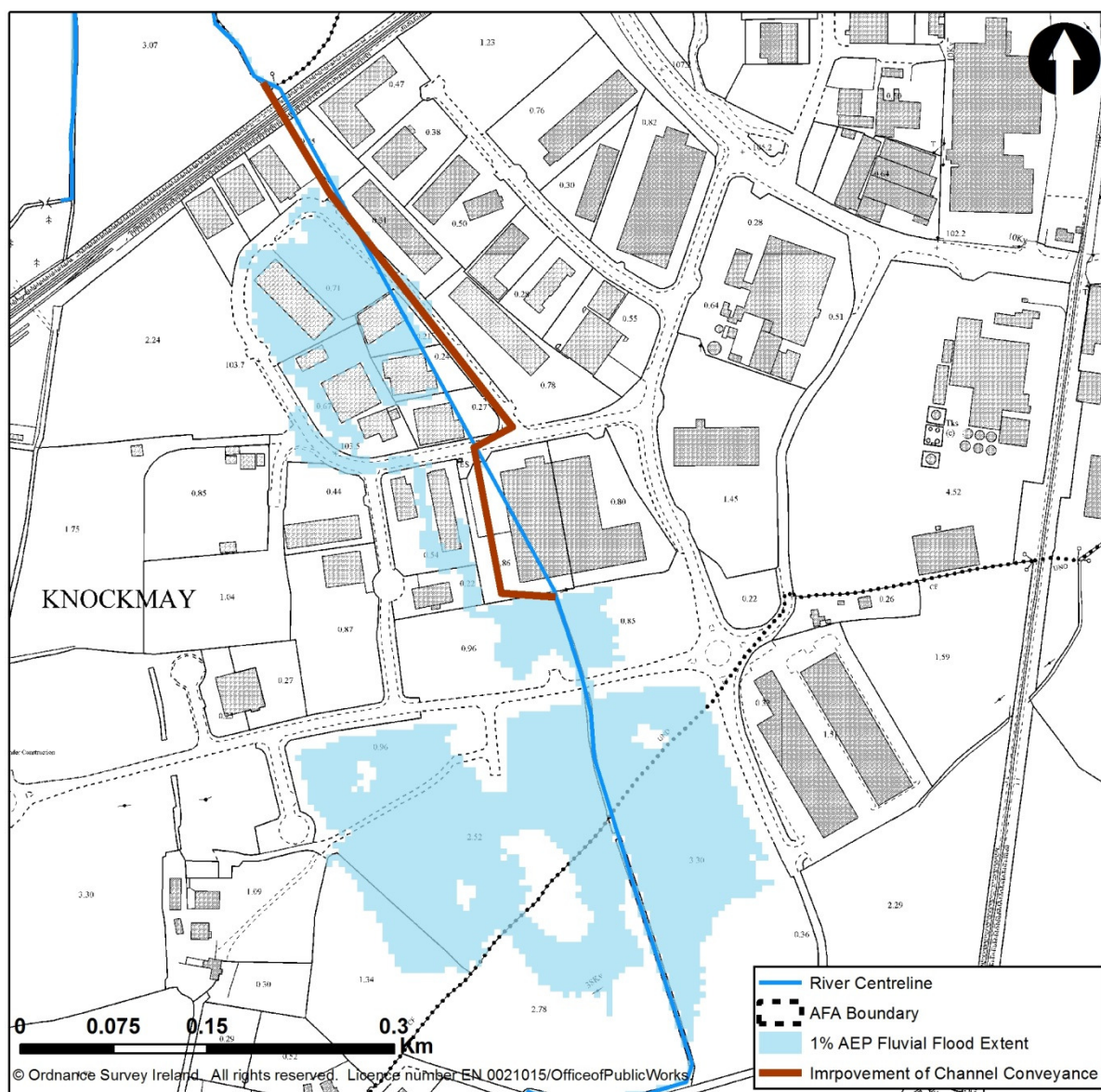
**Figure 8.12.7.1.1.1.1.1 Location of Storage for flood cell 3**

To create the Storage area would require 240m of embankment up to 1.6m in height. In addition an 11m long culvert through the embankment to act as a flow control device and a 1m wide overtopping weir would also be required. The total cost of providing the works is estimated to be €416,102, which is economically viable.

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.

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

A review of various channel conveyance techniques, was carried out for flood cell 3 and the following techniques were found to be the most appropriate way to implement this method. Flooding at flood cell 3 occurs at the inlet headwall of the culvert under the Clonminam Industrial Estate and flooding could be prevented by improving the conveyance of this culvert. This would require replacing the old 0.96 x 0.38m box culvert with a new 1.05m culvert over a distance of 540m as shown in Figure 8.12.7.1.1.1.1.2.



**Figure 8.12.7.1.1.1.1.2**

**Location of Improved Channel Conveyance in flood cell 3**

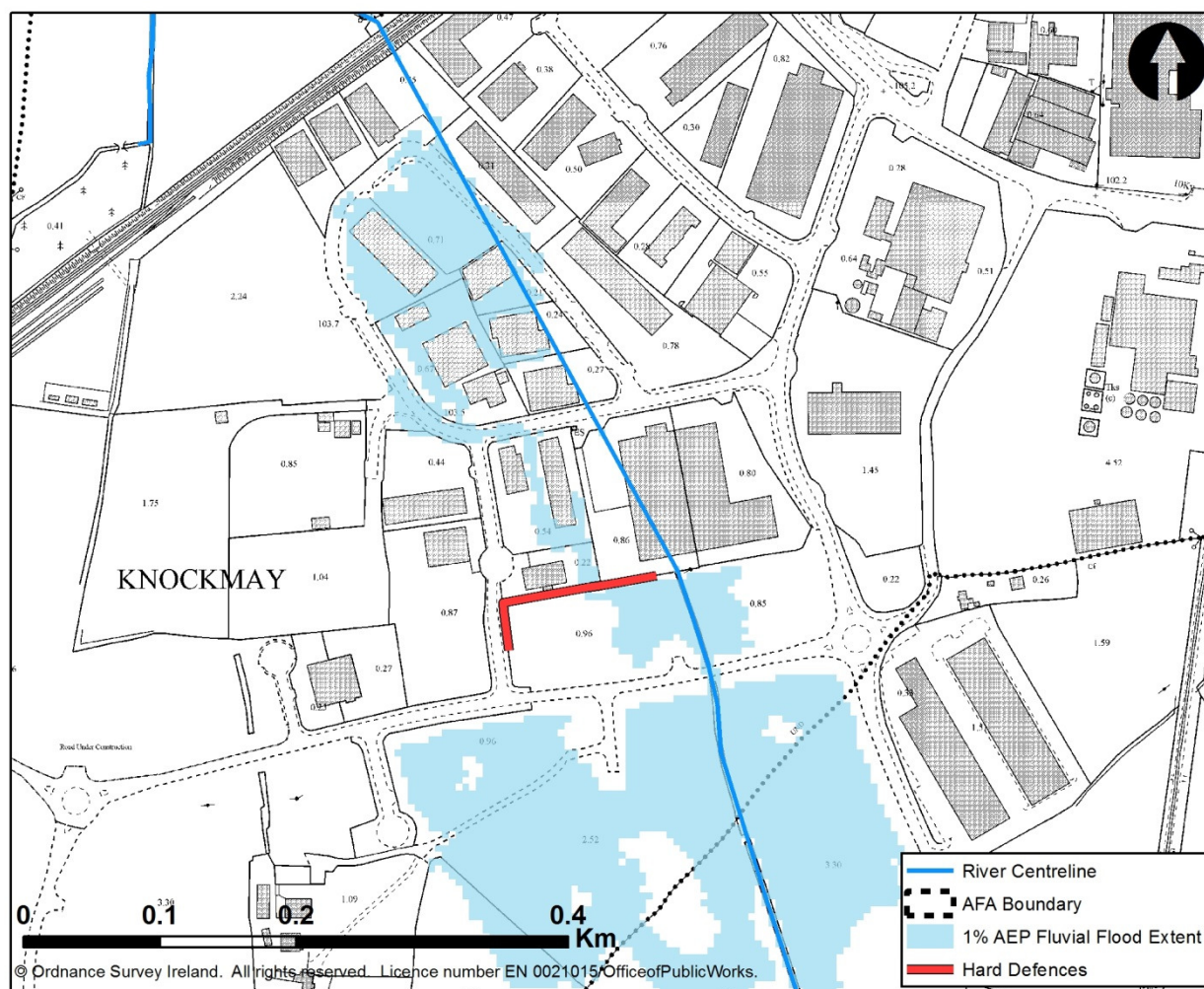
The estimated cost to carry these works out would be approximately €1.8m, which is economically viable.

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.



Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	?	✓

A review was carried out to ascertain where Hard Defences would be required to protect the existing properties in flood cell 3. Figure 8.12.7.1.1.1.1.3 shows the location of the Hard Defences required to protect properties during the 1% AEP event. 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 0.82m and a total length of 150m. The estimated cost to carry these works out would be €62,263.



**Figure 8.12.7.1.1.1.1.3 Location of Hard Defence in flood cell 3**

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.



Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓		
The seven properties at risk during the design event in flood cell 3 are commercial properties within an industrial estate. These properties form a significant core of the industrial estate and as such it is considered these properties are not suitable for relocation. Furthermore the cost to relocate these properties, based on the market value, is €4.35m, resulting in this method being economically unviable.				
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 without diverting the watercourse around the industrial estate. This method is therefore considered technically unfeasible.				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✗	✓	✓	✓
<p>The application of flood warning/forecasting was tested at UoM scale. A suitable location far enough upstream of flood cell 3 is available to provide sufficient warning. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.</p> <p>An economic review estimated that the cost of providing two hydrometric gauging stations with simple forecasting systems would be approximately €94,984. This method is therefore economically viable.</p> <p>The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.</p>				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓
While this method would not provide the required design 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 the pass through the screening process. An economic review estimated that the cost of providing individual property protection for 7 properties (2 requiring manual protection and 5 requiring automatic protection) would be approximately €381,988. This method is therefore economically viable.				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for this flood cell				
8.12.7.2 Summary of Feasibility Review – Flood Cell 3				
<p>The following FRM method has been carried forward to address the flood risk arising from flood cell 3;</p> <ul style="list-style-type: none"> <li>Storage</li> </ul>				

- Improvement of Channel Conveyance
- Hard Defences

Hard Defences provide a significantly lower cost solution than the Storage or Improvement of Channel Conveyance methods. Neither Flood Warning/Forecasting or Individual Property Protection provide the required SoP and should therefore only be used if other methods are deemed unsuitable later in the optioneering process. Consequently, hard defences are the preferred method and are carried forward to address the flood risk arising from flood cell 3.

8.12.7.3 Feasibility Review Summary for flood cell 4				
Method	Technical Screening	Economic Screening	Environmental and Cultural	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				
8.12.7.4 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	✗			
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	✗			

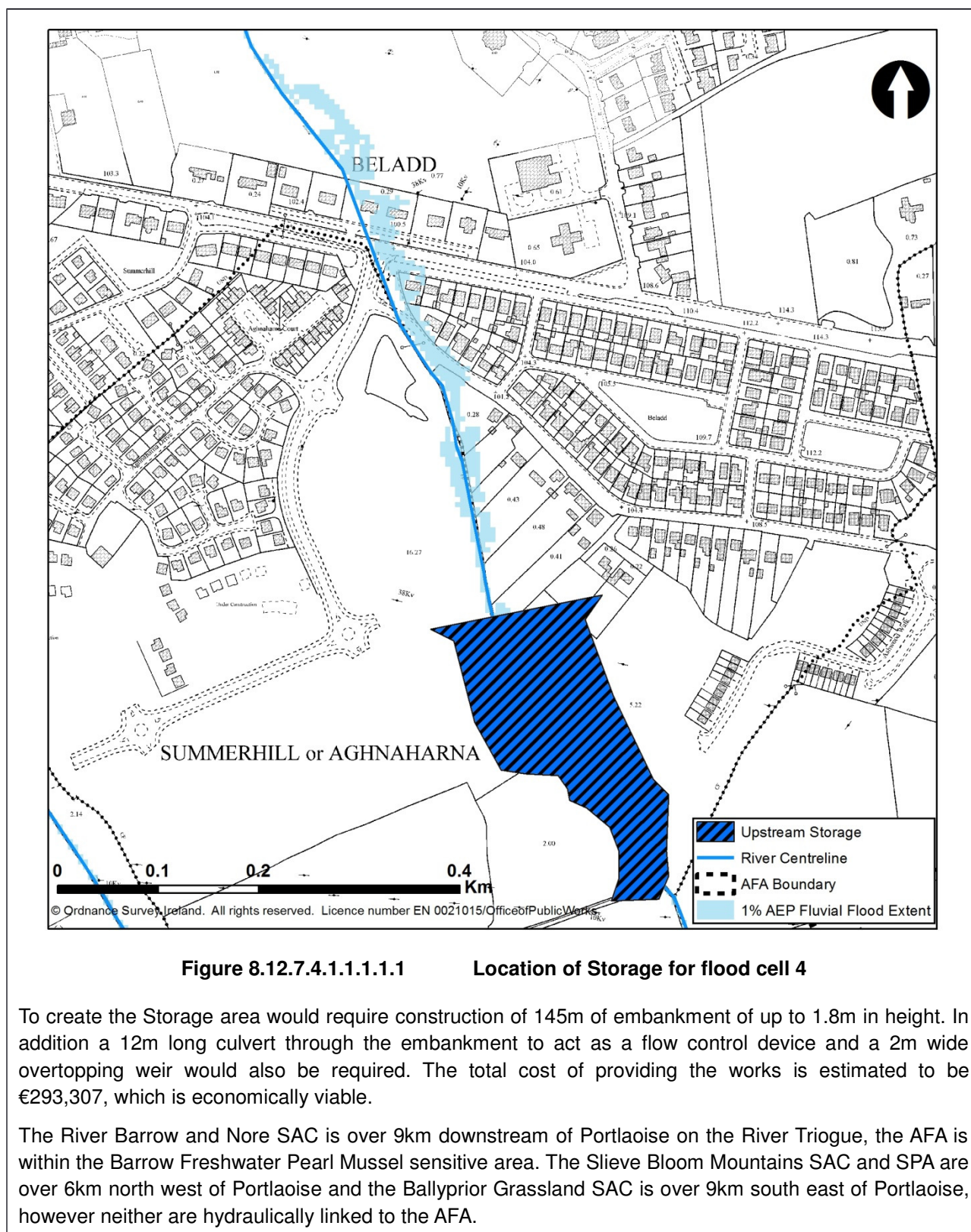
Within the flood cell 4 there is little opportunity to improve the conditions on the River Borris and therefore little scope to reduce the overall flood risk. This is an unacceptable outcome in terms of contributing to achieving a design SoP and this method was therefore rejected from the screening process.

Method	Tech	Econ	Env	Soc
Land Use Management	✗			

The application of land use management measures was tested at UoM scale. Due to the high percentage of urbanisation present in the catchment the method is considered unsuitable to benefit flood cell 4. This method is technically unfeasible.

Method	Tech	Econ	Env	Soc
Storage	✗	✓	?	✓

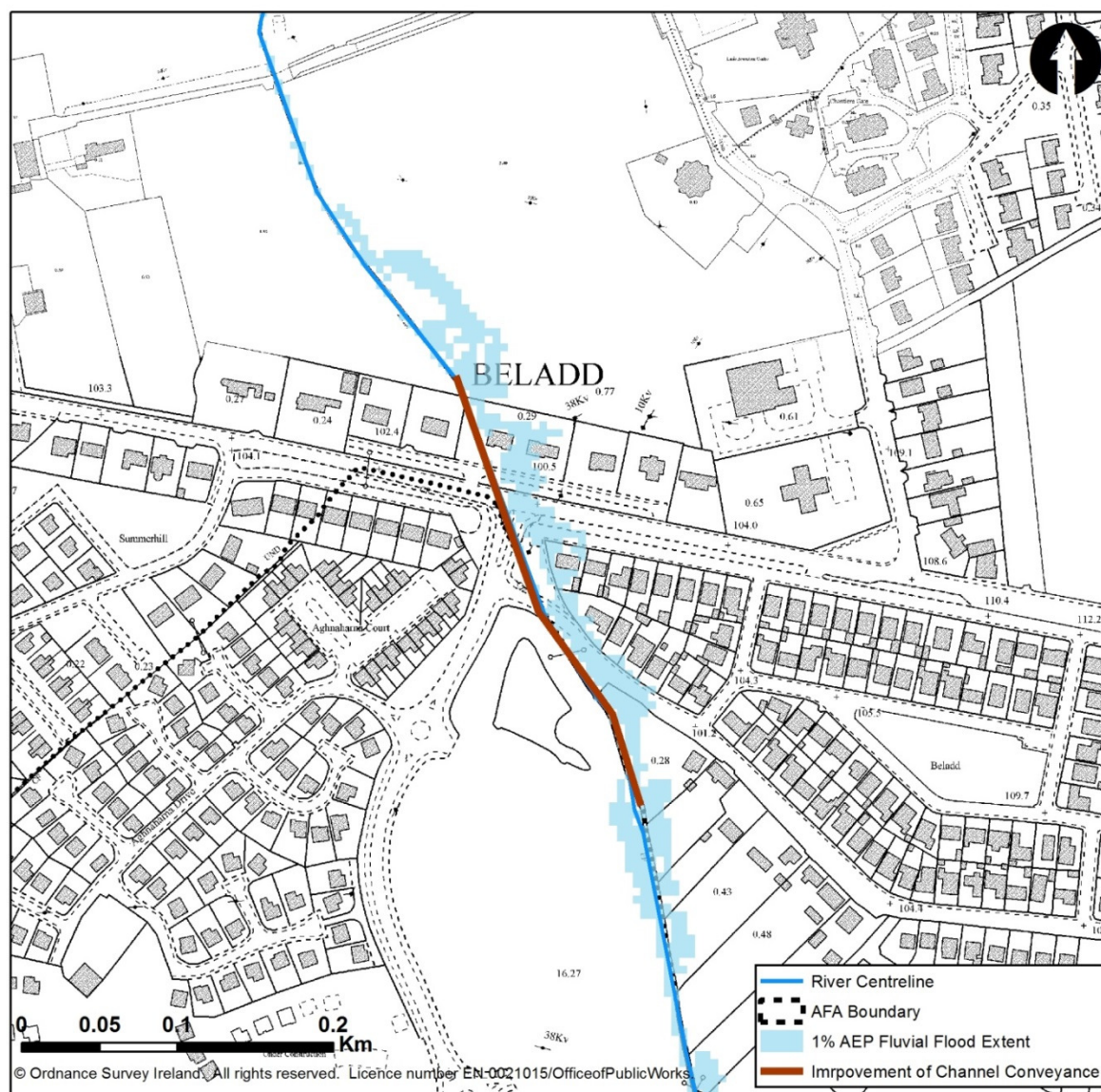
The volume of water required to be stored on the River Borris before reaching flood cell 4 has been estimated to be 7,105m<sup>3</sup>. A review of the surrounding land was carried out and a location was found to the south of flood cell 4 (south of Summerhill Lane). To prevent flooding at flood cell 4 requires the reduction of flow from a 1% AEP event to a 5% AEP event. This method is therefore considered technically feasible and the location of the proposed storage is shown in Figure 8.12.7.4.1.1.1.1.1.





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

A review of the various channel conveyance improvement techniques, was carried out for flood cell 4 and the following techniques were found to be the most appropriate way to implement this method. Flooding at flood cell 4 occurs at the inlet headwall of the River Borris downstream of Summerhill Lane. Flooding could be prevented by improving the conveyance of the watercourse by upgrading this culvert. This would require replacing the 0.9m diameter culvert with a new 1.2m culvert over a distance of 303m as shown in Figure 8.12.7.4.1.1.1.2.



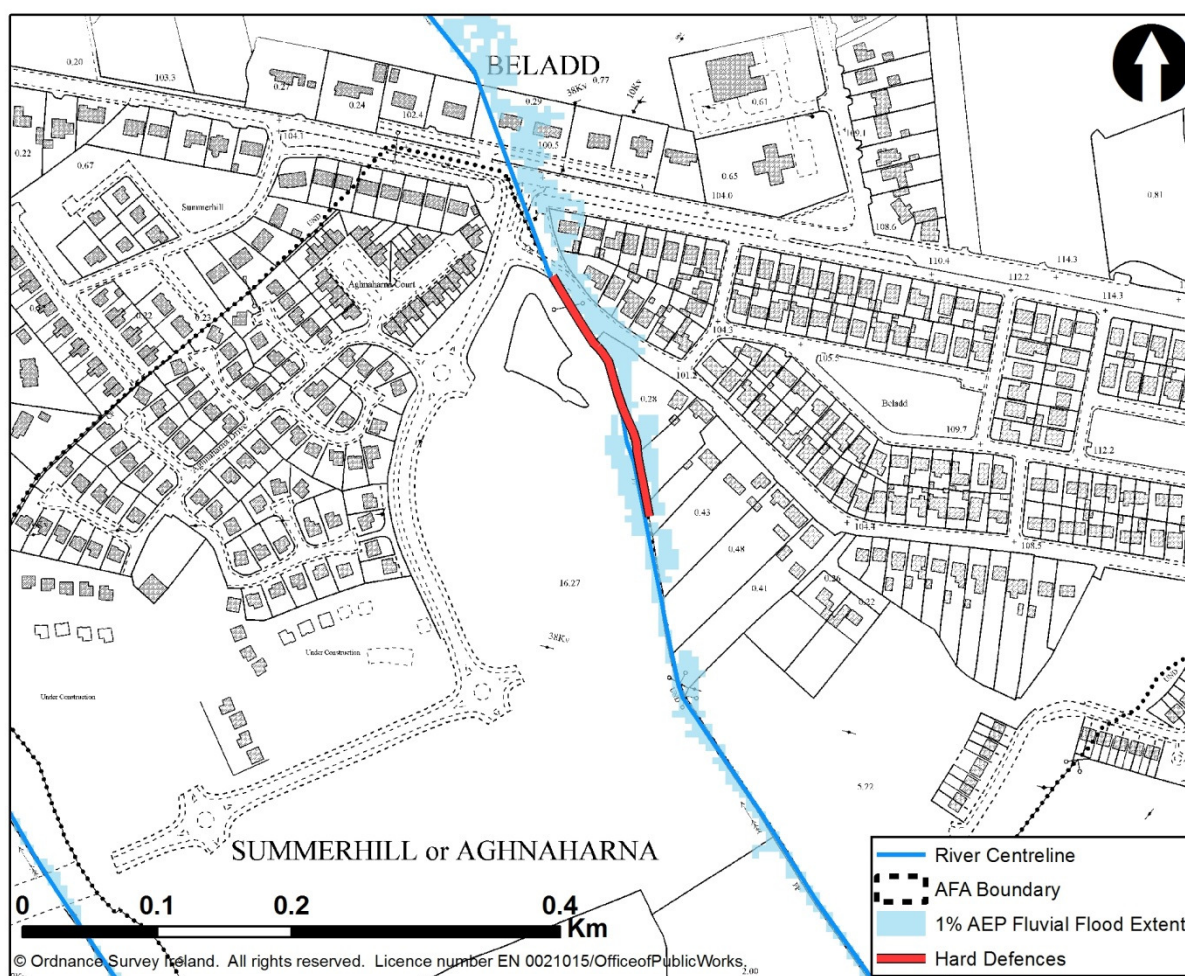
**Figure 8.12.7.4.1.1.1.2 Location of Improved Channel Conveyance in flood cell 4**

The estimated cost to carry these works out would be approximately €1.2m, which is economically viable.

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	?	✓

A review was carried out to ascertain where Hard Defences would be required to protect the existing properties in flood cell 4. Figure 8.12.7.4.1.1.1.1.3 shows the location of the Hard Defences required to protect properties during the 1% AEP event. 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 0.94m and a total length of 195m. The estimated cost to carry these works out would be €94,487.



**Figure 8.12.7.4.1.1.1.1.3 Location of Hard Defence in flood cell 4**

The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.

Method	Tech	Econ	Env	Soc
--------	------	------	-----	-----

Relocation of properties	✓	✓	✓	?
In practice it is always technically possible to relocate properties, however considering the socially negative impacts it should only be considered should no other method be found suitable. The cost of relocating all the properties affected by the 1% AEP event is estimated to be €2.6m, this method is therefore economically viable.				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✓			
A review was carried out to assess the suitability of a flow diversion. The watercourse is relatively straight and takes a direct route through the affected built up area. No location was found where this method could be carried out that did not involve taking a much longer, more complex route around potential properties at risk and going against the natural topography. Therefore this method is considered technically unfeasible.				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x	✓	?	?
<p>The application of flood warning/forecasting was tested at UoM scale. A suitable location far enough upstream of flood cell 4 is available to provide sufficient warning. This method can only provide warning for other methods and does not provide the required SoP as a standalone method. Therefore the method should only be considered if no other methods are suitable during the optioneering process.</p> <p>An economic review estimated that the cost of providing two hydrometric gauging stations with simple forecasting systems would be approximately €94,984. This method is therefore economically viable.</p> <p>The River Barrow and Nore SAC is over 9km downstream of Portlaoise on the River Triogue, the AFA is within the Barrow Freshwater Pearl Mussel sensitive area. The Slieve Bloom Mountains SAC and SPA are over 6km north west of Portlaoise and the Ballyprior Grassland SAC is over 9km south east of Portlaoise, however neither are hydraulically linked to the AFA.</p>				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓
While this method would not provide the required design 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 the pass through the screening process. An economic review estimated that the cost of providing manual individual property protection for 5 properties would be approximately €70,188. This method is therefore economically viable.				
Method	Tech	Econ	Env	Soc
Other Works	✓			
No other works were identified for this flood cell				
8.12.7.5 Summary of Feasibility Review – Flood Cell 4				
<p>The following FRM method has been carried forward to address the flood risk arising from flood cell 4;</p> <ul style="list-style-type: none"> <li>Storage</li> </ul>				

- Improvement of Channel Conveyance
- Hard Defences

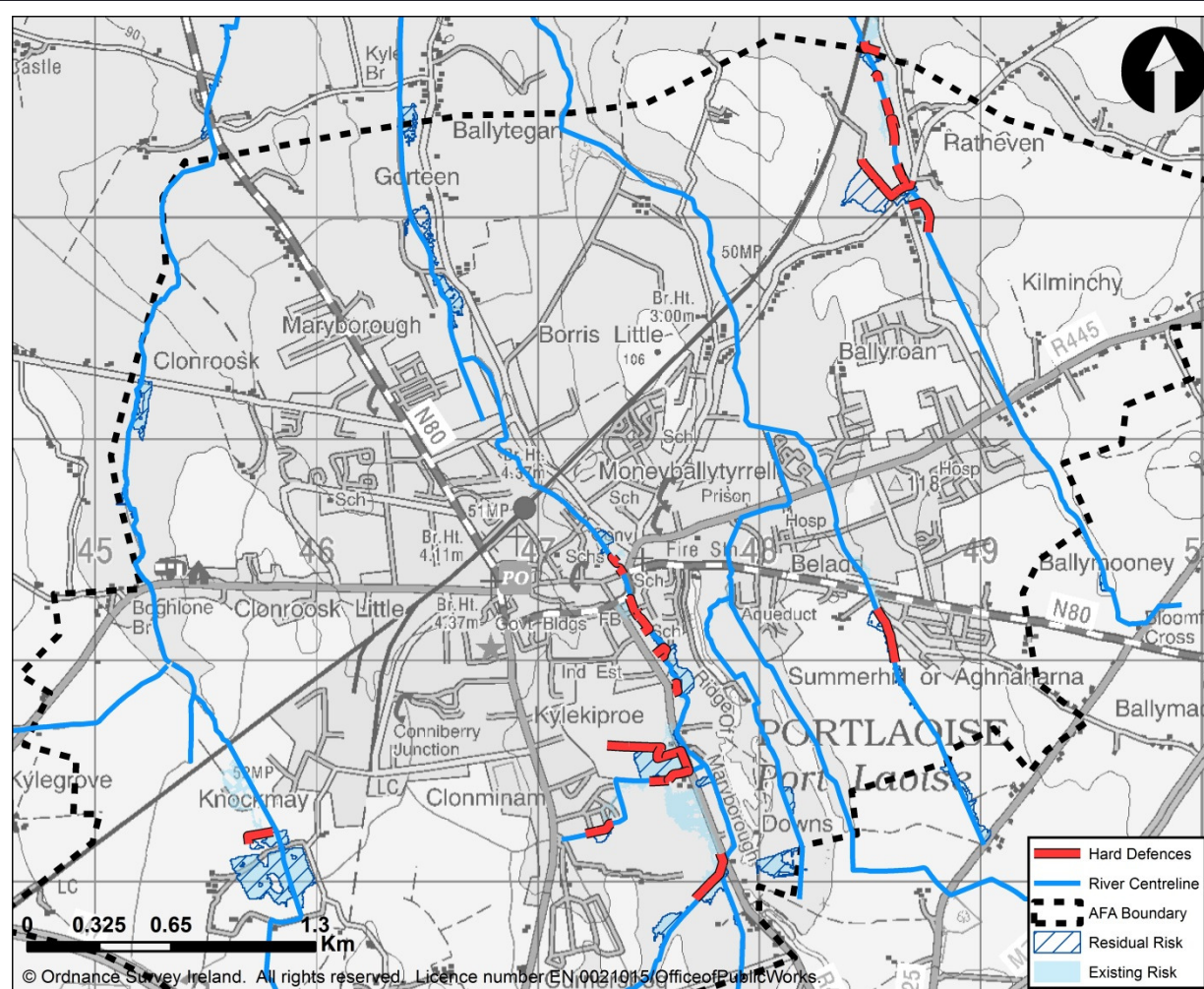
Due to the socially negative impacts associated with Relocation of Properties the method should only be considered if no other method is found suitable. Additionally neither Flood Warning/Forecasting or Individual Property Protection provide the required SoP and should therefore only be used if other methods are deemed unsuitable later in the optioneering process. Hard Defences provide a significantly lower cost solution than the Storage or Improvement of Channel Conveyance methods. Consequently, hard defences are the preferred method and are carried forward to address the flood risk arising from flood cell 4.

### 8.12.8 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Hard Defences	x	✓	✓		
Storage		✓			
Improvement of Channel Conveyance			✓		
<p>Hard Defences is the only economically viable method which provides the full standard of protection in flood cells 1, 2, 3 &amp; 4. In flood cell 5 three methods have been shown to be economically viable; Hard Defences, Storage and Improvement of Channel Conveyance. As such there are three options which would provide the full standard of protection:</p> <p>Option 1 – Hard Defences in all flood cells</p> <p>Option 2 – Hard Defences in flood cells 1 - 4 and Storage in flood cell 5</p> <p>Option 3 – Hard Defences in flood cells 1 - 4 and Improvement of Channel Conveyance in flood cell 5</p>					



## 8.12.8.1 Option 1 details - Hard Defences



**Figure 8.12.8.1.1.1.1.1 Portlaoise 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 0.81m and a total length of 2.6km.

Figure 8.12.8.1.1.1.1.1.1 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).

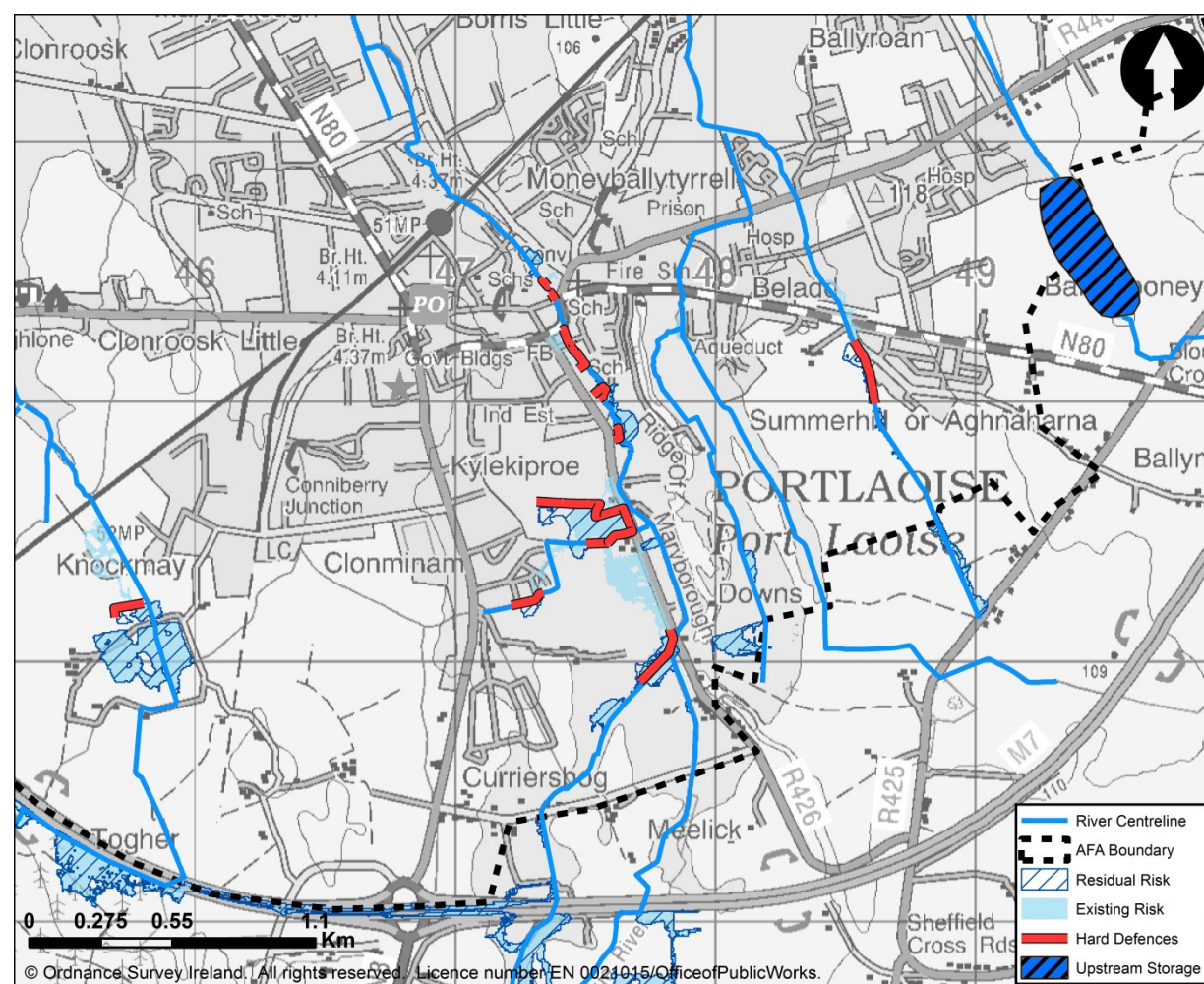
The combination of these methods would protect to the 1% AEP flood. In addition to these methods the following was also identified at UoM level (see section 8.1) to be included in any potential option identified:

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



Option Item	Quantity		Construction Cost
Walls	1.7km length, 0.75m high (average)		€2,010,182
Embankment	1.4km length, 0.9m high (average)		€238,009
Road Raise	15m length, 1m high (average)		€118,618
Total MCA-Benefit Score	Option Cost (€millions)		MCA-Benefit Score / Cost Ratio
505	5.48		92.28
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€6,681,152	€5,476,930	€3,335,332	0.61

## 8.12.8.3 Option 2 details - Hard Defences and Storage



**Figure 8.12.8.3.1.1.1.1 Portlaoise AFA Option 2**

At risk properties would be protected by a series of flood embankments and walls along the Triogue, Borris, Clonmanin and Togher watercourses. These hard defences would protect to the 1% AEP flood event with an average height of 0.82m and a total length of 1.5km. At risk properties in flood cell 5 would be protected by Storage on the Bloomfield watercourse of approximately 98,000m<sup>3</sup> located the south east of the Carrick Hill area.

Figure 8.12.8.3.1.1.1.1.1 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).

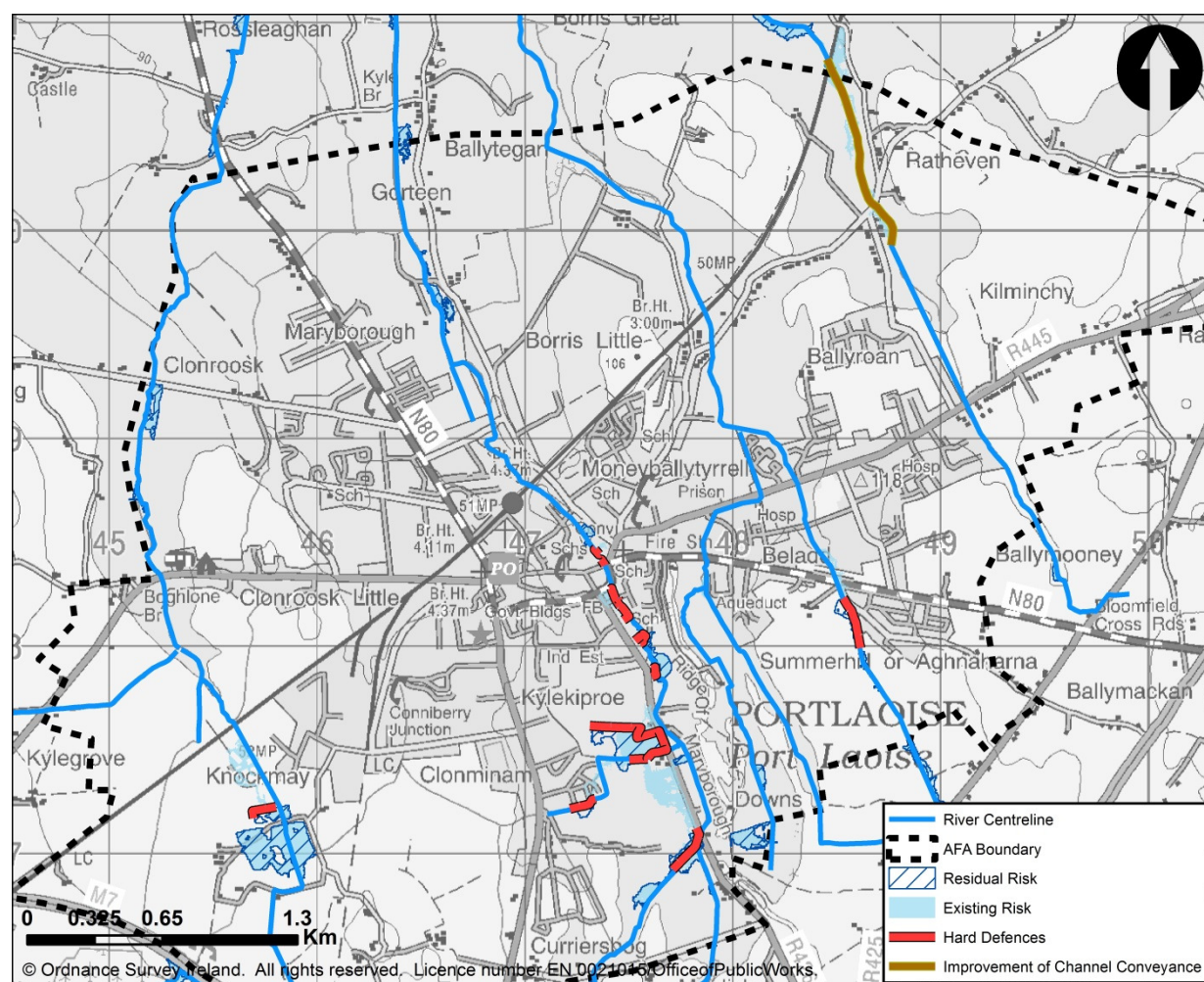
The combination of these methods would protect to the 1% AEP flood. In addition to these methods the following was also identified at UoM level (see section 8.1) to be included in any potential option identified:

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

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Option Item	Quantity	Construction Cost	
Wall	686m length, 0.7m high (average)	€891,790	
Embankment	1.3km length, 0.9m high (average)	€333,729	
Excavation on Land	Excavate 80,000m³ for storage	€325,647	
Weir Construction	Storage overspill weir	€9,726	
Culvert	Through storage embankment	€69,928	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
376	3.92	96.01	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€6.681.152	€3.917.903	€3.335.332	0.85

## 8.12.8.5 Option 3 details - Hard Defences and Improvement of Channel Conveyance



**Figure 8.12.8.5.1.1.1.1 Portlaoise AFA Option 3**

At risk properties would be protected by a series of flood embankments and walls along the Triogue, Borris, Clonmanin and Togher watercourses. These hard defences would protect to the 1% AEP flood event with an average height of 0.82m and a total length of 1.5km. At risk properties in flood cell 5 would be protected by Improvement of Channel Conveyance along the Bloomfield watercourse. The Improvement of Channel Conveyance would include approximately 200m of channel widening and over 400m of culvert upgrades.

Figure 8.12.8.5.1.1.1.1.1 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).

The combination of these methods would protect to the 1% AEP flood. 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
- Sub-catchment Wide SuDs
- Strategic Development Management

- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Wall	686m length, 0.7m high (average)	€891,790	
Embankment	1.3km length, 0.9m high (average)	€217,359	
In-Channel Excavation	200m of widening in FC5	€23,533	
Culvert	Bloomfield Stream	€1,045,900	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
341	6.15	55.49	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€6.681,152	€6.148,118	€3.335,332	0.54



### 8.12.8.7 AFA Sensitivity to Future Change

As shown in Figure 8.12.8.7.1.1.1.1.1 to Figure 8.12.8.7.1.1.1.1.4, during a MRFS 1% AEP flood event the increase in flood extent is minimal due to the surrounding topography which the rivers flow through. An additional 173 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €311,012 to €1,501,275. As a result Portlaoise AFA would be considered to be at high vulnerability from the MRFS.

During the HEFS 1% AEP flood event the flood extent, while larger than the MRFS, is minimal also. An additional 973 properties are estimated to be at flood risk when compared to the present day flood risk. The AAD would increase from €311,012 to € 9,207,326. As a result Portlaoise AFA would be considered to be at high vulnerability from the HEFS.

The main areas of additional flood risk are located along the banks of the Togher, Triogue and Bloomfield Rivers.

The number of additional properties affected by future scenarios indicates a significant increase to the annual average damage and the Portlaoise area of assessment would be considered to be at high vulnerability. Options should be assessed to their adaptability to climate change.

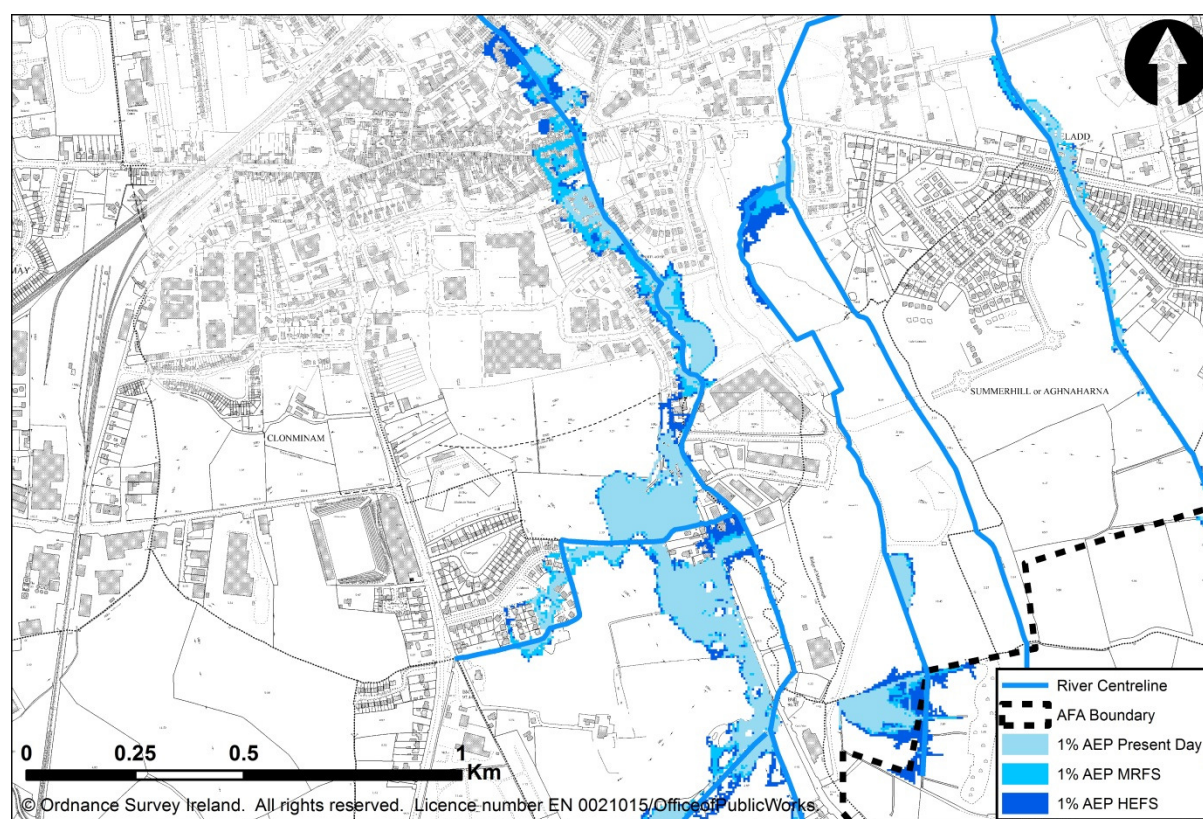


Figure 8.12.8.7.1.1.1.1.1

Future Change Flood Extents (Flood Cell 1 & 2)

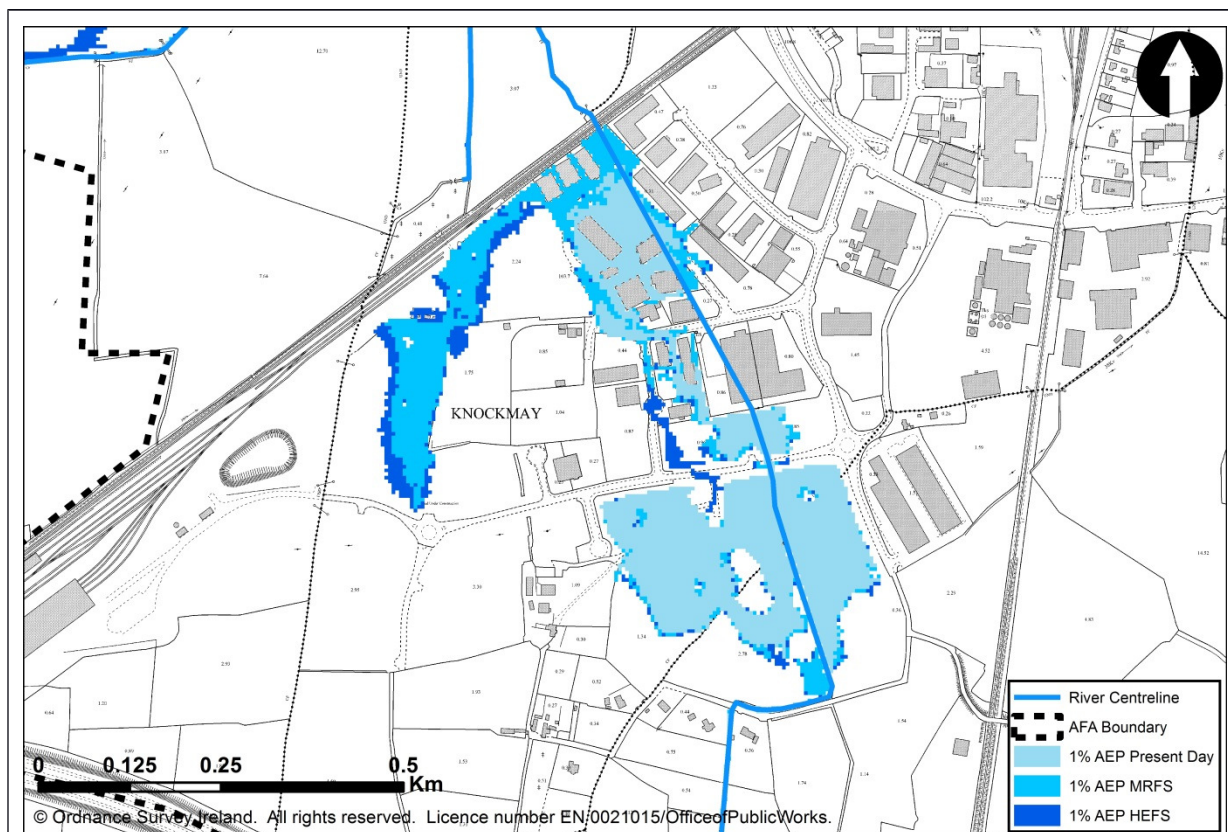


Figure 8.12.8.7.1.1.1.2

Future Change Flood Extents (Flood Cell 3)

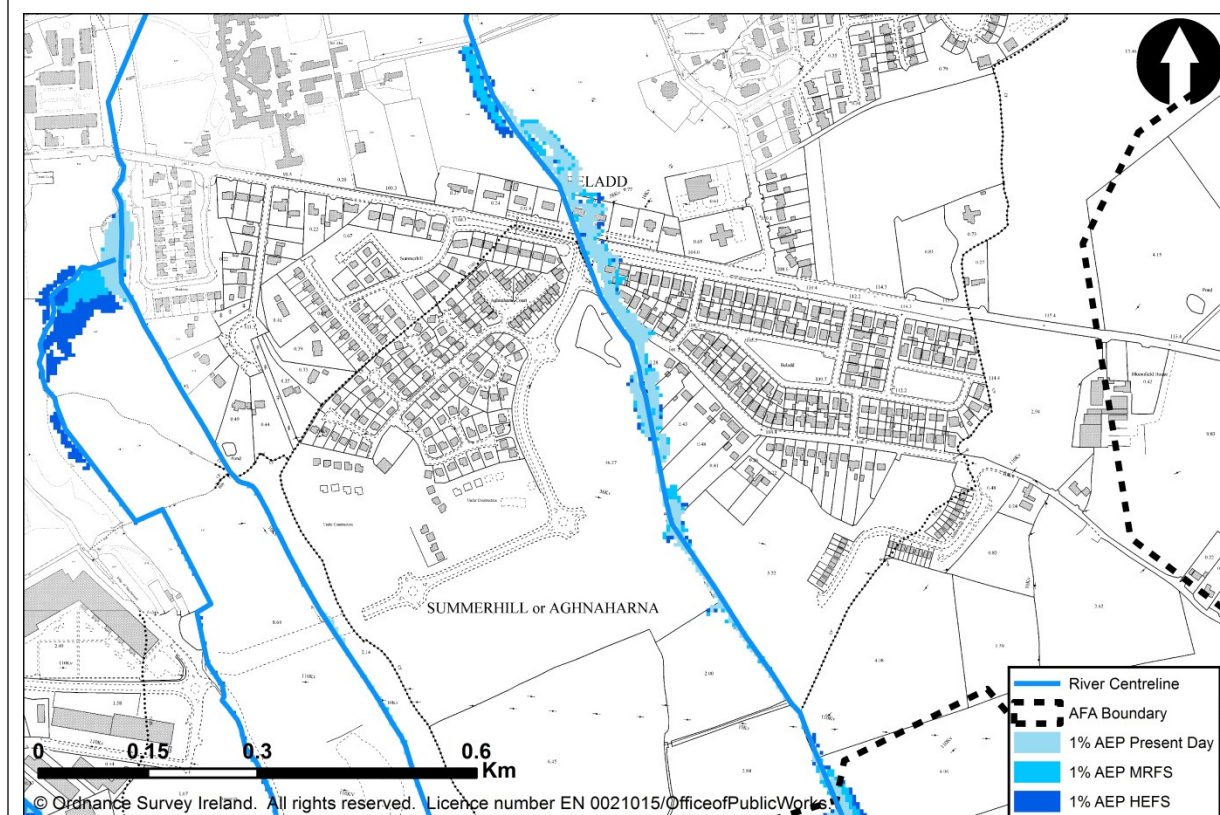
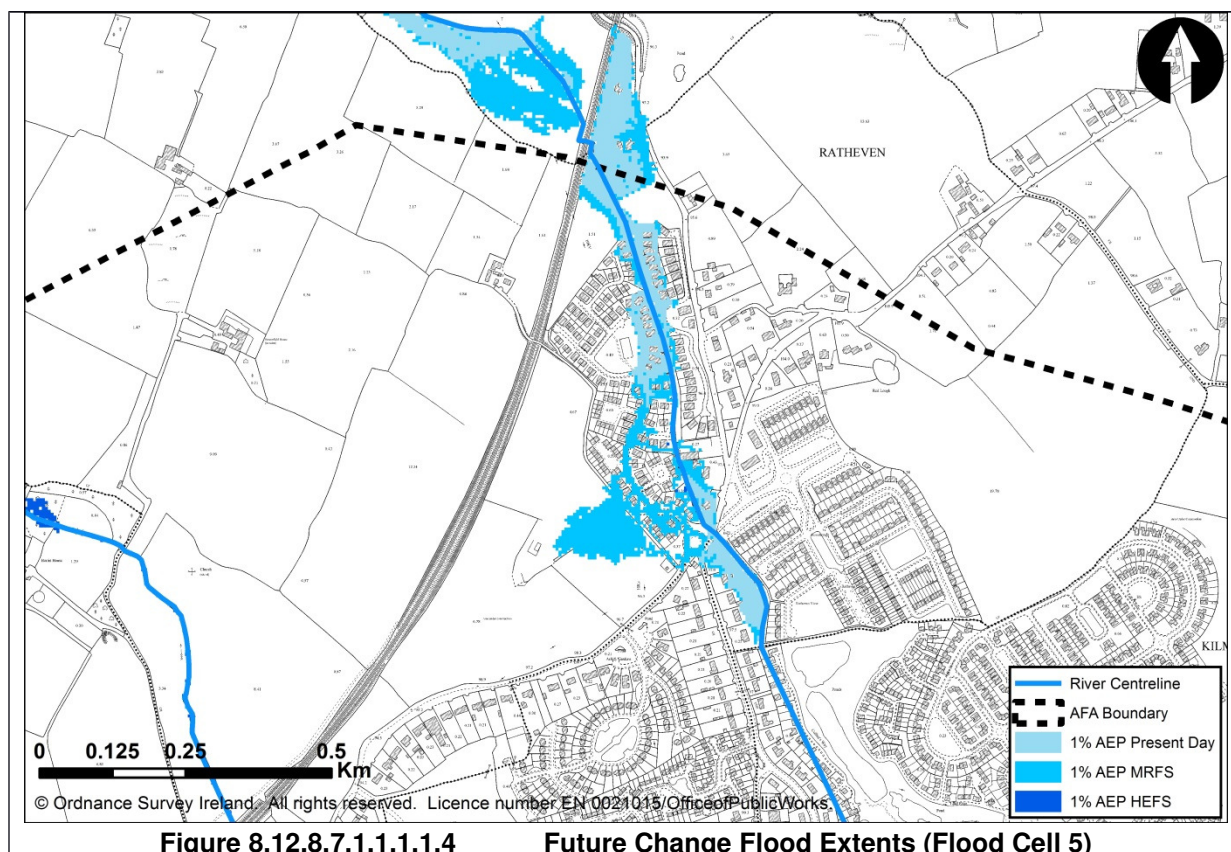


Figure 8.12.8.7.1.1.1.3

Future Change Flood Extents (Flood Cell 4)





#### 8.12.8.8 Future Change Adaptability

The following discusses the adaptability of the potential FRM **methods** proposed in Portlaoise AFA:

**Hard Defences Flood Cell 1** - Hard defences for option 1, 2 & 3 are the same for flood cell 1. This method could be adapted by increasing the height of the walls and embankments and extending their length. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from an average of 0.9m to a max of 1.9m and 2m respectively. This additional height could be accommodated. The review also showed that the additional length of wall preferred could be accommodated. To ensure that the walls would be adaptable the design would need to account for the potential increase on wall height. The embankments would also require space for a larger footprint. This method is considered to have a **moderate** adaptability.

**Hard Defences Flood Cell 2** - Hard defences for option 1,2 & 3 are the same for flood cell 2. This method could be adapted by increasing the height of the wall and extending its length. A review of the effect of the MRFS and the HEFS showed that the walls would need to be increased from an average of 0.7m to a max of 1.2m and 1.4m respectively. This additional wall height could be accommodated. The review also showed that the additional lengths of wall would be required. To ensure that this wall would be adaptable the design would need to account for the potential increase on wall height. This method is considered to have a **moderate** adaptability.

**Hard Defences Flood Cell 3** - Hard defences for option 1,2 & 3 are the same for flood cell 3. This method could be adapted by increasing the height of the embankments and extending their length. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from an average of 0.8m to a max of 1m and 1.1m respectively. This additional height could be accommodated. Embankments would also require space for a larger footprint to ensure adaptability. This method is considered to have a **moderate** adaptability.

**Hard Defences Flood Cell 4** - Hard defences for option 1,2 & 3 are the same for flood cell 4. This method could be adapted by increasing the height of the embankments and extending their length. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from an average of 1m to a max of 1.25m and 1.26m respectively. This additional height could be accommodated. Embankments would also require space for a larger footprint to ensure adaptability. This method is considered to have a **moderate** adaptability.

**Hard Defences Flood Cell 5** - This method could be adapted by increasing the height of the walls and embankments and extending their length. A review of the effect of the MRFS and the HEFS showed that the hard defences would need to be increased from an average of 0.8m to a max of 1.5m and 1.7m respectively. This additional height could be accommodated. The review also showed that the additional length of wall preferred could be accommodated. To ensure that the walls would be adaptable the design would need to account for the potential increase on wall height. The embankments would also require space for a larger footprint. This method is considered to have a **poor** adaptability.

**Storage Flood Cell 5** - This method could be adapted by carrying out further excavation of the storage area. As the retaining structure is a wall it would need to be designed to accommodate additional height in the future. Additional volumes of 73,910m<sup>3</sup> and 412,510m<sup>3</sup> would need to be excavated for the MRFS or HEFS respectively. This would be considered major structural works and storage in FC 5 would therefore be considered to have **poor** adaptability.

**Improvement of Channel Conveyance Flood Cell 5** - This method could be adapted by further dredging the 200m length of Bloomfield and increasing the capacity of 4 culverts. The current proposal is to widen the channel over approximately 200m and upgrade a number of culverts. If the flow were to increase to the MRFS these culverts should have sufficient capacity to convey the 1% AEP flow however during the HEFS 1% event the culverts would have limited capacity to convey the 1% AEP flow. In addition further channel dredging would be required. This adaptation would be

considered as major structural works and improvement of channel conveyance in FC 5 would therefore be considered to have **poor** adaptability.

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 Portlaoise is fairly developed currently there would be limited scope for some of these methods to impact on the area being assessed. Since there is an increase in the number of properties affected in the MRFS and HEFS there is a need to ensure that the owners and users of future receptors at risk are prepared through methods such as public awareness campaign. This is most relevant to options with methods with poor adaptability, such as options 2 & 3.
2. **Does the option make space for water?** Options which provide additional space for water or do not restrict it are more likely to perform well in future scenarios. Options which include hard defences restrict the water making water levels more sensitive to increased flow. Options 1, 2 & 3 would create this situation.
3. **Does the option deliver co-benefits?** No co-benefits were identified. However in option 3 creating a storage area on the Bloomfield Stream could provide co-benefits with recreations and environmental objectives
4. **Does the option provide flexibility?** A review of the potential options show that option 1, Hard Defences, is the most adaptable to the MRFS and HEFS. However alternative FRM methods could be added to all options 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. However should opportunity ever arise, options with channel modification are most easily reverted, such as option 2.

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 the table below summarises how well each option achieves this objective.

Summary of Option Adaptability		
Option	Description	Score
Option 1 – Hard Defences (FC 1-5)	Option is adaptable at moderate cost, difficulty and impact	3
Option 2 - Hard Defences (FC 1-4) and Storage (FC5)	Option is adaptable at moderate to significant cost, difficulty and impact	1
Option 3 - Hard Defences (FC 1-4) and Improvement of Channel Conveyance (FC5)	Option is adaptable at moderate to significant cost, difficulty and impact	1



#### 8.12.8.9 Local Authority Comments

LA representatives reviewed preliminary options in November 2015.

#### 8.12.8.10 Summary

There is moderate confidence in both the hydrology and hydraulics of the Portlaoise AFA due to the presence of a gauging station and flood extent verification events.

The following potential options, with a BCR  $\geq 0.5$  have been identified:

- Option 1 - Hard Defences (FC 1-5)
- Option 2 - Hard Defences (FC 1-4) and Storage (FC5)
- Option 3 - Hard Defences (FC 1-4) and Improvement of Channel Conveyance (FC5)

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 Portlaoise 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

Communities are located downstream of the Portlaoise AFA that could be affected by the potential option identified. The flows at the model boundary was reviewed for the 1% AEP current scenario versus the 1% AEP with the option in place scenario. There is negligible flow differences between the hydraulic model simulations. In addition any interactions with the drainage system in the urbanised area may need to be addressed during the development of the preferred option.

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 adaptive (option 1) or assumptive (options 2&3) approaches to 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.

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## 8. OPTIONEERING OF SSA'S

### 8.15 Rathangan Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Rathangan	Kildare	140175	AFA	Final	15/06/2016

#### 8.13.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.13.2 Flood Cells



Figure 8.13.2.1.1.1.1.1

Rathangan AFA Flood Cells within a 1% AEP Fluvial Flood Extent

#### Summary of Flood Cells:

As shown in Figure 8.13.2.1.1.1.1.1 there are no properties at flood risk during the 1% AEP event, therefore no flood cells have been identified.

### 8.13.1 Existing Regime

The 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 River Slate that flows through Rathangan AFA is located within the Barrow and Rathangan Drainage District, the boundary between these two drainage districts is approximately located within the centre of the AFA. Further details of operations in these districts are presented in section 6.3

The Local Authority (Kildare County Council) carries out inspection and maintenance to these watercourses where resources allow. The existing regime provides the preferred SoP.

### 8.13.3 Summary of Flood Risk within SSA boundary

There are no receptors at risk within the Rathangan AFA during the 1% AEP event.

### 8.13.4 Monetary Damage and Benefit

	Total in AFA
Annual Average Damage (AAD)	€0
Present Value Damage (pvD)	€0
Standard of Protection (SoP)	1% AEP
Number of Properties Benefiting from Design SoP	0
Minimum Present Value Benefit	€0
Capped Minimum Present Value Benefit	€0

\*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.

### 8.13.5 Selection of Options

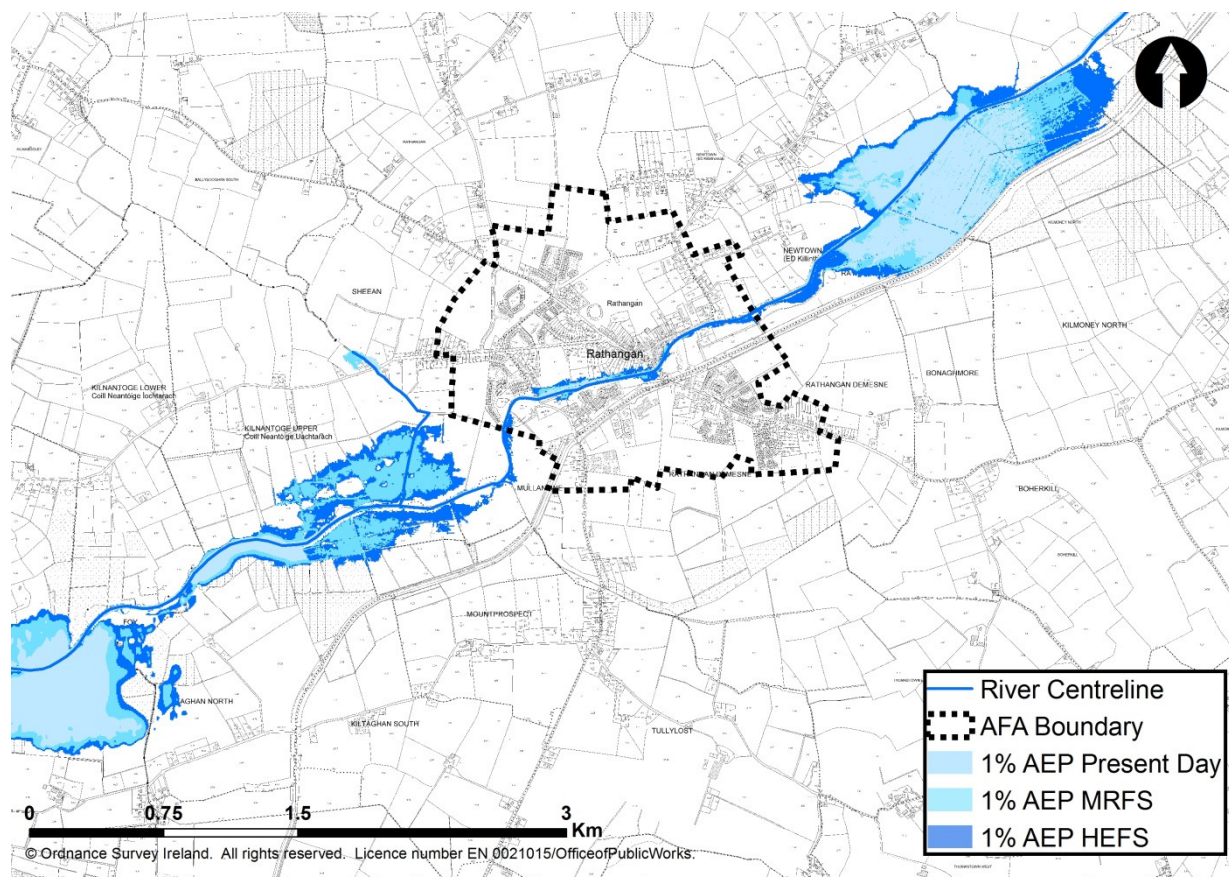
No options were required as there are no properties at risk of flooding during the 1% AEP event. However methods were identified at UoM level (see section 8.1) to be included, along with maintaining the existing regime:

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

#### 8.13.5.1 AFA Sensitivity to Future Change

As shown in Figure 8.13.5.1.1.1.1.1, during a MRFS and HEFS 1% AEP flood event there is no significant increase in flood extent within Rathangan AFA. The extent of flooding is mainly contained within the River Channel. The only area of flooding includes the area around Bridge Street during the HEFS.

During the HEFS an additional 13 properties are estimated to be at risk of flooding when compared to the present day flood risk. The AAD would increase from €0 to €40,662. As a result, Rathangan AFA would be considered to be at moderate vulnerability for the HEFS.



**Figure 8.13.5.1.1.1.1.1**

**Future Change Flood Extents (Rathangan AFA)**

### 8.13.5.2 Local Authority Comments

LA representatives reviewed preliminary options in November 2015. KCC had nothing to add, risk was expected to be low.

### 8.13.5.3 Summary

There is good confidence in both the hydrology and hydraulics of the Rathangan AFA due to the presence of a gauging station and flood extent verification events.

The future change assessment identified that Rathangan AFA is moderately sensitive to climate change.

As no risk was identified in Rathangan AFA and therefore no options were developed, the existing regime should continue in order to maintain the current SoP. The existing and future flood extents should be considered for any proposed planning and development.

Methods also were identified at UoM level (see section 8.1) that are applicable to Rathangan 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

Monastervin AFA is located downstream which should be taken into consideration for any future works carried out in Rathangan.

No risk was identified in Rathangan AFA however the existing regime should be maintained to retain the required SoP.

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



## 8. OPTIONEERING OF SSA'S

### 8.16 Suncroft Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Suncroft	Kildare	140178	AFA	Final	15/06/2016

#### 8.14.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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#### 8.14.2 Flood Cells

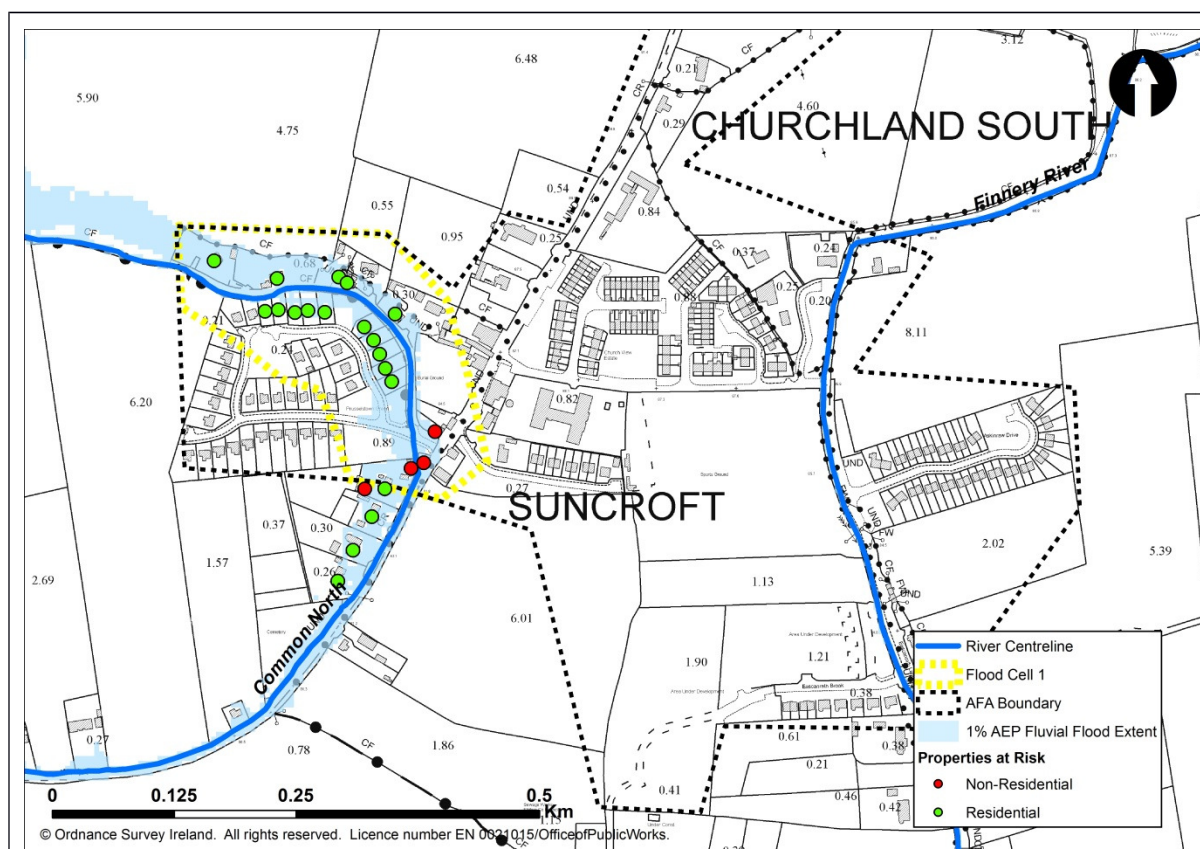


Figure 8.14.2.1.1.1.1.1

Flood Cell 1 within a 1% AEP Fluvial Flood Extent

Suncroft

#### Flood Cell 1:

Due to insufficient channel capacity on the Common North River and the presence of a series of hydraulically critical structures (including 14COMN00247I, 235D, 231D and 220D) 23 properties are affected by flooding, during a 1% AEP fluvial event. Flood cell 1 is defined as a complex flood cell based on the number of properties affected. (see Figure 8.14.2.1.1.1.1.1).

### Summary of Flood Cell:

As shown in Figure 8.14.2.1.1.1.1.1 the main flood risk associated with Suncroft AFA is associated with the Common North River. Flood cell 1 has been defined as a complex flood cell since 23 properties are affected by the flooding resulting from insufficient channel capacity and the presence of several critical structures.

Flood cell 1 is the only flood cell associated with Suncroft AFA, the screening results and option assessment is outlined in Section 8.14.6.

On completion of the optioneering screening assessment, resulting options relating to Suncroft AFA are detailed in Section 8.14.1.

### 8.14.3 Existing Regime

The 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 rivers within Suncroft are not located within a Drainage District or an Arterial Drainage scheme and are, for the most part, in private lands and are not the responsibility of Kildare County Council. Nevertheless, inspections and maintenance are carried out as and when resources are available. The existing regime does not provide the preferred SoP.

### 8.14.4 Summary of Flood Risk within SSA boundary

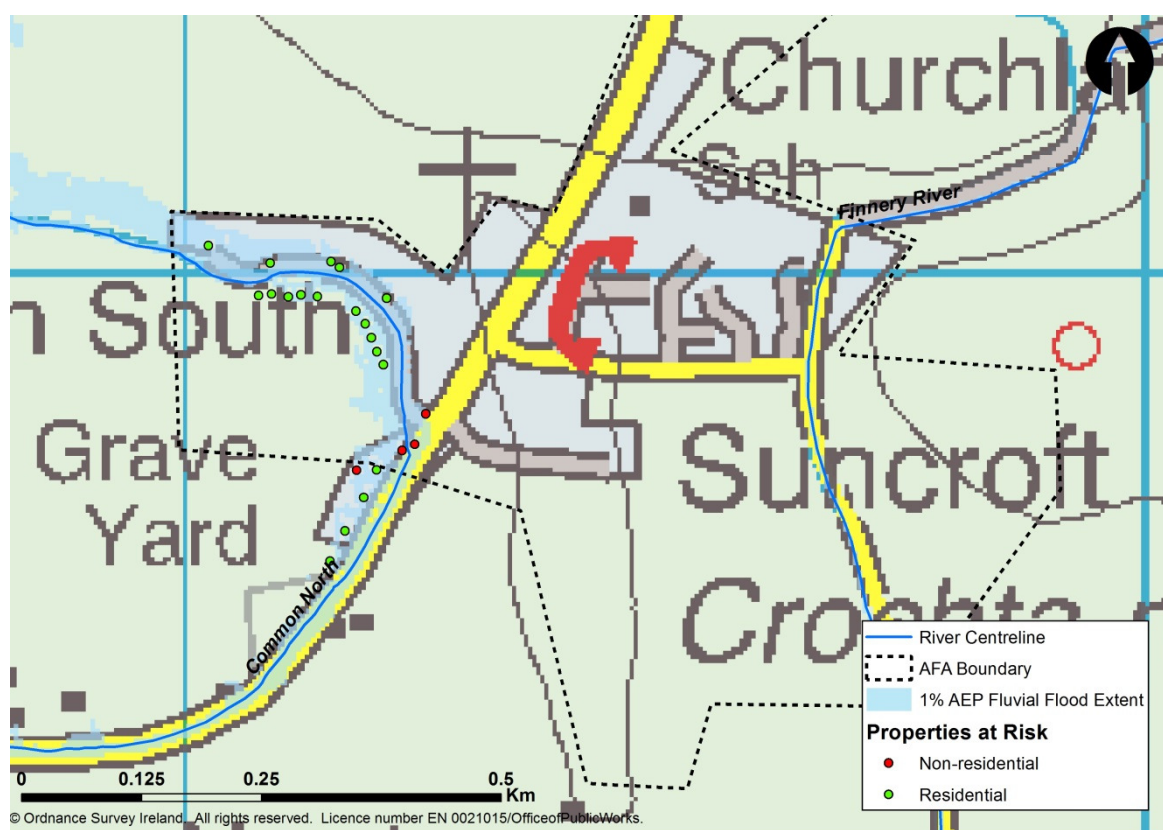


Figure 8.14.4.1.1.1.1.1

Flood risk in Suncroft AFA\* within a 1% Fluvial Event

\* Some properties are located outside of the AFA but have been included in the screening process, as

they are contiguous with the AFA boundary.

In Suncroft AFA the onset of residential and non-residential property damage occurs in the 50% AEP event.

#### 8.14.5 Monetary Damage and Benefit

	Flood Cell 1	Total in AFA
Annual Average Damage (AAD)	€ 142,578	€ 142,578
Present Value Damage (pvD)	€ 3,062,863	€ 3,062,863
Preferred Standard of Protection (SoP)	1% AEP	1% AEP
Number of Properties Benefiting from Design SoP	23	23*
Minimum Present Value Benefit	€2,731,561	€2,731,561
Capped Minimum Present Value Benefit	€2,166,455	€2,166,455

\*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.

5 properties are located outside of the AFA but are included in the Monetary Damage and Benefit estimates in both flood cell 1 and the Total AFA figures.

**8.14.6 Short Listing FRM Methods –Complex Cell (Flood cell 1)**

Method	Review Comment	Continue Screening
		Flood Cell 1
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	✓

## 8.14.6.1 Feasibility Review Summary for Complex Cell (Flood cell 1)

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage	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 impacts identified    ! - Progress, potential for significant impacts identified				

## 8.14.6.2 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	x			
<p>This method considers whether improvements can be made to augment the 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.</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	x			
<p>Do Minimum, applies to the FRM that may include clearance of channels and is also 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>As an example, when applied to flood cell 1 this would mean that individual critical structures (14COMN00247I; 235D, 231D, 220D or 194D); would be upgraded to improve their capacity. Addressing each critical structure in isolation would have a minimal impact on reducing the flooding impact in this flood cell.</p> <p>This is an unacceptable outcome in terms of contributing to achieving a 1%AEP standard of flood protection and this method was therefore rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	x	-	✓	✓
<p>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.</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 reducing 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> <p>A review of the surrounding topography was carried out to locate possible storage areas. One potential storage area was identified that would alleviate flooding within flood cell 1 as shown Figure 8.16.3. A technical assessment has shown that storage would provide protection to 5 properties at risk. The volume of water required to be stored on the Common North watercourse has been estimated to be 35,698m<sup>3</sup>. The construction of a storage area would require a series of embankments with an average height of 2.9m and total length of approximately 150m. In addition, 1 culvert is to be provided to act as a flow control device and convey flow through the embankment.</p>				

Storage is not technically feasible as a standalone method for flood cell1; but could be used in conjunction with another method to create a complete option. An economic review estimated the cost of constructing the storage area to be €305,669 making this method potentially economically viable subject to the costs of the measure with which it is combined.

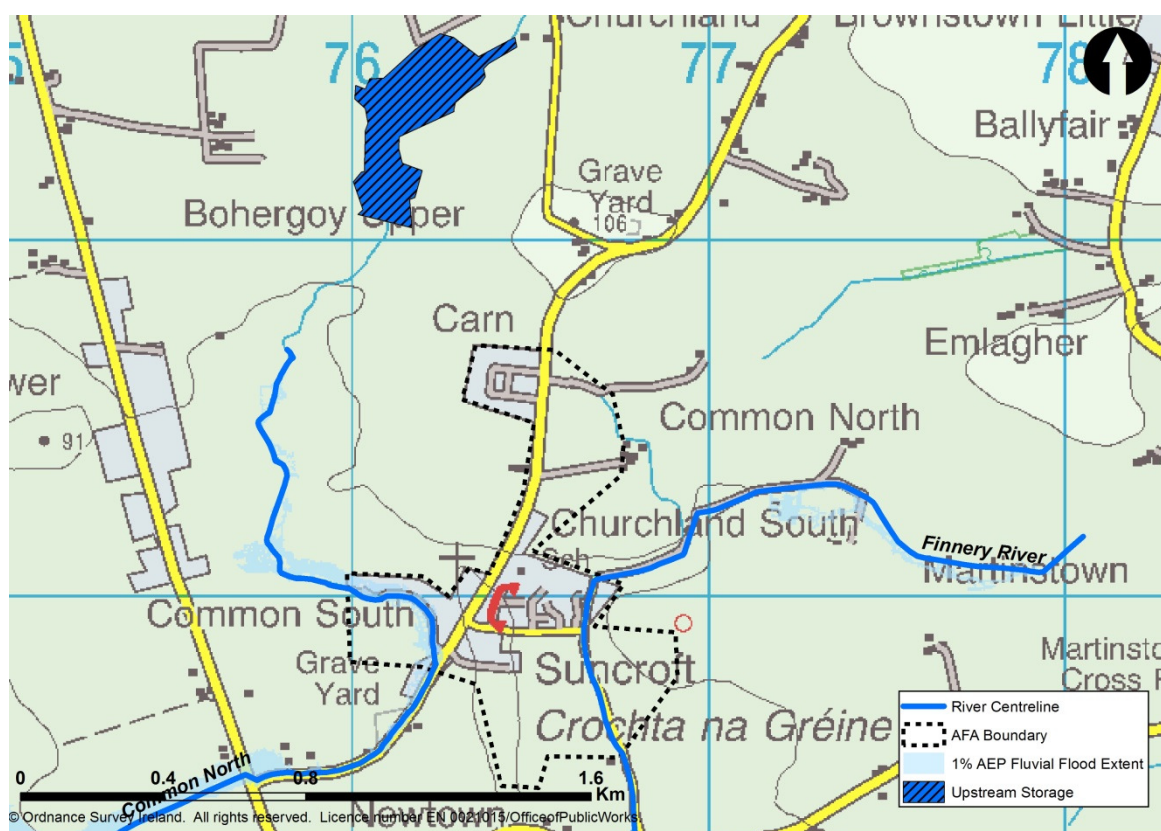


Figure 8.14.6.2.1.1.1.1.1

Potential Storage Options in Suncroft

The River Barrow and River Nore SAC is 4km downstream of the AFA, it is unlikely that the storage of flood waters during a 1% AEP fluvial event should have any significant adverse environmental impact on this location. The Pollardstown Fen SAC and Ramsar Site, and the Mouds Bog SAC are all over 7km north of Suncroft, however these designated areas are not hydraulically linked to the AFA.

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.

Figure 8.14.6.2.1.1.1.1.2 shows where lowering the bed level and upgrading critical structures could ameliorate the flooding. The long section in Figure 8.14.6.2.1.1.1.3 shows a long-section of the extent of channel bed reduction required.

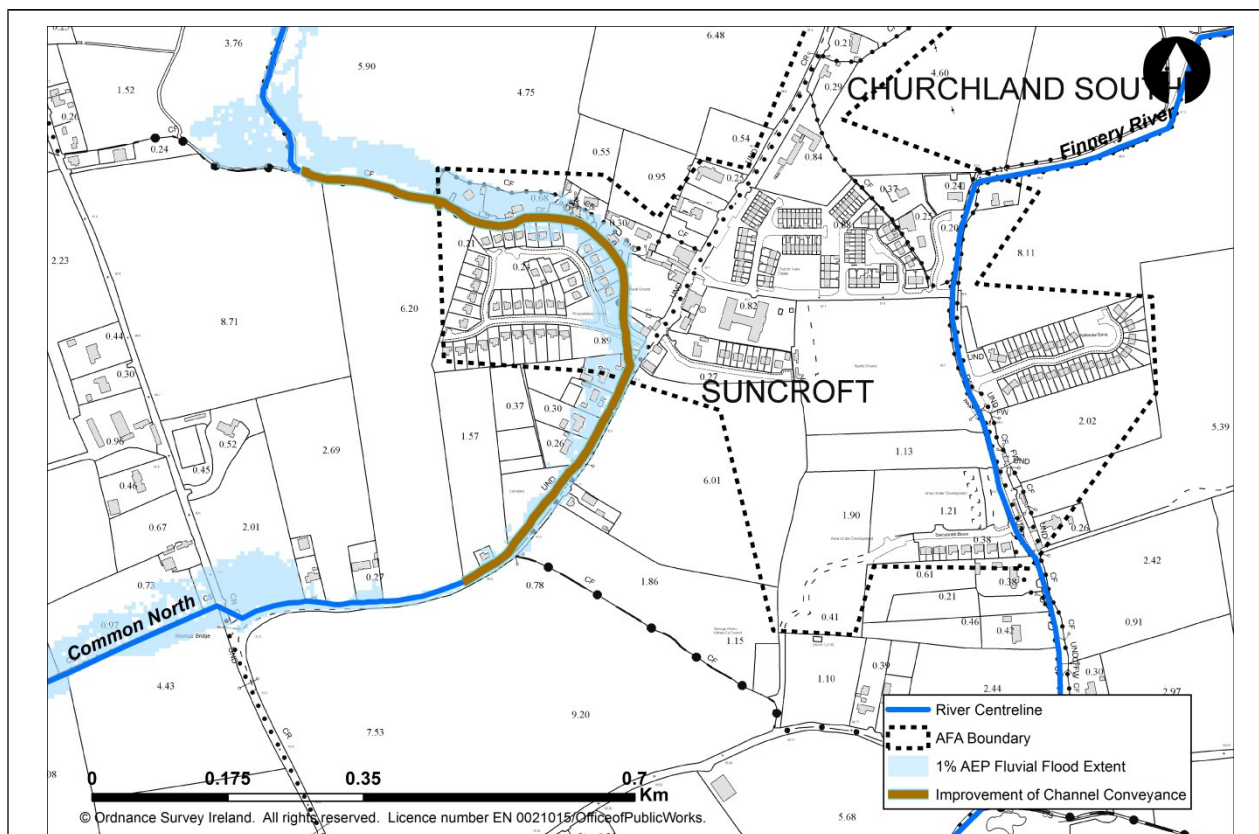


Figure 8.14.6.2.1.1.1.2

Location of Improved Channel Conveyance

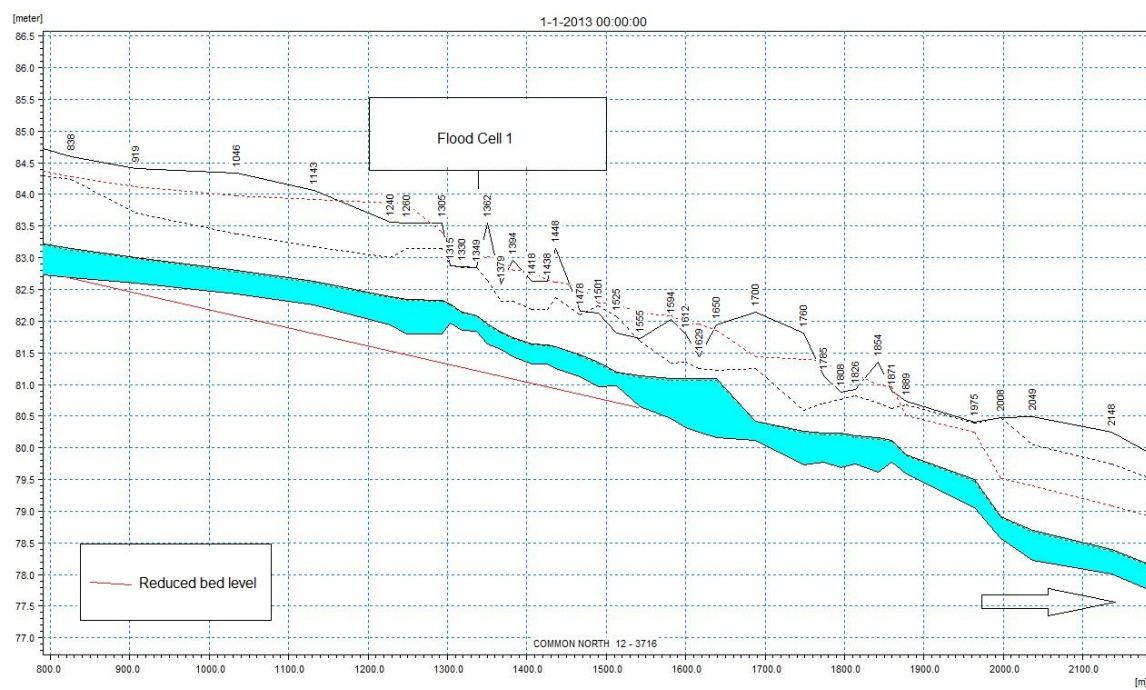


Figure 8.14.6.2.1.1.1.3

Potential Area of Improved Channel Conveyance (Common North River)

In summary, improvement of channel conveyance along the Common North River would involve dredging 0.6km of river, upgrading 4 culverts and underpinning 2 bridges. In applying this scheme, the upgrading of the culvert 14COMN002471 would provide particular benefit to the properties located



upstream of this structure. A capacity assessment indicates the culvert at this point on the Common North River is capable of conveying a maximum of 2.92cumecs, while the peak flow during a 1%AEP event is 4.3cumecs. This means that the diameter of the current culvert should be increased from 1.3m to 2.1m diameter to eliminate surcharging. The enlargement of this culvert would mean that the extent of the 1% flood event would be reduced upstream, but increased downstream. Consequently dredging is required for a further 400m downstream beyond the AFA boundary and increased capacity is required in other critical structures located downstream. All the critical structures 14COMN00235D, 231D, 220D and 194D would need to be improved to increase their current capacity by an average of 0.5cumecs, which means reducing the bed level at these locations by approximately 0.6m.

Model simulations have illustrated that the improvement of channel conveyance as a standalone method is not 100% effective and thus should be considered technically unfeasible. This method could be used in conjunction with another method to create a complete option. An economic review estimated the construction cost of Improved channel Conveyance at €141,590, making this method potentially economically viable subject to the costs of the measure with which it is combined.

Method	Tech	Econ	Env	Soc
Hard Defence	✓	✓	!	✓

The term Hard Defence 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.

For Suncroft, a technical review was conducted to ascertain the optimum locations of Hard Defences, benefitting the greatest number of properties. Figure 8.14.6.2.1.1.1.4 shows the location of Hard Defences with a SoP of 1% AEP.



Figure 8.14.6.2.1.1.1.4

Location of Potential Hard Defences within Suncroft

In order to ascertain the effect 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 0.8m and a total length of 1.3 km. An economic review estimated the cost of the hard defences to be approximately €3,018,114 making this method economically unviable. However a reduced length of Hard Defence when combined with other FRMs may provide an option.

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
Relocation of properties	x	✓	✓	?

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 clusters of properties are located.

An assessment of the distribution of properties within flood cell 1 was carried out. If this scheme was implemented it would require that the cluster of 23 properties are relocated away from this at risk area to an area of less risk. An economic assessment has revealed that based on the current market value of these at risk properties it is estimated that this would cost €8,471,314. Considering the socially negative impacts associated with relocating properties this method should only be considered should if no other method is identified.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✓			

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.

A technical review was conducted to identify possible flow diversion routes. For flow diversion to work it involves diverting flow from upstream of the risk area and discharging it back into the river downstream. A possible flow diversion route which re-directs the Commons North River in a southwards direction from cross-section 14COMN00299 (chainage 739.68m) to re-join the main channel again downstream at cross-section 14COMN00192 (chainage 1807.58) was considered however the adverse gradient rendered this route as technically unfeasible. No further possible flow diversion routes have been identified were the Common North River can by-pass at risk locations within Suncroft.

Method	Tech	Econ	Env	Soc
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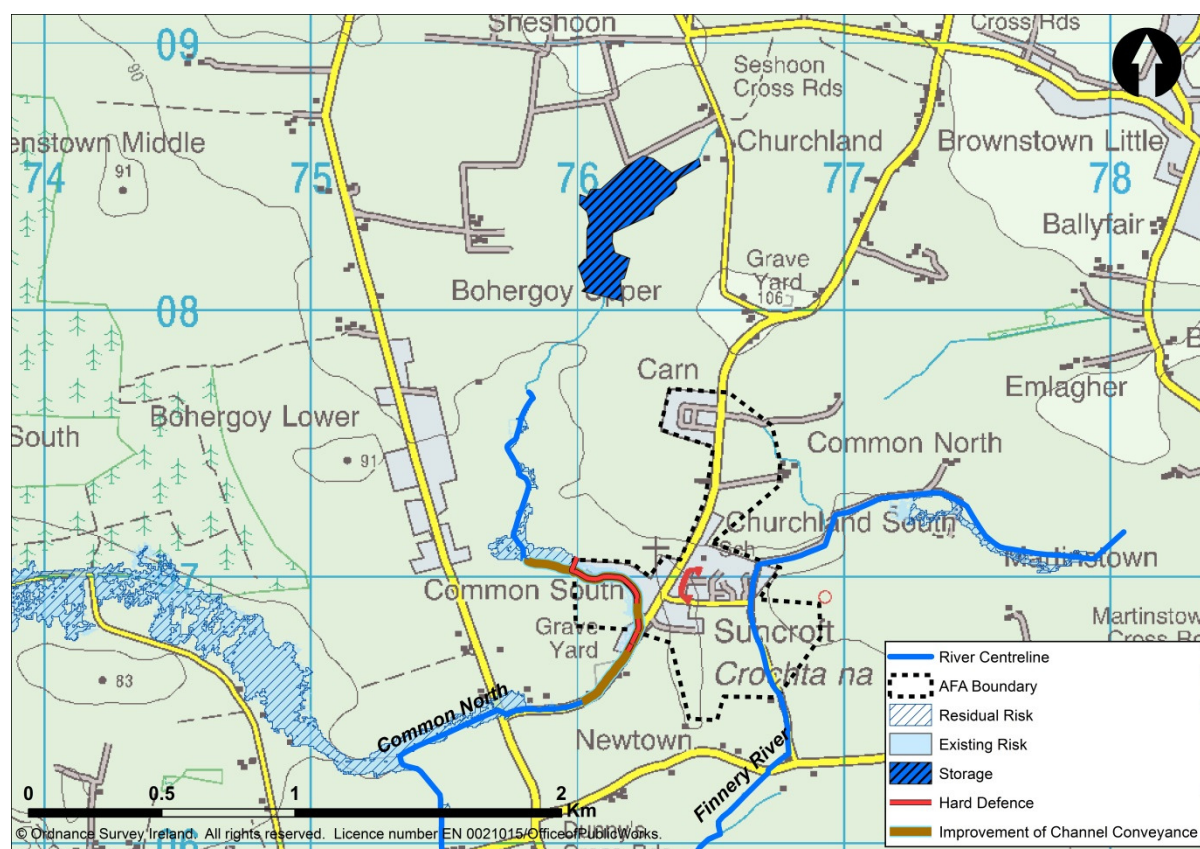


Individual Property Protection	x	✓	✓	✓
<p>This method is aimed at individual properties that are remote from the main risk areas. Where the AFA being considered consists of a small number of remote properties this method is a feasible solution. But for AFAs with multiple properties at risk this method 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 required SoP within flood cell 1, and would therefore not be technically the best method to use. For these reasons this method 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.				
<b>8.14.6.3 Summary of Feasibility Review – Flood Cell 1</b>				
<p>The following FRM methods have been carried forward to address the flood risk arising from flood cell 1 ;</p> <ul style="list-style-type: none"> <li>• Storage</li> <li>• Improved Channel Conveyance</li> <li>• Hard Defence</li> </ul> <p>When Storage is combined with Improved Channel Conveyance and Hard Defences full protection can be provided to all properties in Suncroft during a 1% AEP fluvial flood event. Individual Property Protection should therefore only be used should the combination of the methods listed above, are deemed unsuitable later in the optioneering process.</p>				

#### 8.14.1 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Storage	x				
Improved Channel Conveyance	✓				
Hard Defence	✓				
<p>For flood cell 1 a combination of Storage, Improved Channel Conveyance and Hard Defence can provide the full SoP for the 1% at risk properties during the occurrence of a 1% AEP.</p>					

## 8.6.7.1 Option 1 details – Storage / Conveyance / Hard Defences



**Figure 8.14.1.1.1.1.1.1 Suncroft Option 1**

At risk properties would be protected by the provision of a new storage area located upstream of the Common North. This river (between chainage 739.68 to 1478.5m) will be subjected to improved channel conveyance, whereby the invert level of the channel will be decreased by an average of 0.5m, with further alternations made to the critical structures 14COMN00247I, 235D, 231D and 220D.

Figure 8.14.1.1.1.1.1.1.1 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).

This combined option also requires the construction of approximately 572m of Hard Defence, with an average height of 0.88m. The combination of these methods would protect to the 1% AEP flood within Suncroft AFA. 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
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign



Option Item	Quantity	Construction Cost	
Piled Embankments	150m length, 2m high	€289,950	
Hard Defence (Urban Wall)	522m length, 0.8m high (average)	€681,238	
Hard Defence (Embankment)	51m length,0.6m high average)	€7,068	
In channel excavation	507m³ , bed level lowered 0.6m (average)	€16,224	
Culvert upgrade	As listed above & new culvert for storage method	€54,283	
Bridge underpinning	231D & 220D	€86,802	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
1226	2.83	433.26	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€3,062,863		€2,166,455	0.76

#### 8.14.6.5 AFA Sensitivity to Climate Change Future Change

As shown in Figure 8.14.1.1.1.1.1.2, during a MRFS 1% AEP flood event the increase in flood extent is restricted by the fluvial basin terrain that the Common River North currently flows through. The main area of additional flood risk is associated with School and Newtown Grove area in Suncroft.

An additional 5 properties are estimated to be at risk of flooding when compared to the present flood risk. The ADD would increase from €142,578 to €350,061.

This estimate will increase by another 11 properties when the HEFS 1% AEP flood scenario is applied. The ADD would increase from €142,578 to €691,183.

This increase of properties affected by future scenarios indicates an increase to the annual average damage and the Suncroft area of assessment would be considered at a moderate vulnerability. Options should therefore be assessed in terms of their adaptability to climate change.

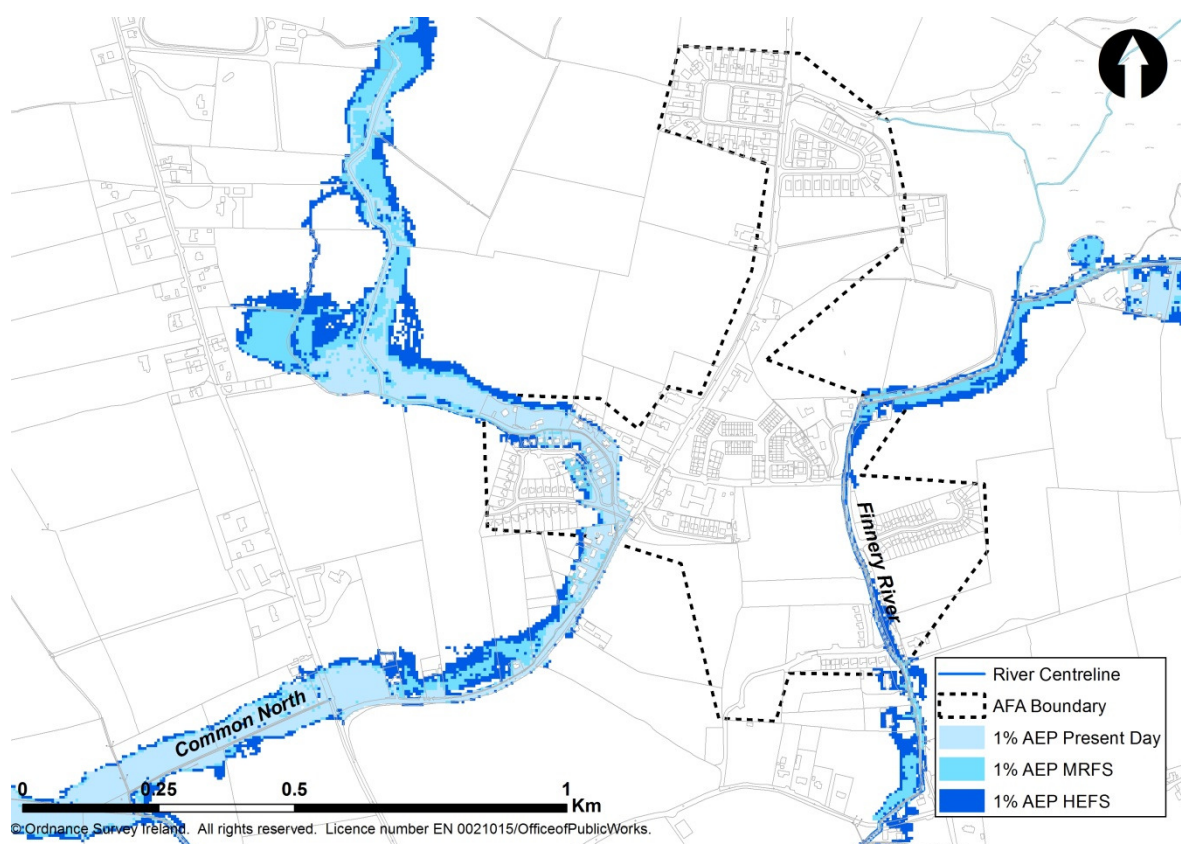


Figure 8.14.1.1.1.1.1.2

Future Change Flood Extents (Flood Cell 1)



#### 8.14.6.7 Future Change Adaptability

The following discusses the adaptability of the potential FRM methods proposed within Suncroft AFA:

**Hard Defence Flood Cell 1** - This method could be adapted by increasing the height of the wall and extending its length. A review of the effect of the MRFS and the HEFS showed that the walls might need to be increased from 0.8m to 1.4m and 1.6m, respectively. This additional wall height could be accommodated. The review also showed that the additional length of wall required would be minimal. To ensure that this wall would be adaptable the design would need to account for the potential increase on wall height. This method is considered to have a **moderate to poor** adaptability.

**Storage Flood cell 1** – This method could be adapted by increasing the height of the retaining structure. 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 3.5m and 4m, for the MRFS and HEFS respectively. Considering that this storage area is located within a rural context it may raise few concerns over the residual risk and social impact. Storage in FC1 would therefore be considered to have a **moderate to poor** adaptability.

**Improved Channel Conveyance Flood cell 1** - This method could be adapted by increasing the culvert capacity of the Common North River channel and critical structures, 4COMN002471, 235D, 231D, 220D and 194D. If the flow was to increase to the MRFS or the HEFS levels these culverts would be rendered insufficient to convey the MRFS and HEFS 1% AEP flow. To be to further increase the culvert capacity would mean increasing the size of these culverts. As adaptation would involve further increasing the size of these culverts and decrease channel invert level. Since increasing the scale of these culverts and channel is already restricted by space, e.g. the presence of residential properties and road; this method is considered to **not adaptable**.

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 these methods other methods aimed at reducing future flood risk has been discussed in section 8.1 at UoM scale. These methods will reduce the vulnerability of potential future receptors. Given that Suncroft is largely rural with a relatively contemporary small population density, the proposed option would have an impact to overall area. Given that there is an 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 campaign.
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. The Option proposed for Suncroft would create this situation.
3. **Does the option deliver co-benefits?** Option 1 requires the creation of a storage area outside of the village; this area could provide co-benefits with recreational and environmental objectives.
4. **Does the option provide flexibility?** A review of the potential option for Suncroft, shows that Hard Defences and Storage, is the most adaptable to the MRFS and HEFS. However alternative FRM methods could be added to all options to provide an increased SoP. This may require the culverting of a section of the Common North River.
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.

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

#### Summary of Option Adaptability

Option	Description	Score
--------	-------------	-------

Option 1 - Storage (FC 1) and Improvement of Channel Conveyance (FC2)	Various element of this option are adaptable at significant cost, difficulty and impact. Those that are not adaptable provide no impediment to future interventions to address new potential future risk areas.	1
<b>8.14.6.8 Local Authority Comments</b>		
LA representatives reviewed preliminary options in December 2015. Kildare County Council had nothing to add relating to the proposed potential option presented. It was further suggested that the landowners involved in storage will be contacted ahead of the PCDs to notify them of the events.		
<b>8.14.6.9 Summary</b>		
<p>There is poor data available for Suncroft AFA with which to verify the model hydrology and hydraulics.</p> <p>The proposed potential option, with a BCR <math>\geq 0.5</math> has been identified:</p> <ul style="list-style-type: none"> <li>Option 1 – Hard Defences combined with Storage and Improved Channel Conveyance.</li> </ul> <p>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.</p> <p>Methods also were identified at UoM level (see section 8.1) that are applicable to Suncroft AFA, that if implemented, will serve to avoid increasing flood risk in the future :</p> <ul style="list-style-type: none"> <li>Planning and Development Control</li> <li>Building Regulations</li> <li>Sub-catchment Wide SuDs</li> <li>Strategic Development Management</li> <li>Public Awareness Campaign</li> </ul> <p>Athy AFA is located downstream and should be taken into consideration for any future works carried out in Suncroft. The flow at the downstream model boundary was reviewed for the 1% AEP current scenario versus the 1% AEP with the option in place scenario. There was a negligible flow difference between the hydraulic model simulations. In addition any interactions with the drainage system within Suncroft may need to be addressed during the development of the preferred option.</p> <p>No critical environmental, cultural heritage or social issues have been identified.</p> <p>It should be noted that this area is sensitive to climate change however no physical provision can be incorporated into detailed design.</p> <p>These recommendations should be taken forward with a view to identification of a preferred option for the flood risk management plan.</p>		

List of background information included:

1. Costings
  - Option 1 - Whole Life Cost
  
2. MCA
  - Option 1 - Hard Defences, Storage & Improvement of Channel Conveyance
  
3. Potential Option Drawings
  - Option 1 - Hard Defences, Storage & Improvement of Channel Conveyance

## 9 SUMMARY OF FRM OPTIONS

Table 9.1 summarises the optioneering appraisal for each AFA within UoM14 considering all SSAs. Details of specific recommendations for each UoM, sub-catchment and AFA can be found in section 8.

**Table 9.1 – Summary of Preliminary Options Identified at AFA SSA within UoM14**

AFA	Design flood event (AEP)	Number of properties at risk in design flood event	Options	Area NPVd	Option NPVb (capped)	Option Cost (€)	Benefit – Cost Ratio	Total MCA-Benefit Score	MCA-Benefit Score / Cost Ratio	Sensitivity to MRFS	Sensitivity to HEFS
UoM14	-	-	<ul style="list-style-type: none"> <li>Sustainable Planning and Development Management</li> <li>Public Awareness Campaign</li> </ul>	-	-	-	-	-	-	-	-
Allenwood	1% Fluvial	2	<ul style="list-style-type: none"> <li>Maintain Existing Regime</li> </ul>	€34,849	€2,735	-	-	-	-	Moderate	Moderate
			<ul style="list-style-type: none"> <li>Option 1 – Hard Defences</li> </ul>	€30,278,083	€13,544,560	€4,112,090	3.29	1642	399.45		
			<ul style="list-style-type: none"> <li>Option 2 – Hard Defences &amp; Relocation of Properties</li> </ul>	€30,278,083	€13,544,560	€4,056,410	3.34	1642	404.89		



AFA	Design flood event (AEP)	Number of properties at risk in design flood event	Options	Area NPVd	Option NPVb (capped)	Option Cost (€)	Benefit – Cost Ratio	Total MCA-Benefit Score	MCA-Benefit Score / Cost Ratio	Sensitivity to MRFS	Sensitivity to HEFS
			<ul style="list-style-type: none"> <li>Option 1 – Hard Defences</li> </ul>	€8,432,650	€846,524	€209,259	4.05	651	3108.65		
			<ul style="list-style-type: none"> <li>Option 2 – Hard Defences &amp; Improvement of Channel Conveyance</li> </ul>	€8,432,650	€846,524	€769,106	1.1	473	614.37		
			<ul style="list-style-type: none"> <li>Option 1 – Hard Defences &amp; Improvement of Channel Conveyance</li> </ul>	€1,714,722	€1,140,087	€2,255,294	0.51	-414	-183.68		
			<ul style="list-style-type: none"> <li>Option 2 – Hard Defences</li> </ul>	€1,714,722	€1,140,087	€2,308,752	0.5	-76	-33.027		

AFA	Design flood event (AEP)	Number of properties at risk in design flood event	Options	Area NPVd	Option NPVb (capped)	Option Cost (€)	Benefit – Cost Ratio	Total MCA-Benefit Score	MCA-Benefit Score / Cost Ratio	Sensitivity to MRFS	Sensitivity to HEFS
Daingean	1% Fluvial	9	<ul style="list-style-type: none"> <li>Land Use Management</li> </ul>	€74,134	€38,322	-	-	-	-	Moderate	Moderate
Graiguenamanagh	1% Fluvial	64	<ul style="list-style-type: none"> <li>Hard Defences</li> </ul>	€1,672,771	€10,260,826	€9,204,904	1.11	1096	119.01	High	High
Leighlinbridge	1% Fluvial	57	<ul style="list-style-type: none"> <li>Hard Defences</li> </ul>	€28,999,499	€3,905,896	€3,291,151	1.19	805	244.56	High	High
Monasterevin	1% Fluvial	13	<ul style="list-style-type: none"> <li>Maintain Existing Regime</li> </ul>	€423,815	€56,919	€261,796	0.22	-	-	Moderate	Moderate

AFA	Design flood event (AEP)	Number of properties at risk in design flood event	Options	Area NPVd	Option NPVb (capped)	Option Cost (€)	Benefit – Cost Ratio	Total MCA-Benefit Score	MCA-Benefit Score / Cost Ratio	Sensitivity to MRFS	Sensitivity to HEFS
Mountmellick	1% Fluvial	45	<ul style="list-style-type: none"> <li>Hard Defences</li> </ul>	€19,096,465	€4,717,397	€3,135,680	1.5	1456	464.38	High	High
New Ross	1% Fluvial 0.5% Coastal	0	<ul style="list-style-type: none"> <li>Maintain Existing Regime</li> </ul>	€1,563,273	€0	-	-	-	-	High	High
Portarlinton	1% Fluvial	144	<ul style="list-style-type: none"> <li>Hard Defences</li> </ul>	€26,624,992	€13,624,398	€5,560,037	2.4	664	119.49	High	High
Suncroft	1% Fluvial	23	<ul style="list-style-type: none"> <li>Option 1 – Hard Defences, Storage &amp; Improvement of Channel Conveyance</li> </ul>	€3,062,863	€2,166,455	€2,829,896	0.76	1226	433.26	Moderate	Moderate

AFA	Design flood event (AEP)	Number of properties at risk in design flood event	Options	Area NPVd	Option NPVb (capped)	Option Cost (€)	Benefit – Cost Ratio	Total MCA-Benefit Score	MCA-Benefit Score / Cost Ratio	Sensitivity to MRFS	Sensitivity to HEFS
			<ul style="list-style-type: none"> <li>Option 1 – Hard Defences</li> </ul>	€6,681,152	€3,335,332	€5,476,930	0.61	505	92.28		
			<ul style="list-style-type: none"> <li>Option 1 – Hard Defences &amp; Storage</li> </ul>	€6,681,152	€3,335,332	€3,917,903	0.85	376	96.01		
			<ul style="list-style-type: none"> <li>Option 1 – Hard Defences &amp; Improvement of Channel Conveyance</li> </ul>	€6,681,152	€3,335,332	€6,148,118	0.54	341	55.49		
Rathangan	1% Fluvial	0	<ul style="list-style-type: none"> <li>Maintain Existing Regime</li> </ul>	€0	€0	-	-	-	-	Low	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, UoM14 Inception Report, IBE0601Rp0005 (RPS, 2012)
4. South Eastern CFRAM Study, UoM14 Hydrology Report, IBE0601Rp0011 (RPS, 2013)
5. South Eastern CFRAM Study, UoM14 Hydraulics Report, IBE0601Rp0017 (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)



