Comhairle Contae Fhine Gall
Fingal County Council

Fingal East Meath Flood Risk Assessment & Management Study

(FEM FRAMS)

Final Report

July 2014

fingal.ie

Contents amendment record

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1	0	Draft	February 2011	AMC
2	1	Final version of Draft Final Report	September 2011	AMC
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List of abbreviations

AAD	Annual Average Damages
AEP	Annual Exceedence Probability
APSR	Area of Potential Significant Risk
APMR	Area of Potential Moderate Risk
AU	Analysis Unit
BCR	Benefit Cost Ratio
CFRAMS	Catchment Flood Risk Assessment and Management Study
DAFF	Department of Agriculture, Fisheries and Food
DCFPP	Dublin Coastal Flooding Protection Project
DEHLG	Department of Environment, Heritage and Local Government
DTM	Digital Terrain Model
EPA	Environmental Protection Agency
ERBD	Eastern River Basin District
ERFB	Eastern Regional Fisheries Board
EU	European Union
FRM	Flood Risk Management
FRMP	Flood Risk Management Plan
HEFS	High End Future Scenario
HPW	High Priority Watercourse
ICPSS	Irish Coastal Protection Strategy Study
IRR	Individual Risk Receptor
Km	Kilometre
km^2	Square kilometre
LiDAR	Light Detection And Ranging
m	metre
m^3	Cubic metre
MCA	Multi Criteria Analysis
MDSF	Modelling Decision Support Framework
mm	millimetre
MPW	Medium Priority Watercourse

MRFS	Mid Range Future Scenario
OPW	Office of Public Works
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
WFD	Water Framework Directive
WTP	Water Treatment Plant
WWTW	Waste Water Treatment Works
Yr	Year
+ve	Positive
-ve	Negative

Executive Summary

Introduction

Flood risk in Ireland has historically been addressed through the use of structural or engineered solutions. In 2004 the Irish Government adopted a new policy that shifted the emphasis towards a catchment based context for managing flood risk, with more proactive risk assessment and management, and increased use of non-structural and flood impact mitigation measures.

Flood Risk Assessment and Management (FRAM) studies are at the core of this new national policy for flood risk management and the strategy for its implementation. This policy is in line with international best practice and meets the requirements of the EU Floods Directive[1].

In 2008, Fingal County Council (FCC), the Office of Public Works (OPW) and Meath County Council (MCC) appointed Halcrow Barry to carry out the Fingal East Meath Flood Risk Assessment and Management Study (FEM FRAMS). This study is one of four pilot projects for the National FRAM programme within Ireland. The main stated objectives for FEM FRAMS are to:

- assess flood risk, through the identification of flood hazard areas and the associated impacts of flooding;
- build the strategic information base necessary for making informed decisions in relation to managing flood risk and provide appropriate data to inform future spatial planning and development;
- identify viable structural and non-structural measures and options for managing the flood risks for localised high-risk areas and within the study area as a whole; and
- prepare a strategic flood risk management plan for the Fingal East Meath area, namely, the Fingal East Meath Flood Risk Management Plan (FEM FRMP) and associated Strategic Environmental Assessment (SEA) that sets out the measures and policies that should be pursued by the Local Authorities and the OPW to achieve the most cost-effective and sustainable management of flood risk within the Fingal and East Meath study area.

This report is the draft Final Report for the FEM FRAMS and summarises all the work undertaken to complete this study. The focus of the report is the flood risk management option development and assessment process, which forms the basis of the strategy as reported in the FEM FRMP.

A number of activities have been undertaken throughout the study, which provides the basis for the assessment of flood risk management options. The main activities include public and stakeholder consultation, data collection, topographic survey of channel cross sections, bridges/culverts and defence assets geometry, hydrological analysis, hydraulic modelling, flood mapping for the current and future scenarios, flood risk assessment, preliminary options assessment and Strategic Environmental Assessment. The details of these activities have already been reported in various technical reports. An overview of each of these activities is presented in this draft Final Report.

[1] EU Council Directive 2007/60/EC on the assessment and management of flood risks

The Preliminary Options Report

The flood risk management option development and assessment process commenced with the preparation of the Preliminary Options Report (December 2010). To ensure the correct focus in determining appropriate flood risk management measures and options, the study area was divided into different areas, called assessment units. These are defined at four spatial scales; study area scale, analysis unit (AU) scale (large subcatchments), areas of potential significant risk (APSR) and individual risk receptors (IRR) which are essential infrastructure assets.

The Preliminary Options Report described the decision-making framework that has been developed and used to ensure that the assessment of flood risk management measures and options are evidence-based, transparent, and inclusive of stakeholder and public views. The SEA and AA have been fully integrated within the decision making framework to ensure that environmental considerations, such as the requirements for the protection of internationally designated nature conservation sites, are incorporated within the decision-making process.

The flood maps produced for the study have been used to identify the level of flood risk in the study area to five flood risk receptor groups: human health (including risk to life); the environment; cultural heritage; critical infrastructure and the economy. An assessment of the vulnerability of each type of identified cultural feature /site (i.e. receptor) was classified based on the importance of the receptor and the degree of potential damage. The risk to the economy focussed on the economic flood damages to residential and non-residential properties in the study area and was determined using the Flood Hazard Research Centre (FHRC) depth damage curves.

Where the economic risk to properties was significant, a full suite of flood risk management measures was assessed for the AUs, APSRs and IRRs. The assessment involved an evaluation of the applicability of a measure for a particular assessment unit and then scoring measures for the assessment units against four core criteria; technical, economic, social and environmental. The scoring of measures was based on the technical viability of a measure and the level of existing economic, social and environmental flood risk in the assessment unit being considered. In addition, the potential impact of a measure on features and assets in the assessment unit was also considered. The outcome from the Preliminary Options Report was a number of viable flood risk management measures for the AUs, APSRs and IRRs in the study area.

Draft Final Report

The purpose of this draft Final Report is to build on the outcome of the Preliminary Options Report; to use these viable measures to develop options; and to assess these options using a multi-criteria analysis.

As discussed in the POR, the objectives cover four core criteria:

(i) Technical: three objectives covering operation (i.e. measures are operationally robust), health and safety and sustainability of FRM options;

(ii) Economic: four objectives covering economic risk, risk to transport infrastructure, risk to utility infrastructure and risk to agricultural land;

(iii) Social: three objectives covering risk to human health and life, community and social amenity; and

(iv) Environmental: six objectives covering the requirements of the Water Framework Directive, risks from pollution, flora and fauna, fisheries, landscape character and cultural heritage.

Associated with each of the objectives are sub-objectives, indicators, minimum targets and aspirational targets. This information is used to assess options as part of the multi criteria assessment, with options scored on how well they perform in meeting the minimum and aspirational targets. The performance of each option against the objectives is reflected in the scores shown on the stage 3 spreadsheets.

Two sets of weighting have been applied to the objectives;

Global weighting; and

Local weighting.

The global weightings have been developed by the OPW and are fixed nationally; they are unchanged for each assessment unit. This level of weighting recognises the key drivers behind FRM options and gives higher weightings to risk to human health and life and economic return on options. Table 4-1 sets out the global weightings.

The local weighting of each objective varies for each assessment unit depending on the level of applicability of that objective to that unit. For some objectives, the local weighting could be 0, since the objective does not apply to that part of the study area. Table 4-2 sets out the range of local weightings that can be applied.

The performance of each option, relative to defined baseline conditions (the present day situation) was scored for each of the sixteen FRM objectives. Following scoring, for each objective, a weighted score was then calculated for each option (where the weighted score = global weighting x local weighting x options performance score). A total multi criteria assessment (MCA) score was then calculated for each objective as the sum of the weighted scores across the 16 objectives for each option. All FRM options with positive MCA scores were then carried forward to the final stage of the process – the identification and assessment of the preferred options.

An ‘appropriate assessment’ of the impacts of the draft FEM FRMP on the sites of European nature conservation importance (Natura 2000 sites) within the study area has also been undertaken

The assessment of flood risk in the study area indicates that the majority of the flood risk to properties is along the Fingal and Meath coastline and estuaries where areas are at risk from both fluvial and coastal flooding. The majority of the IRRs at risk are waste water treatment facilities (waste water treatment plants and pumping stations) and two National Roads.

The preferred options are summarised in the two tables below and as detailed in Chapter 15 of this report.

Preferred options identified for the study area, AUs and APSRs

Spatial scale	Preferred Options
Study area	
Study area	Development (Meath) and enhancement (Fingal) of a **proactive maintenance regime** targeting potential culvert blockage locations.
	Targeted public **awareness and education** campaign and **individual property flood proofing**.
Analysis Unit (AU)	
Nanny & Delvin (N&D)	Develop a fluvial **FFWS** for the **Nanny River**
Broadmeadow & Ward (B&W)	Develop a fluvial **FFWS** for the **Broadmeadow River**
Mayne & Sluice (M&S)	Develop a fluvial **FFWS** for the **Mayne River**
Coastal (C)	Develop a combined fluvial and tidal **FFWS**
Area of Potential Significant Risk (APSR)	
Duleek area (N&D AU)	**Raising existing defence** embankment to a higher standard of protection (to protect up to 0.1% AEP). (For potential longer term implementation)
Ratoath area (B&W AU)	**Improving channel conveyance** by replacing a bridge on the Broadmeadow River at the R125 Ratoath Road, and replacing a culvert along a tributary of the Broadmeadow River with a larger capacity culvert
Rowelstown East area (B&W AU)	Construction of **flood defence embankments** along left bank of Broadmeadow River tributaries upstream of R125
St.Margaret's, Dublin Airport, Belcamp & Balgriffin areas (M&S AU)	**Balgriffin: Improving channel conveyance** by removing old bridge structure combined with construction of flood defence embankments and walls upstream of R123 and along left bank of Mayne River
Portmarnock & Malahide areas (C AU)	**Portmarnock: Rehabilitating and raising** existing coastal defences at **Strand Road** (including rehabilitation of flapped outfall) and construction of flood defence **embankment**.
	Malahide town centre: Construction of demountable flood defences at underpass along with embankments to protect at risk properties in Malahide town centre.
Laytown, Bettystown & Coastal area (C AU)	Construction of flood defence **embankments** to protect properties at risk along the coast and from the **Nanny River**.
Swords area (C AU)	Improve channel conveyance by **widening and deepening** of the Gaybrook Stream to reduce fluvial flood risk to properties at **Aspen near Kinsaley**.
Rush area (C AU)	Improve conveyance by constructing secondary **culvert** along **Channel Road** to protect properties at risk from fluvial flooding along the West Rush stream.
Skerries area (C AU)	Improve channel conveyance by **replacing culverts** under roads and railway with larger capacity culverts, and **widening** channel through park to reduce fluvial flood risk to properties at **Miller Lane and Sherlock Park**.

Preferred options identified for the IRR

Risk receptor	Location	Likely FRM option
Utility asset at Stamullin	Stamullin area APSR	Construction of localised flood defence embankments or IPFP
WWTW at Ballyboghil	Ballyboghil area APSR	Construction of localised flood defence embankments
M1 at Staffordstown	Ballyboghil & Lusk AU	Construction of localised flood defence embankments
Wastewater pumping station in Ashbourne	Ashbourne area APSR	Construction of localised flood defence embankments
WWTWs at Toberburr	Owens Bridge area APSR	Construction of localised flood defence embankments
N32 at Clonshaugh	St Margaret's, Dublin Airport, Belcamp & Balgriffin areas APSR	Construction of localised flood defence embankments
WWTWs at Julianstown	Julianstown area APSR	Construction of localised flood defence embankments

The methodologies and processes developed throughout the FEM FRAMS are suitable for use on future projects but some refinement will be required. Key recommendations for consideration when undertaking future studies include; setting up of national specifications, datasets and databases, developing standard methodologies for undertaking important aspects of work, reducing the level of detail in some areas, ensuring areas being assessed are at significant flood risk and undertaking consultation at key project stages (not specifically key SEA stages).

Overall, the methodologies and outputs from the FEM FRAMS provide a robust, transparent and defendable decision making process for managing flood risk in the Fingal East Meath study area and Ireland.

All of this information, including the results of all the studies, investigations and the consultation process, will feed into the final deliverable for the project namely the Flood Risk Management Plan (FRMP).

1. Introduction

Background

Flooding is a natural process that can happen at any time in a wide variety of locations, and its causes, extent and impacts are varied and complex. There is a consequent risk when people and human assets, property, infrastructure, agricultural land, heritage, etc., are present in the area that floods.

Flood risk in Ireland has historically been addressed largely through a reactive approach and the use of structural or engineered solutions. In line with internationally changing perspectives, the Irish Government adopted a new policy in 2004[2] that shifted the emphasis in flood risk towards:

- a catchment context for managing risk;
- more proactive risk assessment and management, with a view to avoiding or minimising future increases in risk; and
- increased use of non-structural and flood impact mitigation measures.

Notwithstanding this shift, engineered solutions to manage existing risks are likely to continue to form a key component of any flood risk management strategy.

Catchment Flood Risk Assessment and Management Studies (CFRAMSs) and their product - Catchment Flood Risk Management Plans (CFRMPs) - are at the core of this new national policy for flood risk management and the strategy for its implementation. These studies have been developed to meet the requirements of the EU Directive on the assessment and management of flood risks (the Floods Directive[3]).

Underlying this policy shift is the acceptance of flooding as a natural phenomenon and the realisation that we must learn to live with and adapt to flood events. An integrated, holistic and catchment-based approach to flood risk management is the way forward, something that is consistent with and complements the Water Framework Directive[4] (WFD).

[2] Report of the Flood Policy Review Group, OPW, 2004

[3] EU Council Directive 2007/60/EC on the assessment and management of flood risks

[4] EU Water Framework Directive (2000/60/EC)

FEM FRAMS

Fingal County Council (FCC) commissioned Halcrow Barry to undertake the Fingal-East Meath Flood Risk Assessment and Management Study (FEM FRAMS) in May 2008. The study is being carried out in conjunction with the Office of Public Works (OPW) and Meath County Council (MCC).

FCC, OPW and MCC have recognised the existing flood risk in the Fingal and East Meath area. There is also potential for significant increases in this risk due to climate change, ongoing development and other pressures that may arise in the future.

The Fingal East Meath study area comprises a group of 23 rivers and streams, three estuaries and the Fingal and Meath coastline. The study area is approximately 772km^2 in plan area (Figure 1-1). A more detailed figure of the study area with the modelled watercourses (high priority watercourse (HPW) and medium priority watercourses (MPW)), existing defences and areas of potential significant risk (APSRs) is included at the back of this report as Figure 1.

The study area is bounded by the River Boyne & Mornington River catchment areas to the north and west, the Tolka and Santry river catchments to the south, and by the Irish Sea to the east. All watercourses in the study area flow to the Irish Sea either directly or via the three estuaries (Baldoyle, Broadmeadow and Rogerstown).

The study involves modelling 23 rivers and streams in the study area and three estuaries as detailed in Table 1-1 below. Modelling of surface water (pluvial) flooding and coastal flooding was also undertaken.

Table 1-1 Rivers, streams and estuaries included in the FEM FRAMS

River name (abbreviation)		
Mayne River (MAY)	Baleally Stream (BAY)	Balbriggan North Stream (BNS)
Sluice River (SLU)	Bride's Stream (BRI)	Delvin River (DEL)
Gaybrook Stream (GAY)	Jone's Stream (JON)	Mosney Stream* (MOS)
Ward River (WAR)	Rush West Stream (RWS)	River Nanny (NAN)
Broadmeadow River (BRO)	Rush Town Stream (RUT)	Brookside's Stream (BSS)
Lissenhall Stream (LIS)	St Catherine's Stream (CAT)	
Turvey River (TUR)	Rush Road Stream (RUR)	Baldoyle Estuary
Ballyboghil River (BAL)	Mill Stream (MIL)	Broadmeadow Estuary
Corduff River (COR)	Bracken River (BRA)	Rogerstown Estuary

** The Mosney Stream is also known as the Bradden Stream*

Figure 1-1 Fingal-East Meath study area

(Refer to Figure 1 at the back of the report for more detail).

Objectives

In line with Government policy, the Fingal East Meath Flood Risk Assessment and Management Study (FEM FRAMS) was initiated, its objectives being to:

Identify and map the existing and potential future flood hazard and risk areas within the study area;

Build the strategic information base necessary for making informed decisions in relation to managing flood risk in the study area;

Identify viable structural and non-structural measures and options for managing the flood risks for localised high-risk areas and within the study area as a whole; and

Prepare a Flood Risk Management Plan (FRMP) for the study area, and associated Strategic Environmental Assessment (SEA), that sets out the measures and policies, including guidance on appropriate future development, that should be pursued by the Local Authorities, the OPW and other Stakeholders to achieve the most cost-effective and sustainable management of flood risk within the study area taking account of the effects of climate change and complying with the requirements of the Water Framework Directive.

The flood hazards and risks to be addressed include both those that currently exist and those that might potentially (foreseeably) arise in the future. While the FEM FRAM Study considers flood risk on a study area rivers/streams catchment-wide basis, it has focused on areas where the flood risk was understood to be, or might become, significant (the Areas of Potentially Significant Risk, or 'APSRs'). These areas were identified by the Local Authorities (FCC and MCC) and the OPW based on historic records of flooding and the local knowledge of the Local Authorities and OPW staff.

FEM FRAMS also includes a Strategic Environmental Assessment (SEA) to ensure that environmental issues and opportunities for enhancement are fully considered throughout and integrated with the development of the FRMP and that the identified long-term strategy is environmentally appropriate.

Purpose of the Final Report

The purpose of this report is to build upon previously submitted project reports and detail the work and analysis undertaken, and the resulting findings and conclusions, to define the preferred options for the flood risk management strategy. Chapter two of this report provides an overall summary of the consultation process, the data collected, methodology used, analyses undertaken and a summary of the main technical report to date. This chapter also discusses the Preliminary Options Report (December 2010) which provided detail on the potential flood risk management measures identified for the FEM FRAMS study area.

The remaining sections of the Final Report detail the assessment and appraisal process used to identify options for managing flood hazard in the study area. The flood hazards and risks to be addressed include both those that currently exist and those that might potentially arise in the future, as a result of, for example, climate and land use change. In order to identify suitable flood risk management measures and options, a decision making framework has been developed for the study (Chapter four).

Details of various reports prepared as part of the FEM FRAMS are included on the project website, www.fingaleastmeathframs.ie and available from the Local Authorities (FCC and MCC) and the OPW.

Interface with other studies

Reference has been made throughout this study with other projects which relate to this study area or to this type of study. A full list of references is included at the back of this report. In particular reference was made to the following key studies:

- **Dublin Coastal Flooding Protection Project (DCFPP).** This project was undertaken by Royal Haskoning for Dublin City Council and Fingal County Council and the final report was published in April 2005. The project covers the Dublin City coastal area from Martello Tower in Sandymount to the North of Portmarnock. The DCFPP Report included information on existing defence assets, tide levels, drawings showing the extent of the February 2002 tidal flood event, predictive flood hazard maps for the 0.5% AEP tidal event and proposed flood protection works. The results of this study were considered in the Hydraulics report and the results of the defence asset survey were incorporated into the FEM FRAMS Defence Asset Database (DAD).

- **Irish Coastal Protection Strategy Study (ICPSS) Phase III.** This project was undertaken by RPS consulting for DAFF (now incorporated into the OPW). The Draft Final Technical Report was published in August 2008. The ICPSS covered the coastline between Dalkey and Omeath. The ICPSS used numerical modelling of combined storm surges and tide levels to obtain extreme water levels along the coastline. The application of extreme value analysis and joint probability analysis to both historic recorded tide gauge data and data generated by the numerical model allowed an estimation of the extreme water levels of defined exceedance probability to be established along the coastline. The resulting floodplain maps, including flood depth maps, were compared to the coastal results for the FEM FRAMS study.

- **Greater Dublin Strategic Drainage Study**. This project was undertaken by RPS consulting for Dublin City Council. The Report was published in March 2005 and includes information about the study area, hydrological analysis, joint probability analysis, recommendations for flood proofing and so forth.

- **Mornington District Surface Water and Flood Protection Scheme**. The Preliminary Report was published in January 2004 by Kirk McClure Morton for Meath County Council and OPW. The Mornington River is located to the north of the FEM FRAM study area and the river discharges into the Boyne River. The proposed flood defence works are currently under construction and hence this river has not been included in the FEM FRAM study area. Information in relation to tide and flood levels and joint probability analysis was sourced from this study.

- **The Planning System and Flood Risk Management Guidelines for Planning Authorities**. This report was published by the DEHLG and the OPW in November 2009. The guidelines requires the planning system at national, regional and local levels to avoid development in flood risk areas; adopt a sequential approach to flood risk management; and to incorporate flood risk assessments into planning applications. The flood zone maps produced for FEM FRAMS are consistent with the requirements of the guidelines.

2. Project activities

Introduction

Figure 2-1 shows a flow chart setting out discrete, but inter related project activities that are undertaken as part of a flood risk management study (FRAMS). Over the last three years work has been completed on the majority of these activities which has provided the evidence base on which to determine the identification and assessment of flood risk management measures and options. The main activities included public and stakeholder consultation, data collection, topographic survey of channel cross sections, bridges/culverts and defence assets geometry, hydrological analysis, hydraulic modelling, flood mapping for the current and future scenarios, flood risk assessment, preliminary options assessment and Strategic Environmental Assessment. The details of these activities have already been reported in various technical reports.

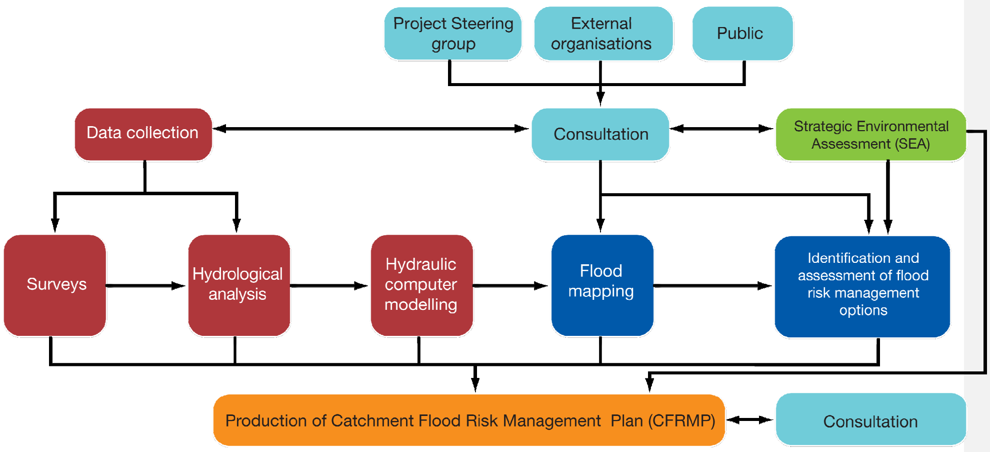


Figure 2-1 Flowchart of key project activities

Details of the project reports associated with the various project activities which have been completed to date are provided in Table 2-1. A number of technical notes were also issued to support these project reports. A brief summary of each of the reports completed to date are detailed below. Further information is available in each of the project reports.

Table 2-1 Project reports associated with project activities undertaken to date

Project Stage	Activities	Reports
Consultation	Consultation	Environmental Scoping Report (June 2009) AA Screening Report (February 2011)
Strategic Environmental Assessment (SEA)	Strategic Environmental Assessment	
Assessment of flood risk	Data collection	Hydrology Report (April 2010)
	Surveys Hydrological Analysis Hydraulic computer modelling	Hydraulics Report (draft August 2010, February 2011)
Management of flood risk	Flood mapping Identification and assessment of flood risk management options	Preliminary Options Report (December 2010) Draft Final Report (February 2011)

This chapter provides details on the following project activities undertaken since the commencement of the project in May 2008;

- Consultation
- Data collection
- Surveys
- Hydrological analysis
- Hydraulic modelling;
- Flood mapping;
- Preliminary options assessment; and
- SEA

Consultation

Consultation at various phases of the project was important to both meet statutory requirements for consultation with relevant parties as well as to ensure that the knowledge, experience and views of the project steering group, stakeholders and the general public were taken into account throughout the development of the FRMP. Further details of all consultation events undertaken throughout the study are provided in the SEA Environmental Report (March 2011).

Project steering group

The Project Steering Group, which included representatives from Fingal County Council, Meath County Council and the OPW, was responsible for overseeing and directing the study, and reviewing key outputs and deliverables.

Dissemination of information related to FEM FRAMS and feedback

The dissemination of information relating to the FEM FRAM Study to stakeholders and to the general public and receiving feedback was undertaken throughout the study period, through the following measures:

- The creation and maintenance of a project website www.fingaleastmeathframs.ie;
- The provision of a dedicated email address fem-frams@fingalcoco.ie to receive feedback;
- The publication of the newsletters on the project website, making the hard copies available at local council offices and public libraries in the study area, emailing copies to persons that had registered on the project website; and
- The publication of all final reports and flood extent maps on the project website.

Stakeholder consultation

A range of statutory, non-statutory and local organisations were identified as stakeholders and were invited to get involved in the development and future implementation of the FEM FRMP and associated SEA. These stakeholders included:

- Planning, Transport and Water Services personnel from FCC and MCC;
- Area Engineers from the OPW;
- Environmental bodies;
- Government departments and agencies;
- Local political representatives;
- Non-governmental organisations; and
- Local business and industry representatives.

The complete list of the stakeholders involved in the FEM FRAMS is included in Appendix K.

Opportunities provided to interested stakeholders to participate in the development of the FRMP and its SEA included:

- An introductory letter and questionnaire were issued to all potential interested parties seeking data and their views on the key issues within the FEM study area;
- Three stakeholder workshops were held in February 2009, June 2010 and November 2010 to discuss progress and to seek feedback on the developing outputs of the study;

- Invitations to comment on project outputs such as the Environmental Scoping Report published for formal consultation in June 2009;
- Two mapping workshops were held in December 2009 and March 2010 to discuss the 10% and 1% AEP flood outlines with the local area engineers from the Local Authorities and the OPW.
- In addition, presentations were made to the Fingal County Council and Meath County Council main council meetings and to the Strategic Policy Committees (SPCs), to the FCC and MCC Planning Departments and at the National Hydrology Conferences in both 2009 and 2010.

All feedback and comments received from these consultation and engagement activities have contributed to the development and outcomes of the FEM FRMP and its SEA.

Public consultation

A series of four public information and consultation days were held in November 2010 in the key locations around the study area as follows:

- 22nd November 2010 at Fingal County Hall, Swords;
- 23rd November 2010 at Ashbourne Library;
- 24th November 2010 at Balbriggan Library; and
- 25th November 2010 at Duleek Library.

The objectives of the November 2010 public consultation process was to ensure people were aware of the study and had sufficient opportunity to express their views and comments on the draft outputs (i.e. the draft flood maps); and to discuss the FRM options under consideration. Further details of all consultation events undertaken throughout the FEM FRAM study area are provided in the SEA Environmental Report (ER).

The next and final stage of the consultation process will start with the publication of the draft FEM FRMP and accompanying SEA ER.

Data Collection

A significant amount of data was collected throughout the study, which provided the basis for undertaking the various assessments and analyses including hydrological analysis, hydraulic modelling, pluvial assessment, groundwater hazard assessment, geomorphological assessment and SEA.

Table 2-2 below summarises the various data collected as part of the FEM FRAMS, the source of the data and the use of data for various analyses/assessments. A full list of the data collected is contained in Appendix A. A more detailed list of the data collected for the options assessment is provided in Table 3-1 Indicator datasets.

Table 2-2 Summary of key data collected for the FEM FRAM Study

Data	Source	Use of data	Reference report
Hydrometric data - instantaneous / annual maximum series of water level and flow data from 12 gauges (9 gauges as per the Brief and 3 additional gauges suggested by the EPA during the course of the study) in the study area and further 12 gauges in the neighbouring catchments - flow rating data at the 12 gauges in the study area	OPW, and EPA	Hydrological analysis , Hydraulic simulations	Inception Report, Preliminary Hydrology Report, Hydrology Report, Hydraulics Report
Rainfall data - daily rainfall data from ten stations in the study area and four stations in the neighbouring catchments - FSU - Depth Duration Frequency curves	Met Eireann, OPW	Hydrological analysis, Strategic SUDS analysis	Inception Report, Preliminary Hydrology Report, Hydrology Report, Hydraulics Report
Historic flood data - records/details of historic flood events from the national flood hazard mapping website www.floodmaps.ie - other available information on historic flood in the study area - the Public	OPW, FCC, MCC, various flood study reports and other sources including members of the public	Hydrological analysis, Hydraulic model build, flood maps	Inception Report, Preliminary Hydrology Report, Hydrology Report, Hydraulics Report
Tidal data - historical tidal data at Dublin Port and at Port Oriel, Clogherhead - the study area coastal flood outlines for various design events - Admiralty tide tables	OPW, DAFF (Irish Coastal Protection Strategy Study, Phase III)	Hydrological analysis, Hydraulic model build, flood maps	Hydrology Report, Hydraulics Report
Mapping data - 1:1,000 OSI vector maps - 1:2,500 raster maps - 1:2,500 vector maps - 1:5,000 vector maps - 1:50,000 Discovery series	FCC, MCC, DCC, OPW, Online	Survey, Hydrological analysis, Hydraulic model build, flood maps, flood risk	Survey specification, Hydrology Report, Hydraulics Report, Preliminary Options Report

Data	Source	Use of data	Reference report
raster maps - Aerial photography - Google maps, OSI online maps		assessment, FRM option assessments	
LiDAR data - 2m, 5m and 10m DTM covering the HPWs, MPWs, APSRs and APMRs - 2m DEM covering the HPWs, MPWs, APSRs and APMRs - 2m low tide LiDAR DTM at the coastal area and estuaries - hydrologically corrected DTM (hDTM) of 20 m resolution	OPW (2, 5 & 10m DTM), EPA (20m hDTM)	Hydrological analysis, Hydraulic model build, flood maps	Hydrology Report, Hydraulics Report,
Defence asset data - Defence asset data of Dublin coastline compiled as part of the DCFPP	FCC, OPW	Defence asset database, hydraulic model build	Hydraulics Report
Bathymetric survey data - Bathymetric and cross section data of the Broadmeadow Estuary and railway embankment	FCC	Hydraulic model build	Hydraulics Report
Land use, soil, sub-soil, bedrock geology and ground water data - Corine land cover data - Soil and sub-soil data - Aquifer vulnerability data - Bedrock geology data	EPA/Teagasc, Geological Survey of Ireland website (www.gsi.ie)	Hydrological analysis, GW assessment, Geo-morphological assessment, Strategic SUDS assessment	Scoping Report, Hydrology Report, Hydraulics Report, Preliminary Options Report, AA Screening Report
Planning data - Fingal & Meath Development Plan - Local Area Plans	FCC, MCC and their websites	Hydrological analysis, Optioneering, Environmental assessments	Hydrology Report, Preliminary Options Report, AA Screening Report
Environmental data - Cultural vulnerability - RMP and Protected structures database - Natura 2000 sites - WQ & ecology data	FCC, MCC, DCC, OPW, DEHLG, ERBD, IFI Online	Environmental assessments	Scoping Report, Preliminary Options Report, AA Screening Report

Data	Source	Use of data	Reference report
- Salmonid waters, Shellfish areas - Drinking water abstraction sites - Landscape data			
Flood risk assessment data - GeoDirectory - Multicoloured manual - Costings from Flood Defence schemes - Utility infrastructure - Hospitals, nursing homes etc - Pollution sources	FCC, MCC, OPW, EPA in house resources	Assessment of measures Benefit cost ratio (BCR) Environmental assessments	Preliminary Options Report AA Screening Report

A number of tools have been used for the display, storage and manipulation of data. GIS has been used as a tool throughout the project for the spatial representation of data, as well as storage, analysis, management, calculation and graphical display of the many different formats of data used.

Surveys

A number of surveys were undertaken to inform the project activities. A summary of the surveys is contained in Sections 0 to 0. Further details on each of the surveys and their use within the various work packages can be found in the relevant project reports detailed in Table 2-1. The main surveys were as follows:

- channel, structure and defence asset geometry survey;
- defence asset survey;
- floodplain survey; and
- property survey.

Channel, structure and defence asset geometry survey

The topographic survey of the channel cross sections, structure details and defence asset geometry was undertaken by DigiTech 3D (D3D) Surveys through a separate contract which was managed by Halcrow Barry. The topographic survey work commenced in January 2009 and was completed in November 2009. Some minor survey work on additional streams, which were not part of the original scope of work, was undertaken in 2010.

The main scope of topographic survey included 305km of river channel (165km in high priority watercourses (HPWs) and 140km in medium priority watercourses (MPWs)) along the 23 watercourses and their tributaries in the study area. Additional topographic surveys were also undertaken at Baldoyle and Rogerstown estuaries; the bathymetric and cross section data for the Broadmeadow Estuary and railway embankment was provided by FCC. Figure 2-2 provides details of the HPW and MPW rivers surveyed. Figure 1, at the back of this report, provides further details of the rivers surveyed.

Figure 2-2 Extent of the HPW and MPW rivers surveyed.

The topographic survey gathered details of the river and structure profiles, including cross-sections of the river channel, the river banks and any structures in the river channel such as bridges, culverts and weirs. It also included the collection of geometric data of the defence assets in the study area (see below).

Defence asset survey

The defence asset survey (DAS) involved gathering information (including photographs) on the type and condition of various defence assets in the study area, detailed quality checking of the data and entering this data in to the Fingal East Meath Flood Defence Asset Database

(FEM FDAD). Defence assets surveyed included walls, embankments, flap valves, culverts, bridges and sand dunes.

Under the defence asset survey programme, 57km of asset length of defence assets were surveyed which included 47 km of river defence assets and 11km of coastal defences along the Meath coastline.

The OPW provided defence asset data for the Dublin coastline, which Halcrow Barry entered into the FEM FDAD. Halcrow Barry identified some gaps in the Dublin coastline defence asset data. The OPW further consulted with Consultant for the Dublin study, and carried out additional surveys, and entered this additional data into the FEM FDAD using in-house resources.

After the completion of the topographic surveys (see above), the geometric data of the defence assets were manually entered into the FEM FDAD. The final FEM FDAD was submitted to the Client, in digital format, in October 2010.

Floodplain survey

The floodplain survey of the study area was undertaken using a LiDAR (Light Detection and Ranging) technique. The OPW commissioned Terra Imaging Ltd, who used a fixed-wing aircraft, to capture the LiDAR data. The following LiDAR data of the study area was provided by the OPW in February 2009:

- 2m, 5m and 10m DTM (digital terrain model) covering the floodplain of the HPWs, MPWs, APSRs and APMRs in the study area;
- 2m DEM (digital elevation model) covering the floodplain of the HPWs, MPWs, APSRs and APMRs in the study area; and
- 2m low tide LiDAR DTM along the coastal area and estuaries.

The OPW undertook a quality check of the LiDAR data, to confirm that the quality satisfies the required specifications of the contract (i.e., ±0.2m in horizontal and vertical direction; and a root mean square error of less than 0.2m with 99% of all points falling within 2RMSE). Halcrow Barry also carried out further checks on the accuracy of the LiDAR data as part of the hydraulic model build.

Surveyed channel cross sections were extended for 10m into the left and right bank floodplains to allow for an overlap with the LiDAR DTM in the floodplain. This allowed for a comparison in levels between the surveyed cross sections and the LiDAR DTM.

Property threshold survey

The property threshold survey was undertaken using GPS (Global Positioning System) to record the finished floor level of non-residential buildings at risk in the study area. 150 non-residential buildings with the largest floor areas located within the 0.1% AEP flood extents were selected for the survey. 150 non-residential buildings represents approximately 30% of the total number of non-residential building at risk for the 0.1% AEP current scenario event and provides sufficient information for improving the accuracy of the economic risk assessment. A total of 194 non-residential were surveyed, with a number of additional buildings surveyed in the vicinity of the identified buildings. A number of the originally selected buildings were not surveyed due to access issues and errors in the GeoDirectory coding. Further information is available in the Preliminary Options Report (Halcrow Barry,2010).

The location of these buildings were identified through the review of the GeoDirectory commercial properties dataset and using the GIS tool together with the 0.1% AEP flood extent map and the 1:2500 OSI landline vector mapping data (which contains digital outline of the buildings in the study area).

This information was then used to assist with the accuracy of the economic damage assessment in the analysis of various options for the management of flood risk in the study area.

Hydrological Analysis

The hydrological analysis is concerned with the estimation of extreme flows, which form the basis for subsequent hydraulic modelling and flood risk mapping stages of the FEM FRAM study. The overall hydrological analysis of the study area was undertaken in two stages, namely, preliminary hydrological analysis and detailed hydrological analysis. The preliminary hydrological analysis involved the collection and analysis of the available data (hydrometric, historic flood, rainfall, soil and geology, land-use, tidal datasets etc), and the results are included in the Preliminary Hydrology Report (February, 2009). The detailed hydrological analysis involved the review of the rating at the gauging stations and refined the hydrological analysis of the preliminary hydrological study using revised flow data at the gauges.

The study applied the Flood Studies Report (FSR), Flood Estimation Handbook (FEH) and Irish Flood Studies Update (FSU) methodologies to enable the determination of design hydrological inputs (flow and water level) for the current scenario as well as for the future scenarios which may arise due to future climate changes likely to influence flood risk. The results of the detailed hydrological analysis are presented in the Hydrology Report (April 2010). Thus the two reports (Preliminary Hydrology Report and Hydrology Report) detail the overall hydrological analysis undertaken for the FEM FRAMS.

The Fingal East Meath study area comprises a group of river catchments and neighbouring coastal areas in Irish Hydrometric Area 08 (HA 08) and some of Hydrometric Area 09 in counties Dublin and Meath (refer to Figure 2-2). The study area is bounded by the River Boyne catchment (HA 07) to the north and west, the Tolka and Santry River catchments (HA 09) to the south, and by the Irish Sea to the east.

Rainfall Analysis

Although rainfall data 14 stations (ten from the study area and four from neighbouring catchments) was acquired from Met Eireann, the data of two stations from the study area was not used due to its quality and completeness (refer to Section 4.2.1 and Table B-1 of Hydrology Report). Therefore, the rainfall series of twelve stations with data records of 9 to 67 years were analysed both individually and in a group following the procedures of both the FSR Volume II – Meteorological Analysis and the FEH-Rainfall Analysis. The results of the study were compared with those of the Depth Duration Frequency curves of the FSU. The FSU-DDF curves were broadly adopted for estimating the design floods in the watercourses of the study area. However, the analysis also indicated that the rainfall values obtained from the FSU-DDF model needed to be scaled at some local sub-catchments in the vicinity of three stations (Bellewstown, Ratoath and Dunshaughlin).

Rating review

A detailed rating review was undertaken for nine hydrometric stations in the study area. This includes:

- one station on the Nanny catchment (08011 Duleek);
- two on the Delvin catchment (08002 Naul and 08010 Garristown);
- one on the Ballyboghill catchment (08012 Ballyboghill);
- three on the Broadmeadow catchment (08003 Fieldstown, 08007 Ashbourne and 08008 Broadmeadow);
- one on the Ward catchment (08009 Balheary); and
- one on the Sluice catchment (08005 Kinsaley Hall).

Due to the quality of hydrometric data and possible obstruction of the downstream bridges, the hydrometric data of Station 08003 Fieldstown was excluded from further analysis.

The rating curve review assessed the existing rating and extended the rating curve to high flow using 1D ISIS based local hydraulic models in the vicinity of the gauging station and following the guidance in the "Extension of Rating Curves at Gauging Stations – Best Practice Guidance Manual, R & D Manual W06-061/M (2003)" produced by the UK Environment Agency.

Estimation of design flow at hydrometric stations

The design flows at gauging stations were estimated following the procedure of the Flood Estimation Handbook and Flood Studies Update pooling group method. For this purpose, annual maximum flood data from eight hydrometric stations in the neighbouring catchments (Hydrometric Areas of 07 and 09) were also included in the analysis. Hydrological statistical analysis was undertaken to derive the study area growth curve. The design flood value at the gauging station was obtained by multiplying the gauging station median flow with the study area growth curve.

Integration of hydrology and hydraulic modelling

The statistical analysis estimated design flow only at the gauging stations. In order to represent the hydrological processes in sufficient detail to enhance the hydraulic model outputs, each watercourse in the study area were sub-divided into a number of smaller sub-catchments. The 23 watercourses in the study area to be modelled were divided into a total of 270 sub-catchments. The design inflows at sub-catchment level were calculated using the FSSR 16 and Institute of Hydrology Report No. 124 Unit Hydrograph (UH) method.

For the gauged catchments, the total (routed) inflows at hydrometric stations generated from the FSSR 16/IOH 124 UH methods (ISIS boundary units) at sub-catchment levels were reconciled with the return period floods estimated from the statistical method. The scaling factors obtained from such reconciliation were used to calculate study average scaling factors to be used for the ungauged catchments.

Future environmental and climate change

The dominant factors influencing future flood risk in the Fingal and East Meath study area include changes in climate, land use and urban growth. As little afforestation is likely to occur in the study area, the main factors for future flood risks can be considered as climate change and urbanisation. Table 2-3 (reproduced from Table 7-6 of the Hydrology Report) summarise the recommended projections for climate change and urbanisation for the two future scenarios, namely, the mid range future scenario (MRFS) and the high end future scenario (HEFS) for FEM FRAMS and this combinations of drivers for future flood risk were applied during the hydraulic model runs for future scenarios.

Table 2-3 Relevant combinations of drivers to provide boundaries for future flood risk

Driver	Scenario	
	MRFS	HEFS
Climate change - rainfall	+ 20%	+30%
Climate change - net sea level rise	+35cm	+100cm
Land use change – urbanisation	100% increase in urban area	400% increase in urban area

Joint probability analysis

Detailed investigation of the fluvial/tidal joint probability analysis (JPA), based on the approach of the UK Defra/EA (2006) and the Lee CFRAM Pilot study, was undertaken during the hydrological analysis. Additional research on this topic and sensitivity analyses involving further simulations of the hydraulic models, was undertaken during the hydraulic analysis. The results of this research and sensitivity analysis are presented in the Technical Note on JPA in Appendix C2 of the Hydraulics Report. The recommended JPA combination is detailed in Table 2-4 below.

Table 2-4 Combinations of individual return periods necessary to produce design event

Design event	Boundary return period	
	Fluvial boundary	Sea level boundary
2 year	2	2
5 year	5	2
5 year	2	5
10 year	10	2
10 year	2	10
25 year	25	2
25 year	2	25
50 year	50	2
50 year	2	50
100 year	100	5
100 year	5	100
200 year	200	10
200 year	10	200
1000 year	1000	50
1000 year	50	1000

Hydraulic modelling

A detailed hydraulic assessment has been undertaken for the study with the objective of determining the flood risk from the watercourses (fluvial flooding), from the sea (coastal flooding) and from pluvial (surface water) flooding in the Fingal and East Meath area, for specific design events and future scenarios. For this, the study has developed hydraulic models for all 23 watercourses and their estuaries, of which three are one dimensional (1D) models and the remaining twenty are 1D-2D linked models. In addition, a 2D coastal model and a pluvial model were developed for the coastal and pluvial (surface water) analysis of the study area.

In building the river hydraulic models, 1D only models were used when the flow paths could be reasonably well represented with a 1D approach. The 1D approach was used even for some HPWs which had a constrained flow path (i.e. narrow river corridor) and for which the out-of-bank flows were reasonably parallel to the river corridor (i.e. parallel contour lines). On the other hand, the HPWs in populated areas and/or where the flow path could not be well represented by a 1D model, the 1D-2D linked modelling approach was used.

A summary of the various activities undertaken during hydraulic modelling is presented in the following paragraphs.

Surveys and analysis

The main input for the hydraulic modelling is the topographic survey data of the river cross sections and structures, the flood plain survey data, the defence asset survey and the results of the hydrometric assessment. These are all described in previous sections of this report.

River hydraulic modelling

Dynamic river hydraulic models have been developed for HPWs and MPWs to estimate design and potential future flood levels, depths, velocities and extents, and to assist in the development and appraisal of potential flood risk management measures and potential strategies. Where possible the models have been calibrated and verified against observed flood events.

Three of the models incorporated two river systems where there were known interactions between the rivers. These include the following watercourses:

- Broadmeadow and Ward Rivers ;
- Ballyboghil and Corduff Rivers; and
- Bride's Stream and Jone's Stream.

Therefore, a total of 20 river models were developed. The river reaches included within these models and their associated floodplains are summarised in Table 2-5, together with the model type. Figure 1, at the back of this report, shows the extent of each model with additional information on the location of HPW and MPW watercourses, 2D model domains and ISIS reservoir units.

Table 2-5 River reaches and model types

Model	Model Name	Length (km)		Model Type
		HPW	MPW	
1	Broadmeadow and Ward Rivers (BRO_WAR)	57.6	35.1	1D – 2D
2	River Nanny (NAN)	12.5	35.9	1D – 2D
3	Lissenhall Stream (LIS)	4.4	-	1D
4	Turvey River (TUR)	5.4	-	1D – 2D
5	Rushroad Stream (RUR)	-	2.2	1D
6	Mosney Stream (MOS)	1.4	3.3	1D – 2D
7	Delvin River (DEL)	11.7	15.5	1D – 2D
8	Brookside Stream (BSS)	3.0	-	1D – 2D
9	Ballyboghil and Corduff Rivers (BAL_COR)	8.8	16.3	1D – 2D
10	Balbriggan North Stream (BNS)	3.1	-	1D – 2D
11	Bracken River (BRA)	10.5	3.6	1D – 2D
12	Mill Stream (MIL)	3.2	1.0	1D – 2D
13	Gaybrook Stream (GAY)	5.7	-	1D – 2D

Model	Model Name	Length (km)		Model Type
		HPW	MPW	
14	Mayne River (MAY)	11.3	11.3	1D – 2D
15	Sluice River (SLU)	16.7	5.1	1D – 2D
16	St Catherine's Stream(CAT)	1.2	1.2	1D – 2D
17	Baleally Stream (BAY)	2.0	2.8	1D – 2D
18	Bride's Stream and Jone's Stream (BRI_JON)	1.9	6.0	1D – 2D
19	Rush Town Stream (RUT)	2.1	0.6	1D
20	Rush West Stream (RSW)	1.9	0.6	1D – 2D

Details on the river modelling methodology, assumptions and results for each river are presented in Chapters 4 and 5 of the Hydraulics Report (February 2011).

Coastal modelling

Coastal modelling to simulate flooding from the sea has been undertaken for the Fingal East Meath study area coastline using the ISIS 2D, part of the ISIS suite which has been used for the other modelling elements of the study. The coastal model was developed using the LiDAR data received from the OPW, namely, the 2m and 5m LiDAR DTM of the study area coastline and the 2m low tide LiDAR DTM at the coastal and estuary area. The modelling has considered the existing coastal defences (including high ground and coastal dunes) to protect the coastline.

The extreme sea levels derived from the Department of Agriculture, Fisheries and Food (DAFF) Strategic Coastal Flood Risk and Erosion Study have been used and thus coastal models to simulate off-shore or near-shore tide or surge dynamics or wave action, or extreme sea levels has not formed part of this work. Flooding due to overtopping has also not been considered as part of the analysis.

The results of the coastal analysis showed that there is limited coastal flooding in the Fingal-East Meath study area, mainly due to the high level of land along the coast. Localised coastal flooding for lower probability AEP events (i.e. 1%, 0.5% and 0.1%) does occur in Bettystown, Laytown, Skerries, Rush, the Burrows Malahide and Portmarnock. The results also indicated that there is an increase in the flood extent and hence the risk of coastal flooding for the MRFS, particularly in Balbriggan, Skerries, Malahide, Portmarnock and Baldoyle.

Details on the coastal modelling are presented in Chapter 6 of the Hydraulics Report.

Simulations in the hydraulic models

The hydraulic models (fluvial and coastal) have been run for design flood events with a range of annual exceedence probabilities (AEPs) of 50%, 20%, 10%, 4%, 2%, 1%, 0.5% and 0.1% for existing conditions and for the MRFS, and for design flood events for the 10%, 1% and 0.1% AEP events for the HEFS. However, the flood mapping is available only for the current scenario and MRFS but not for the HEFS.

The river hydraulic models were also run for a range of defence failures (both river defence and tidal defence) and structure blockage scenarios.

Pluvial flood hazard

The main objective of the pluvial (surface water) flood hazard was to assess the potential locations where pluvial (surface water) floodwaters and runoff might accumulate within APSRs during extreme rainfall events and/or blockage or saturation of the stormwater drainage systems. The pluvial (surface water) flood hazard also assessed the potential degree (extent and depth) of flooding that could occur. The ISIS-2D (FAST) computational engine and LiDAR DTM has been used to route pluvial flood water over the floodplain.

The result of pluvial model analysis was then presented in 1:50,000 maps (extent and depths) for review purpose. The results indicated that only a few of the APSRs are at risk of flooding from pluvial sources only, whereas other areas are at risk of flooding from fluvial, coastal, pluvial or a combination of all three types of flood sources.

Details on the pluvial flood hazard are presented in the Technical Note on Pluvial Flood Hazard in Appendix E of Hydraulics Report

Groundwater flood hazard

The main objective of the Groundwater Flood Hazard analysis was to undertake a desk study review of the available data on groundwater to produce a meaningful assessment of the groundwater flood risk in the FEM FRAM study area; to investigate the necessity of GW monitoring in the study area, and if required, recommend GW monitoring locations. The study also investigates the mechanisms by which groundwater flooding can occur in the study area and their remedial measures.

The hydro-geological conditions in the Fingal East Meath study area together with all other available information indicates that the conditions do not exist for groundwater flooding and hence that groundwater flooding is not a significant risk within the study area. However, there is a risk of groundwater flooding from poorly constructed basements or deep excavations. For such developments, the study recommends the drilling of a borehole and the installation of a piezometer to establish the depth of the groundwater table in relation to the base of the excavation. If the water table is within 1 meter of the base then the development needs to be conditioned to ensure that the basement is adequately sealed / tanked. All basements must be designed in accordance with British Standard BS8102:2009.

Details on the GW flood hazard are presented in the Technical Note on Groundwater, in Appendix D of Hydraulics Report.

Geomorphological assessment

A preliminary assessment into the fluvial geomorphology of the watercourses and their catchments in the FEM FRAM study was undertaken to investigate the sediment erosion, transport and deposition processes which transport sediments from upland areas within river catchments, into and through the valley lowlands to the coastal zone. To identify locations with the potential for high rates of erosion or deposition, the preliminary desk-based assessment was undertaken using the key variables such as channel gradient, channel sinuosity, dominant drift geology and dominant land use of each of the watercourses in the study area.

The results of the preliminary study reveal that with the predominantly low to medium gradient of all watercourses; the ability of the watercourses to transport sediment is relatively low.

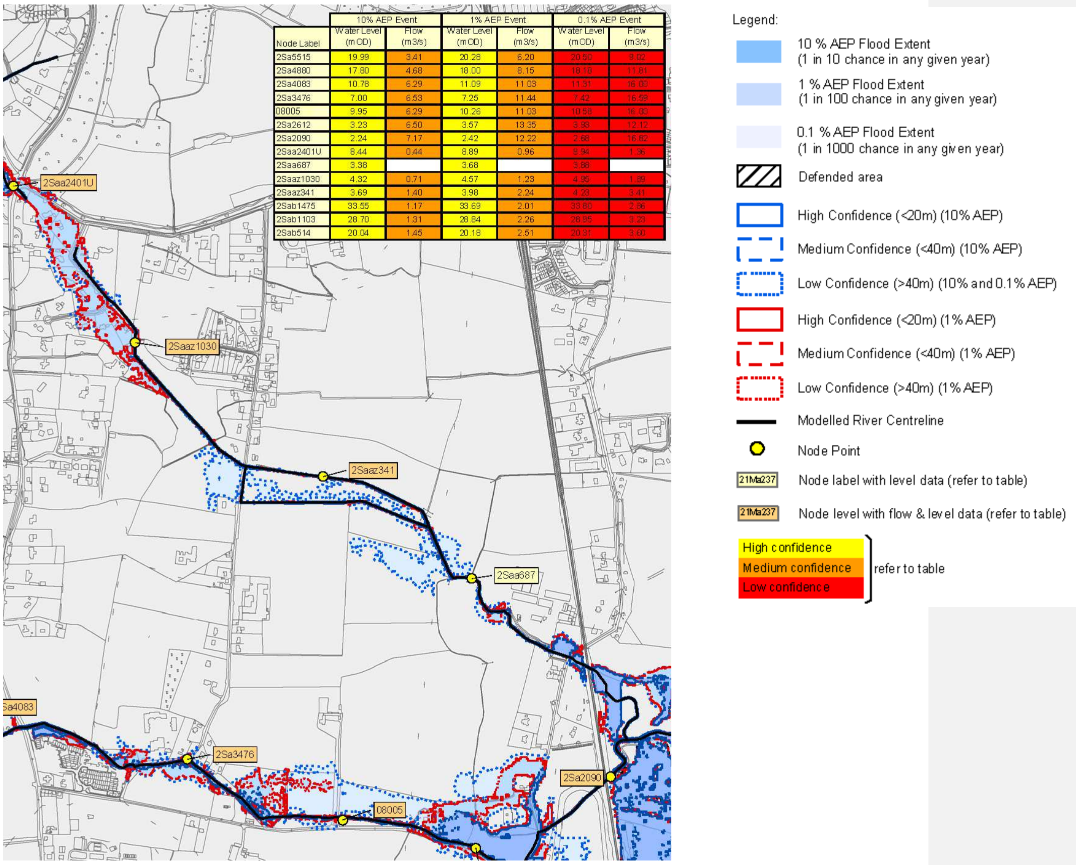
Sediment transfer is more likely to be “pulsed” during high flow events with temporary storage of sediment in-channel features such as bars. Therefore, sediment deposition under normal flow conditions (i.e. not during time of flood) is likely to occur within the channel. The study recommends that more detailed field survey work is undertaken at detailed design stage such as walk over surveys, (noting for example current geomorphology), river channel shape (width, depth, cross-section), slope, planform and any historical meanders, floodplain geomorphology, land use on the floodplain, bed sediment, bed features (e.g. riffle-pools etc), management of banks (bank profile, bank material, bank protection), channel management regime and organisation undertaking at the major crossings of the of the Rivers (M1, N1 and railway crossings) in order to ascertain any threat from flooding and erosion to the road / railway line / housing estate etc:

Details on the geomorphological assessment are presented in a separate Technical Note in Appendix F of the Hydraulics Report.

Flood mapping

Flood maps are one of the main outputs of the study and are the way in which the hydraulic model results are communicated to the end users. The flood maps represent all areas that are likely to be inundated at some point during a flood event. The key types of mapping developed have been:

- Flood extent maps – show the estimated area inundated by a flood event of a given AEP. These maps also show levels of confidence in the flood extents, plus water levels, flows and defended areas (refer to ***Figure 2-3*** for an example of a flood extent map);
- Flood zone maps – show flood zones A, B and C representing high, moderate or low risk areas in accordance with the Guidelines on the Planning System and Flood Risk Management;
- Flood depth maps – show the estimated flood depths for areas inundated by a particular flood event using graduated colours;
- Flood velocity maps - show the speed of the flood water for areas inundated by a particular flood event using graduated colours; and
- Flood hazard maps – show the harm or danger which may be experienced by people from a flood event of a given annual exceedance probability, calculated as a function of depth and velocity of flood waters.



	10% AEP Event		1% AEP Event		0.1% AEP Event	
Node Label	Water Level (mOD)	Flow (m3/s)	Water Level (mOD)	Flow (m3/s)	Water Level (mOD)	Flow (m3/s)
2Sa5515	19.99	3.41	20.28	6.20	20.50	9.02
2Sa4880	17.80	4.68	18.00	8.15	18.18	11.81
2Sa4083	10.78	6.29	11.09	11.03	11.31	16.00
2Sa3476	7.00	6.53	7.25	11.44	7.42	16.59
08005	9.95	6.29	10.26	11.03	10.58	16.00
2Sa2612	3.23	6.50	3.57	13.35	3.93	12.12
2Sa2090	2.24	7.17	2.42	12.22	2.68	16.82
2Saa2401U	8.44	0.44	8.89	0.96	8.94	1.36
2Saa687	3.38		3.68		3.88	
2Saaz1030	4.32	0.71	4.57	1.23	4.95	1.89
2Saaz341	3.69	1.40	3.98	2.24	4.23	3.41
2Sab1475	33.55	1.17	33.69	2.01	33.80	2.86
2Sab1103	28.70	1.31	28.84	2.26	28.95	3.23
2Sab514	20.04	1.45	20.18	2.51	20.31	3.60

Figure 2-3 Extract from fluvial flood extent map

The predictive flood maps prepared for this study provide valuable information regarding flooding within the study area for both technical and non technical users. The maps have been used within the study to identify areas that are prone to significant flooding, assess the flood risk to flood risk indicators, as described in the Preliminary Options Report and to inform the development of flood risk management options. These flood maps can also be used to:

- raise awareness of flood hazard to property and life;
- aid flood event response planning and action; and
- inform spatial planning and development management within the floodplain and support the implementation of the Guidelines on the Planning System and Flood Risk Management (OPW and DEHLG, 2009).

Full details of the flood maps and the various flood mapping formats are available in the Hydraulics Report (February 2011). A separately bound volume of draft flood extent, zone, depth, velocity and hazard maps, representing the current flood hazard, accompanies the draft FRMP. Digital copies of the flood extent maps are also available on the FEM FRAMS website, www.fingaleastmeathframs.ie. It is anticipated that the maps will also be made available on the OPW National Flood Hazard Mapping website in the near future (www.floodmaps.ie).

Preliminary options assessment

The principal objective of the preliminary options assessment was to undertake a detailed analysis to identify potential flood risk management measures for the FEM FRAM study area. A staged decision making process has been implemented to ensure that the assessment of flood risk management measures and options is evidence-based, transparent, and inclusive of stakeholder and public views. The staged decision making process steps are shown in Figure 2-4.

The Preliminary Options Report (December 2010) provided details on step 1 - Establish the decision making framework and evidence base (green box), step 2 - Assess the flood risk within each assessment unit (red box) and step 3, stage 1 - Identification of potential flood risk management measures and screen using the core criteria (part of the blue box). The remaining activities under step 3 (blue box) are reported on in this Final Report and all of this information, including the results of the additional studies, investigations and the consultation process, will feed into the final deliverable the Flood Risk Management Plan (FRMP) (orange box).

The assessment of flood risk management measures has focussed on providing measures to residential and non residential properties at economic risk of flooding; and to the Individual risk receptors

In identification of potential flood risk management options for the study area, our understanding of the flood risk in the study area based on an assessment of flood risk to mainly five flood risk receptor groups, namely:

- human health (including risk to life);
- the environment;
- the economy;
- cultural heritage; and
- critical Infrastructure.

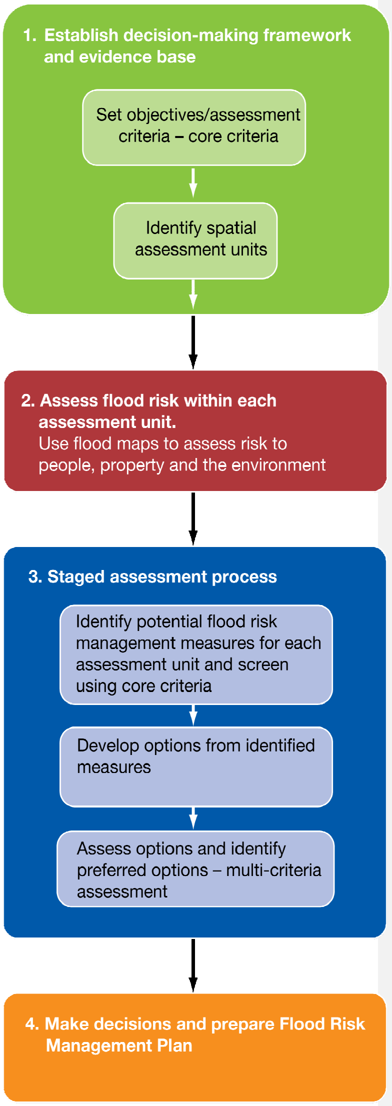


Figure 2-4 Staged decision making process

The outcome of this preliminary assessment was reported in the Preliminary Options Report, which was published in December 2010. Further details on the Preliminary Options report is provided in Chapters 3 and 4. The next stage, which is the selection of the preferred options, is reported in Chapters 4 to 13 of this Draft Final Report.

The Preliminary Options Report provides details on the level of flood risk in the study area and the procedures for identifying suitable flood risk management measures for managing the flood risk. To ensure the correct focus in determining appropriate flood risk management measures, the study area was divided into different areas, called assessment units. These are defined at four spatial scales; study area scale, analysis unit (AU) scale (large sub-catchments), areas of potential significant risk (APSR) and individual risk receptors (IRRs).

The flood maps produced for the study were used to identify the level of flood risk in the study area to five flood risk receptor groups. An assessment of the vulnerability of each type of identified cultural feature/site (i.e. receptor) was classified based on the importance of the receptor and the degree of potential damage. An extract from a flood risk maps is shown in Figure 2-5.

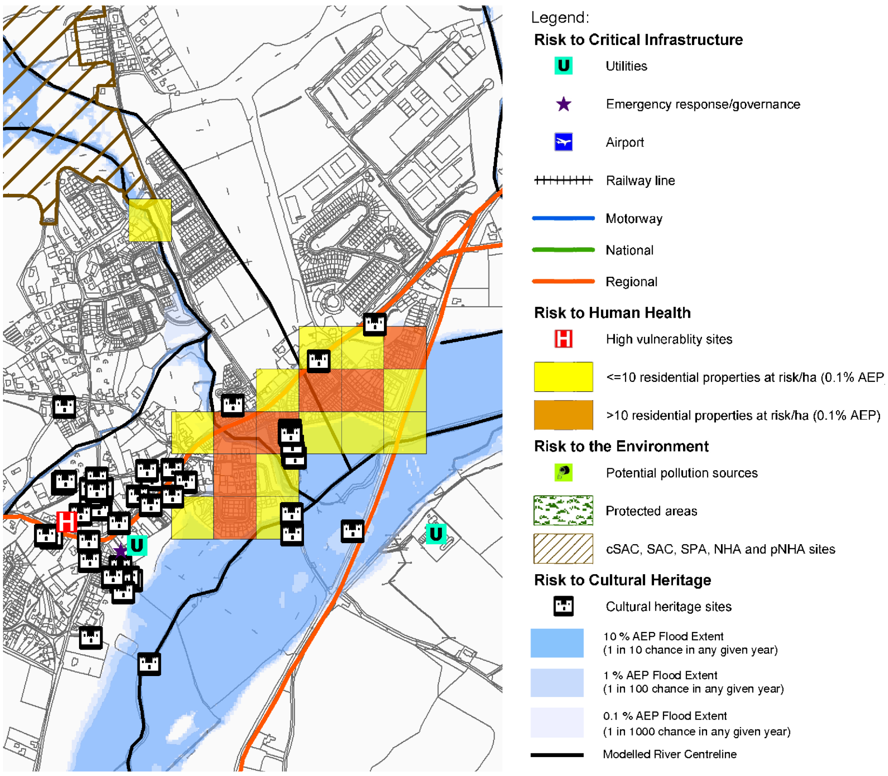


Figure 2-5 Extract from a flood risk indicator map

The risk to the economy focussed on the economic flood damages to residential and non-residential properties in the study area and was determined using the Flood Hazard Research Centre (FHRC) depth damage curves. Economic damages occur where floodwater gets above the threshold level of a building, for example, an entrance door to a building. Assessment of the economic flood risk to infrastructure assets was undertaken for both nationally and regionally available infrastructure datasets. The infrastructure assets include transport routes (e.g. road and rail) and utility assets (e.g. waste water and water treatment plants).

Figure 2-6 provides a graphical representation of the economic risk in the study area for the 0.1% AEP fluvial and tidal event for the current scenario.

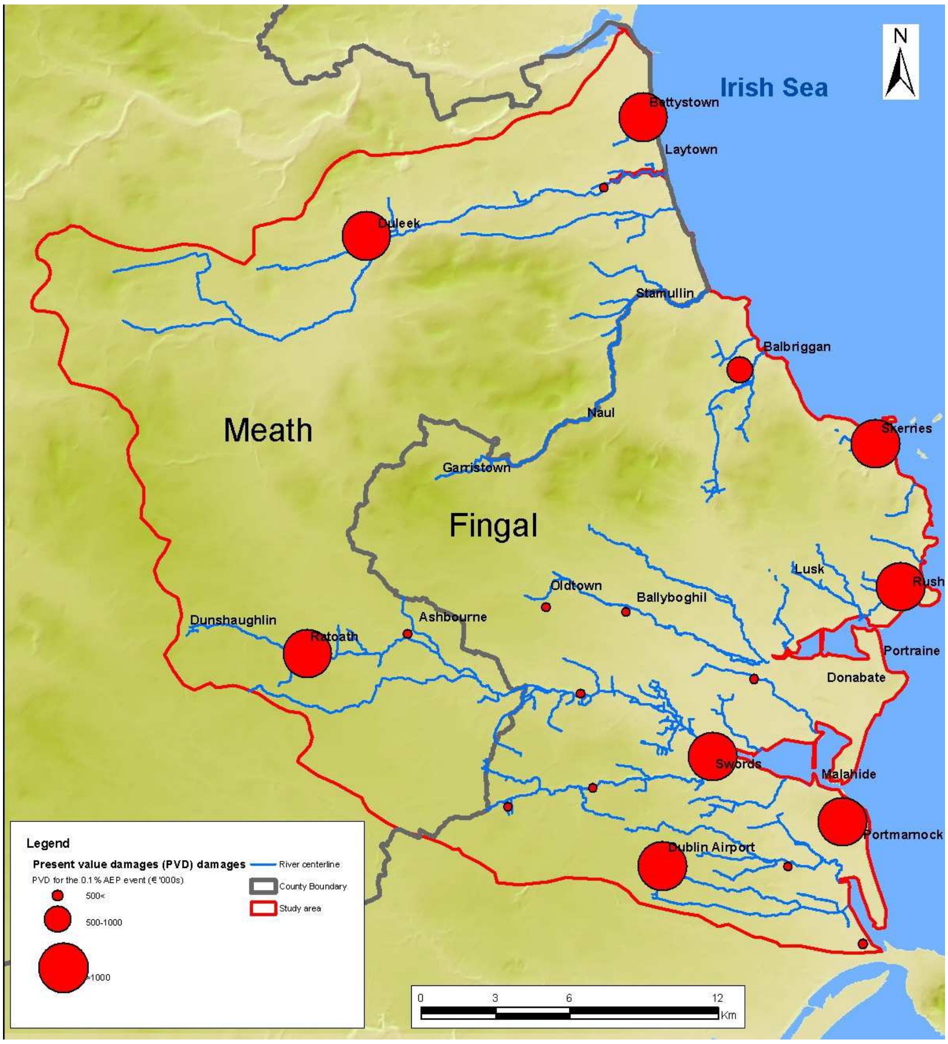


Figure 2-6 Graphical representation of economic risk areas in the study area (current scenario)

Where the economic risk to properties was significant, a full suite of flood risk management measures was assessed for the AU, APSR and IRR. The outcomes from this assessment process are a number of viable flood risk management measures for the AUs, APSRs and IRRs in the study area. These measures were used to inform the next stages of the decision making process, i.e. development of options and assessment of options using a multi-criteria analysis. The preferred options will form part of the Flood Risk Management Plan.

Strategic Environmental Assessment (SEA)

Strategic Environmental Assessment (SEA) is an integral part of the development of any large scale plan, programme or strategy. The FEM FRAMS includes a Strategic Environmental Assessment (SEA) to ensure that environmental issues and opportunities for enhancement are fully considered throughout the study and that the identified long-term flood risk management strategy is environmentally appropriate. This SEA process has been designed to be compliant with the requirements of the EU SEA Directive and the transposing Irish Regulations.

The overall SEA process comprises the six main stages shown in Figure 2-7 to be undertaken in parallel with the development of the FEM FRAMS FRMP.

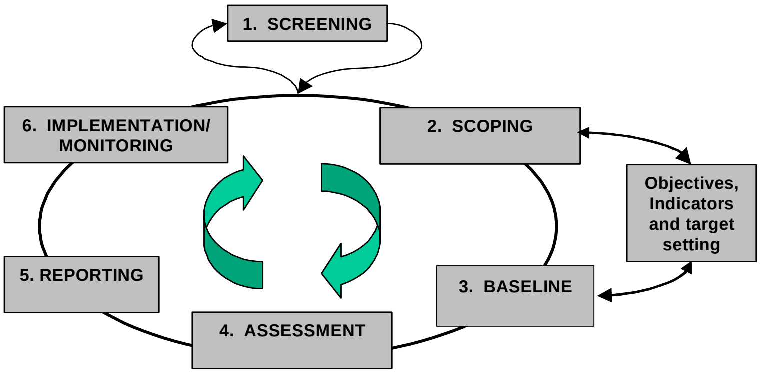
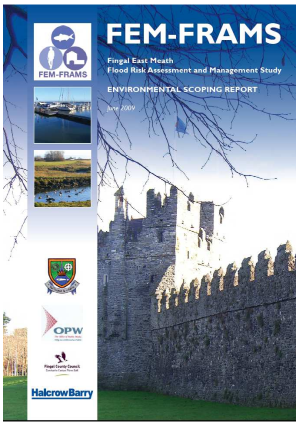


Figure 2-7 – Key stages of the SEA process

In Stage 1 – screening was undertaken by the OPW which established the need for SEA for the FEM FRAMS.

In Stage 2 – scoping study was undertaken by Halcrow Barry in 2008 / 2009 and the outcome of the study was published for consultation in the final Scoping Report in June 2009. The scoping stage was mainly concerned with identifying the key social and environmental issues in the study area to be considered in the latter stages. Consultation with stakeholders was a key part of this process.



The Scoping study identified the environmental characteristics of the study area, both now and in the future, under the following eleven headings:

Geology, soil and land use

Water (rivers, lakes, estuaries, coastal waters and groundwater)

Morphology, fluvial and coastal processes

Air and climate

Biodiversity, flora and fauna

Fisheries

Landscape and visual amenity

Population and health

Development, infrastructure and material assets

Tourism and recreation

Archaeology and cultural heritage

The Environmental Scoping Report describes the environmental characteristics of the FEM study area under the above eleven separate headings and presents the initial understanding of the key social and environmental issues within the study area relating to flooding and its management, and identifies issues that are not relevant to the study and therefore do not require further consideration.

The Environmental Scoping Report also identifies a set of SEA objectives for the study based on the identified key social and environmental issues relating to flood risk management. Following consultation, these objectives were amended and incorporated within the overall flood risk management objectives for the study.

The preparation of the Environmental Scoping Report was informed by consultation with statutory organisations and other interested parties, including a scoping workshop held on the 10th February 2009 attended by key stakeholders.

Stages 3 – 5 – these stages are currently underway and will be reported on in the separate SEA Environmental Report.

Stage 6 will require the monitoring of the impacts of the FRMP during its implementation.

The above environmental assessment process is consistent with the recommendations of the Environmental Protection Agency (EPA) publications entitled Development of Strategic Environmental Assessment (SEA) Methodologies for Plans and Programmes in Ireland – Synthesis Report (EPA 2001), the SEA Pack (EPA 2008) and the 2004 SEA Guidelines produced by the DoEHLG. Accordingly, the FEM FRAMS SEA meets the requirements of the SEA Directive and associated Regulations.

Habitats Directive Assessment

Under Article 6(3) of the EU Habitats Directive, an “appropriate assessment” is required where any plan or project, either alone or ‘in combination’ with other plans or projects, could have an adverse effect on the integrity of a *Natura 2000* site. This specific assessment considers whether the recommendations of the draft FEM FRMP are likely to have an effect on the ecological integrity of the Natura 2000 sites within the study area:

- Boyne Coast and Estuary candidate Special Area of Conservation (cSAC);
- Boyne Estuary Special Protection Area (SPA);
- River Nanny Estuary and Shore SPA;
- Skerries Islands SPA;
- Rogerstown Estuary cSAC and SPA;
- Broadmeadow Estuary/Swords SPA;
- Malahide Estuary cSAC;

- Baldoyle Bay cSAC and SPA; and
- Ireland's Eye cSAC and SPA.

The screening report was prepared in February 2011 and concluded that the proposed draft Fingal East Meath FRMP has the potential to have significant effects, on five of the *Natura 2000* sites considered:

- River Nanny Estuary and Shore SPA;
- Broadmeadow Estuary/Swords SPA;
- Malahide Estuary cSAC;
- Baldoyle Bay cSAC; and
- Baldoyle Bay SPA.

The results of the appropriate assessment, including both the initial screening stage and a subsequent, more detailed, assessment, are reported on in the SEA Environmental Report.

3. Option assessment data

Introduction

A number of organisations and websites have been consulted to obtain the data necessary for the flood risk management options assessment process. These include FCC, MCC, the OPW, the Environmental Protection Agency (EPA), the Health Service Executive (HSE), the National Parks and Wildlife Service (NPWS) and the Eastern River Basin District (ERBD) – River Basin Management Project under Water Framework Directive (now run by Dublin City Council).

A summary of key data used in the FEM FRAMS, including mapping and survey data used in the Options assessment process is presented in Table 2-2 previously. Additional data used mainly for the Options assessment process, including the indicator data and costing data are summarised in the subsequent sections. Detail description of this data is provided in Chapter 2 of the Preliminary Options Report.

Indicator data

Measurable indicators were used to identify the key issues relating to flood risk and to determine the existing baseline characteristics of the study area in relation to economic, social and environmental objectives. The indicators were primarily selected based on the availability of suitable GIS datasets for the entire study area and their relevance to the flood risk management objective. Table 3-1 lists the indicator data gathered for the options assessment.

Table 3-1 Indicator datasets

Indicator	Data set	Data source
Number of transport routes (road, rail, navigation) at risk from flooding	Road network *(GIS data)*	FCC, MCC, OPW
	Rail, tunnel, ports and airports *(Visual inspection of 50000 scale raster maps)*	OSi, FCC, MCC, OPW
Number of utility infrastructure assets (power stations, WWTWs, WTWs) at risk from flooding	ESB, GAS and EIRCOM utilities	OPW
	Water Treatment Works *(GIS data)*	FCC, MCC
	Waste Water Treatment Works *(GIS data)*	FCC, MCC
Area of agricultural land (CORINE or other data) not benefiting from flood risk management measures	Agricultural Land *(GIS data)* (four CORINE land use classes, namely, 211, 231, 242 and 243).	EPA CORINE Land Cover map (2006)
Number of residential properties at risk from flooding	Residential property classification in GeoDirectory *(GIS data)*	An Post GeoDirectory (MCC, FCC)
Number of high vulnerability properties at risk from flooding	Nursing homes, hospitals, health centres and GP clinics *(GIS data)*	HSE (hospitals & health centres); GeoDirectory (nursing homes), OPW
Number of high-value social infrastructural assets at risk from	Schools, colleges, universities, Garda stations and fire stations classification	OPW

Indicator	Data set	Data source
flooding	*(GIS data)*	
Number of non- residential properties at risk from flooding	Non residential property classification in GeoDirectory *(GIS data)*	An Post GeoDirectory (MCC, FCC)
Number of flood-sensitive social amenity sites at risk from flooding	Sports grounds, parks and beaches *(visual inspection of 5000 scale raster maps)*	OSi maps
Ecological status of water-bodies Chemical status of water-bodies	Eastern River Basin District Management Plan (2009) *(GIS data)*	ERBD RBMP (2009 - 2015) www.erbd.ie
Number of potential pollution sources at risk from flooding (including those licensed under Directives 96/61/EC and 92/271/EC)	IPC/IPPC licensed sites, Waste Water Treatment Works & Seveso Sites *(all GIS data)*	EPA, FCC, MCC
	Waste Management Permit Sites *(GIS data)*	FCC, MCC
	Section 4 and 16 licences (FCC and MCC)	FCC, MCC
Reported conservation status of designated sites relating to FRM	*Natura 2000* (SPA and cSAC/SAC), Ramsar and pNHA/NHA sites (*GIS data*)	NPWS and DEHLG (*GIS data, 2009)*
Presence and/or extent and quality of suitable habitat supporting legally protected species and other known species of conservation concern ('target species')	*"Grid 10k" protected species information on the NPWS website: www.designatednatureareas.ie* ERBD Management Plan (2009) *(GIS data)* Species records/distribution: FCC and MCC (anecdotal information)	NPWS, ERBD RBMP (2009 - 2015) FCC
Area and quality of riverine, wetland and coastal habitat maintained or created/ restored as a result of flood risk management measures	Habitat inventories *(GIS data)* FCC Ecological Network including Ecological buffer zones and Nature Development Areas River Corridors along major rivers	FCC and MCC
Area and quality of suitable habitat supporting salmonid and other fisheries and number of upstream barriers	Salmonid waters – WFD Protected Area *(GIS data)* Barriers to fish movement (e.g. one way flap valves; sluice gates, weirs dams; etc) Fisheries populations (anecdotal information) Fishing/angling activity (anecdotal information)	ERBD RBMP (2009 - 2015) ERBD – Location and type of barrier to fish movement ERFB (2009)
Classification of designated Shellfish Waters	Shellfish waters – WFD Protected Area *(GIS data)*; Shellfish Waters Final Characterisation Reports and	ERBD RBMP (2009 - 2015), DEHLG (2009)

Indicator	Data set	Data source
	Pollution Reduction Plans – status, actions required relating to FRM	
Compliance with landscape character objectives, including those for designated highly sensitive landscapes, relevant to flood risk management measures	Landscape character areas *(GIS data)* Highly Sensitive Landscapes and High Amenity Areas *(GIS data)*	FCC and MCC
Quality of visual amenity at important views relevant to flood risk management measures	Important views and prospects *(GIS data)*	FCC, MCC
Numbers and types of internationally, nationally and locally designated areas, buildings, structures and features at risk from flooding	Record of Protected Structures *(GIS data)* Listing on Sites and Monuments Record *(GIS Data)* Architectural Conservation Areas *(GIS data)* National Recorded Monuments *(GIS data)*	FCC, MCC, DOEHLG

Costing data

A number of sources of data were used to develop a cost database for calculating the preliminary costs for flood risk management measures as shown in Table 3-2. Appendix J contains details of the full costing database used to cost the options.

Table 3-2 Sources of data used for developing cost database.

Measure	Source
Do minimum	
Reduce existing activities	N/A
Proactive maintenance	Halcrow Barry, FCC, OPW
Non-structural measures/ minor & localised modifications	
Develop a flood forecasting system	Halcrow Barry (fluvial), Marcon (Tidal)
Targeted public awareness and education campaign	Halcrow Barry
Individual property flood-proofing	Halcrow Barry
Sediment management	Halcrow Barry
Land management	Halcrow Barry
Structural measures	

Measure	Source
Sustainable Urban Drainage Systems (SUDS)	Halcrow Barry
Rehabilitation, improvement of existing defences	Halcrow, SPONS Civil Engineering and Highways Price Book, OPW,
Improvement in channel conveyance	Halcrow, OPW, Environment Agency (EA) Unit Cost Database
Provision of permanent flood walls/ embankments	EA Unit Cost Database
Provision of demountable flood defences	Halcrow Barry
Use of overland floodways (e.g. allowing flooding of roads in a controlled manner)	SPONS
Flow diversion (full diversion / bypass channel, flood relief channel, etc.)	EA Unit Cost Database
Flood storage reservoirs	Halcrow Barry
Beach Recharge/sand dunes	EA Unit Cost Database
Groynes	EA Unit Cost Database
Breakwater	EA Unit Cost Database
Managed realignment	EA Unit Cost Database
Tidal barrier/Tidal barrage	Halcrow
Relocation of at risk assets (roads, properties, etc)	Halcrow

4. Option assessment process

Introduction

The option assessment process was introduced in the Preliminary Options Report (Halcrow Barry, December 2010), which focussed on the first stage of the assessment process. This final report builds on the findings of the Preliminary Options Report and presents the results of the second (development of options) and third (evaluation of options) stages of the process.

The flood maps identify locations within the study area at risk from economic, social and environmental flood risk. Where the risks are significant, the study has identified a range of potential options to reduce these risks. Flood risk management options were developed for AUs and APSRs (refer to Figure 4-1), through a three stage process:

(i) Stage 1 – assessment of measures: a long list of measures was screened for each AU and APSR to filter out any measures which were not applicable. The remaining measures were evaluated, based on the core criteria, to provide a short list of measures for each assessment unit;

(ii) Stage 2 – development of options: the list of measures was developed into potential flood risk management options for each AU and APSR (Section 0); and

(iii) Stage 3 – detailed assessment of options: a process of detailed multi criteria analysis was used to determine the preferred option(s) for each AU and APSR, to be included as part of the Fingal-East Meath FRMP (Section 0).

This three stage process is based around the flood risk management objectives introduced in Chapter 3 of the Preliminary Options Report. The FRM objectives are discussed further in Section 0 below. In assessing flood risk management options, the combined fluvial and tidal flood risk scenarios have been analysed in the first instance. Details of the Stage 1, 2 and 3 assessments for each of the AUs and APSRs in the Fingal-East Meath study area are detailed in Chapters 7 to 12. Details of the assessment of options for the IRRs are contained in Chapter 13.

The detailed assessment of flood risk management options is based on the existing levels of flood risk and development in the study area. Options are not considered for lands zoned for development but not yet developed.

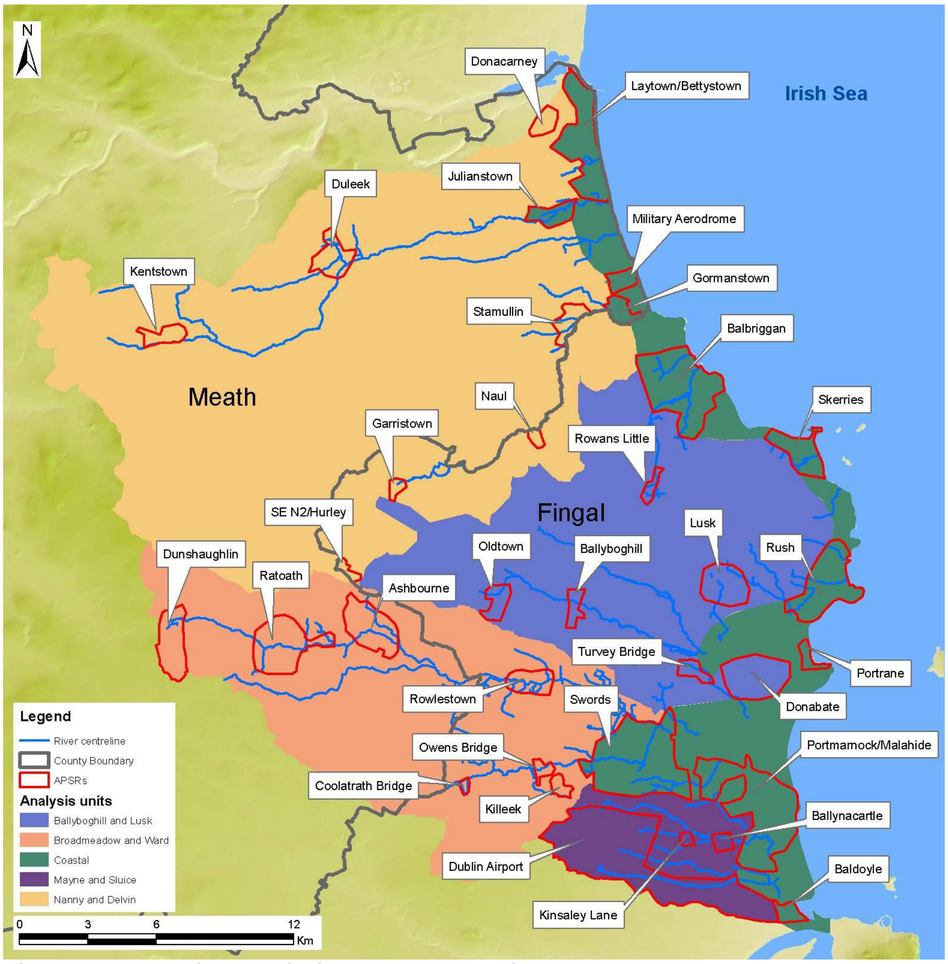


Figure 4-1 AUs and APSRs in the FEM FRAM study area

Flood risk management objectives

As discussed in the Preliminary Options Report, the purpose of the flood risk management (FRM) objectives is to provide a basis by which the flood risk management measures and options can be assessed. Appendix I provides details of the full list of objectives used in the study. The objectives are based on the generic objectives developed by OPW for the national roll out of CFRAM studies. They incorporate all relevant SEA-related objectives identified within the study's Environmental Scoping Report (2009) and cover four core criteria:

(i) Technical: three objectives covering operation (i.e. measures are operationally robust), health and safety and sustainability of FRM options;

(ii) Economic: four objectives covering economic risk, risk to transport infrastructure, risk to utility infrastructure and risk to agricultural land;

(iii) Social: three objectives covering risk to human health and life, community and social amenity; and

(iv) Environmental: six objectives covering the requirements of the Water Framework Directive, risks from pollution, flora and fauna, fisheries, landscape character and cultural heritage.

Associated with each of the objectives are sub-objectives, indicators, minimum targets and aspirational targets. This information is used to assess options as part of stage 3 of the staged assessment process, i.e. multi criteria assessment, with options scored on how well they perform in meeting the minimum and aspirational targets. The performance of each option against the objectives is reflected in the scores shown on the stage 3 spreadsheets (refer to Chapters 7 to 12 for more details). Further information on the scoring methodology is included in Section 4.4.4.

Stage 1 – identification of flood risk management measures

The first stage of the assessment process is discussed in detail in the Preliminary Options Report. The methodology and the results of the assessment are presented in Chapter 6 and Chapter 7 of this report.

The stage 1 assessment identified a number of viable flood risk management measures for the AUs, APSRs, localised areas and the IRRs which will be considered further. There are a number of measures which carry forward from the stage 1 assessment and which are consistent across the various analysis units. These include:

- Development (Meath County Council) and enhancement (Fingal County Council) of a proactive maintenance regime targeting potential culvert blockage locations;
- Targeted public awareness and education campaign; and
- Individual property flood proofing.

These measures can all be applied at the AU scale and provide a reduction in flood risk to all properties in the study area.

Other measures which carry forward from the stage 1 assessment and which can reduce flood risk to large parts of the study area include:

- Development of fluvial and tidal flood forecasting and warning system (FFWS) for a number of rivers and for the Fingal and Meath coastline; and
- Regular inspection and maintenance of coastal defences including walls embankments and flap valves.

The remaining measures are generally structural measures which focus on protecting properties at risk in the APSRs, clusters of properties at risk in the study area and the IRRs. These measures include:

- Rehabilitating and raising existing coastal defences;
- Construction of embankments and walls;
- Provision of demountable flood defences;

- Improving channel conveyance;
- Constructing flow diversion channels;
- Construction of flood storage reservoirs; and
- Relocation of residential properties.

In general, the remaining flood risk management measures did not carry forward from the stage 1 assessment on either technical or economic grounds. The low level of existing flood risk resulted in large and complex measures (such as breakwaters and tidal barriers) receiving a benefit cost ratio (BCR) significantly less than 1 which ruled them out on economic grounds.

A summary of the results for each assessment unit is included in Appendix B.

Stage 2 – development of potential options

A short list of measures for each assessment unit was brought forward to the option development stage. The short list of measures was reviewed and developed into potential flood risk management options for each assessment unit. The options are made up of either single, or a combination of, measures carried forward from stage 1. Further information on the development of potential options is contained in Chapter 5.

Stage 3 – assessment of potential options

The detailed assessment of potential options used a detailed MCA process to score the performance of each option in managing flood risk relative to the baseline flood risk data for each of the 16 flood risk management objectives (Section 0). Each objective was weighted (refer to section 4.4.3) to reflect its importance and/or sensitivity, and ensure that those objectives most relevant to the location under consideration were given priority in the decision-making process. As part of this process further consideration was given to the location, alignment and type of defence for each AU and APSR (refer to Section 0).

4.4.0. Technical objectives

The technical objectives address issues relating to the operation, health and safety and sustainability of FRM options. The sustainability of the options assessed the potential ability of options to be adapted to allow for future increases in flood risk. With most defence types, adaptability to future flood risk will be incorporated through adequacy of foundations and provision for incremental increase of the defence height. No baseline data is available for the three technical objectives.

4.4.1. SEA objectives

The SEA objectives comprise 12 of the 16 FRM objectives used during the option assessment process, including three of the economic objectives, all three social objectives and six environmental objectives.

The objectives address issues relating to all of the SEA topics required for consideration under the SEA Directive, except where particular topics have been identified as not relevant to the study through the scoping process, such as air and climate.

4.4.2. Use of objectives

Each of the objectives, where appropriate, is divided into more specific sub-objectives relating to each topic. For the economic, social and environmental objectives, and associated sub-objective(s), a framework of associated indicators and targets was established; thus enabling the use of these objectives as appraisal criteria within the option assessment process. For the technical objectives, a framework of targets was established.

During the Stage 3 process, the performance of each option was measured, quantitatively where appropriate, for each sub-objective relative to baseline conditions (defined in terms of each of the specified indicators). For the technical objectives a guidance note was prepared on measuring the performance of each option. In order to determine whether this performance is acceptable, two levels of targets have been set for each objective and associated sub-objective(s):

- The first target sets the minimum requirement that needs to be met for an option to be acceptable; or at least, could be acceptable through the implementation of appropriate mitigation strategies to offset any potential adverse effects; and
- The second, more demanding aspirational target does not need to be met for the acceptance of options; although options meeting these higher targets are likely to be favoured.

This system enabled the scoring of options as described in Section 4.4.4.

4.4.3. Weighting of objectives

Two sets of weighting have been applied to the objectives;

- Global weighting; and
- Local weighting.

The global weightings have been developed by the OPW and are fixed nationally; they are unchanged for each assessment unit. This level of weighting recognises the key drivers behind FRM options and gives higher weightings to risk to human health and life and economic return on options. Table 4-1 sets out the global weightings.

The local weighting of each objective varies for each assessment unit depending on the level of applicability of that objective to that unit. For some objectives, the local weighting could be 0, since the objective does not apply to that part of the study area. Table 4-2 sets out the range of local weightings that can be applied.

The relevance or importance of an objective to a particular assessment unit is dependent on the level of risk and the indicator at risk. For example, if a local road is flooded then a local weighting of 2 might apply but if a national route or motorway is flooded then a local weighting of 4 might apply. In addition, if a designated EU Special Area of Conservation is located within an assessment unit and may be impacted upon by the level of flood risk and/or the proposed option then the relevant environmental objectives may be given a local weighting of 5.

These two types of weighting are multiplied together to give an overall weighting. Details of the guidance used for setting local weightings for each of the objectives are presented in Appendix D1.

One of the main objectives of using local weightings is to ensure local issues are appropriately taken into account. To facilitate this OPW and FCC arranged for a local weightings questionnaire to be issued to key stakeholders in the study area. The results of the questionnaire are summarised in the SEA Environmental Report.

Table 4-1 Global weightings

Criterion	Objective	Global Weighting
Technical	Operationally Robust	5
Technical	Health & Safety Risk	5
Technical	Adaptability	5
Economic	Economic Return	25
Economic	Transport Infrastructure	5
Economic	Utility Infrastructure	10
Economic	Agriculture	5
Social	Risk to Human Health	30
Social	Community Risk	10
Social	Risk to Social Amenity	5
Environmental	Ecological Status	5
Environmental	Pollution Sources	15
Environmental	Habitats	10
Environmental	Fisheries	5
Environmental	Landscape Character	5
Environmental	Cultural Heritage	5

Table 4-2 Local weighting

Weight	Relevance/Importance
5	Major/International importance
4	Significant/National importance
3	Medium/Regional importance
2	Minor/Local importance
1	Negligible importance
0	Not relevant

4.4.4. Scoring of options

The performance of each option, relative to defined baseline conditions (the present day situation) was scored for each of the 16 FRM objectives. The scores used ranged between -999 and 5, using the general criteria shown in Appendix D2. Following scoring, for each objective, a weighted score (weighted score = global weighting x local weighting x options performance score) was then calculated for each option as shown in Table 4-3.

Table 4-3 Scoring of options

Objectives	Global Weighting (GW)	Local Weighting (LW)	Option performance (relative to baseline, where 0 = no change)	
			Score (S)*	Weighted Score (WS)
Technical	5	0 – 5	-999 to + 5	WS = (GW x LW) x S
Economic	5 – 25	0 – 5	-999 to + 5	WS = (GW x LW) x S
Social	5 – 30	0 – 5	-999 to + 5	WS = (GW x LW) x S
Environmental	5 – 15	0 – 5	-999 to + 5	WS = (GW x LW) x S
				MCA score = Total WS (all objectives)

A total MCA score was then calculated for each objective as the sum of the weighted scores across the 16 objectives for each option. This MCA score reflected the performance of the scheme in terms of the study's objectives. The results of this process and details of the MCA scores of all options considered are presented in Appendix E and discussed in Chapters 7 to 12.

All FRM options with positive MCA scores were then carried forward to the final stage of the process – the identification and assessment of the preferred options (Chapter 14).

5. Development of potential options

Initial approach

Following completion of the stage 1 assessment, the short list of measures for each assessment unit was reviewed and developed into potential options to be carried forward for detailed assessment under stage 3. When developing the stage 2 spreadsheet with the potential options for all assessment units, the following points were considered:

- Measures that were carried forward for all assessment units;
- Measures that were carried forward for all APSRs within an AU;
- Measures that were more appropriate at a catchment scale; and
- Measures specific to APSRs/localised areas.

In addition to the above it was important to consider the following:

- Potential links between options in different assessment units;
- Potential impacts and benefits of an option in one assessment unit on other areas;
- Dependence of one option on another option being implemented; and
- Mutual benefits of different options at different spatial scales.

When undertaking the stage 1 assessment each measure (both non-structural and structural) was assessed for their applicability to manage flood risk in each AU, APSR and IRR. FRM measures were considered for all clusters of properties at risk of flooding regardless of whether they were located within an APSR. This was done due to the nature of flood risk in the Fingal-East Meath study area. Many of the APSRs had very little flood risk whereas other urban areas did have flood risk but were not within APSRs. Therefore, when the stage 2 spreadsheet was developed the FRM options for localised urban areas were included at the same spatial scale as APSRs.

In addition, individual properties at significant risk of flooding (i.e. with a damage value greater than the current market value of the property) were considered for relocation out of the floodplain. No other measures were considered for these properties, as in general, other measures were only considered for clusters of properties together to make them viable.

When developing options for each of the spatial scales the results of the stage 1 assessment determined which measures were applicable to each spatial scale. For example, the proactive maintenance measure carried forward from each stage 1 assessment and therefore was considered applicable to the whole study area. A detailed table showing the options developed for each assessment unit at each spatial scale is contained in Appendix C.

Final options brought forward to stage 3

Due to the complex nature of the flood risk in the study area, that is flood risk arising from many small watercourses, risk to very small clusters of properties and a combination of fluvial and tidal risk in many areas, lengthy discussions were held to determine the best way forward for the detailed assessment of options and identifying preferred options for the plan. The two main points of discussion were:

- Position of FRM options for localised urban areas outside of APSRs; and
- Viability of considering individual properties for relocation out of the floodplain.

Following the discussions it was agreed to only consider specific structural options for properties within APSRs. It was also agreed not to include options for relocating existing properties out of the floodplain in the stage 3 assessment. Instead information on clusters of properties and individual properties at significant risk of flooding but outside of APSRs would be provided to the Local Authorities and OPW. Owners of these properties would be advised, by the Local Authority or OPW, of the flood risk and have the option to pursue FRM options being implemented under the OPW Minor Works Programme. Potential options that have been identified for clusters of properties at risk of flooding outside of APSRs are included in Appendix H.

The final options going forward to stage 3 for each spatial scale are discussed in sections 0 to 0. Further detail on each of the options and the results of the multi-criteria assessment of these options are in Chapters 7 to 12.

Catchment scale

Fingal-East Meath Study Area

Two options were carried forward for the study area scale:

- Proactive maintenance; and
- Targeted public awareness and preparedness campaign and individual property flood proofing (IPFP).

Analysis unit scale

Of the five analysis units, two options were carried forward for the Coastal AU and one each for the Nanny & Delvin, Broadmeadow & Ward and Mayne & Sluice AUs. No options were carried forward for the Ballyboghil AU.

Coastal AU

- Fluvial & tidal flood forecasting and warning system.
- Proactive maintenance of coastal defences.

Nanny and Delvin AU; Broadmeadow & Ward AU; Mayne & Sluice AU

- Flood Forecasting & Warning System (FFWS) on the Nanny River, Broadmeadow River and Mayne River.

APSR scale

Of the 34 APSRs identified by the client in the brief, a total of 9 APSRs have options to protect properties at risk carried forward to stage 3. The majority of the APSRs just have one viable option carried forward but some APSRs, with a greater level of risk, have a number of different options being carried forward to stage 3.

Duleek APSR

- Improving existing defences by raising the existing defence embankments along the Nanny River and Paramadden Stream to a higher standard of protection (to protect up to 0.1% AEP).

Ratoath area APSR

- Improve channel conveyance by replacing a bridge on the Broadmeadow River at the R125 Ratoath Road and replacing a culvert on a tributary of the Broadmeadow River.

Rowlestown East APSR

- Construction of flood defence embankments along the left bank of the Broadmeadow River tributary upstream of the R125.

St Margaret's, Dublin Airport, Belcamp & Balgriffin area APSR

- Improve channel conveyance by removing an old bridge structure combined with the construction of flood defence embankments & walls upstream of the R123 and along the left bank of the Mayne River and tributary.

Portmarnock and Malahide areas APSR

- Rehabilitating and raising existing coastal defences at Strand Road, Portmarnock (including rehabilitation walls and flapped outfall) and construction of flood defence embankments;
- Replacement of flapped outfall on Sluice River and construction of flood defence embankments and walls to protect at risk properties at Strand Road, Portmarnock;
- Construction of flood defence embankments along the coast road and walls in Malahide town centre to protect at risk properties along the coast road and in Malahide town centre;
- Construction of flood defence embankments along the coast road combined with walls and rehabilitation and raising of existing coastal defences in Malahide town centre to protect at risk properties along the coast road and in Malahide town centre; and
- Construction of demountable flood defences along with embankments along the coast road and in Malahide town centre to protect at risk properties along the coast road and in Malahide town centre.

Swords area APSR

- Improve channel conveyance by widening the Gaybrook Stream to reduce fluvial flood risk to properties at Aspen near Kinsaley; and
- Construction of flood defence walls to protect properties at risk from tidal flooding in Swords town centre.

Rush area APSR

- Construction of flood defence embankments and walls and replacing culvert along Channel Road, Rush to protect at risk properties along the coast and from the Rush West stream.

Skerries area APSR

- Rehabilitating and raising existing coastal defences at Harbour Road to reduce tidal flood risk;
- Improve channel conveyance by replacing culverts under roads and railway with larger capacity culverts and widening the channel through the park to reduce fluvial flood risk to properties at Miller Lane and Sherlock Park;
- Constructing a flow diversion channel to run in a culvert under the railway and roads at Miller lane and Sherlock Park to reduce fluvial flood risk to properties at Miller Lane and Sherlock Park;
- Overland flood route using existing roads by lowering road levels and raising kerb levels along Miller Lane and Sherlock Park to allow controlled flooding along these roads to reduce fluvial flood risk to properties;
- Construction of a flood storage reservoir on industrial zoned land to the west of railway embankment to provide flood storage upstream of Skerries area APSR to reduce fluvial flood risk to properties along Miller Lane and Sherlock Park; and
- Construction of a flood storage reservoir on industrial zoned land to the west t of the railway embankment to provide flood storage upstream of Skerries area APSR along with replacing culverts under roads and railway with larger capacity culverts to reduce fluvial flood risk to properties along Miller Lane and Sherlock Park.

Laytown, Bettystown and Coastal area APSR

- Construction of flood defence embankments to protect properties at risk along the coast and from the Nanny River; and
- Construction of demountable flood defences to protect at risk properties along the coast and from the Nanny River.

IRRs

Potential FRM options for IRRs were assessed at stage 1. The options carried forward from stage 1 for each IRR are shown in Table 5-1.

Table 5-1 List of IRRs at risk of flooding in the study area

AU/APSR	Category	Asset at Risk	Options
Stamullen area APSR.	Utilities Infrastructure	1 Utilities asset (ESB, GAS and EIRCOM utilities)	Construction of flood defence embankments Construction of flood diversion channel Individual property flood proofing (IPFP)
Ballyboghil area APSR.	Utilities Infrastructure	1 Wastewater treatment works	Construction of flood defence embankments Construction of flood diversion channel
Ashbourne area APSR	Utilities Infrastructure	1 Wastewater pumping station (Castle Street Pumping Station)	Construction of flood defence embankments
Julianstown area APSR	Utilities Infrastructure	1 Wastewater treatment works	Construction of flood defence embankments
Owens Bridge area APSR	Utilities Infrastructure	1 Wastewater treatment works at Toberburr	Construction of flood defence embankments
St Margarets, Dublin Airport, Belcamp and Balgriffin areas APSR	Transport Infrastructure	110m of National Primary (N32) near Clonshaugh	Construction of flood defence embankments
Ballyboghil and Lusk AU	Transport Infrastructure	400m of the northbound carriageway of the M1 at Staffordstown	Construction of flood defence embankments Construction of flood diversion channel

6. Modelling and costing of potential options

Introduction

The previous chapter details the option assessment process used to identify FRM options for the Fingal-East Meath study area. This chapter provides an overview on adding detail to measures and options, such as identifying the location and alignment of defences, modelling of options and costing of options. More specific details of options considered for each AU and APSR are discussed in Chapters 7 to 12.

In order to determine the costs and impact of structural options, an estimate of the location, and dimensions are required. In this chapter, information is provided on the indicative alignment and location, hydraulic modelling, costing and economic benefits of options.

The indicative alignment and location of defences only applied to the following structural measures:

- Improvement in channel conveyance;
- Permanent and demountable defences; and
- Flood storage reservoirs.

The hydraulic modelling of options applied to all of the above structural measures. Further information on location and modelling of these structural options is presented in Sections 0 and 0.

For the remaining structural and non structural options, hydraulic modelling of the option was not necessary to determine costs and impacts of that option (Section 0). Details on the costs and economic benefits of both structural and non structural options are in Sections 0 and 0.

Location and indicative alignment of structural measures and options

6.1.0. Introduction

For the stage 1 and 2 assessments, the location and alignment of structural measures were based on OSi maps, flood extent maps and the results from the economic damage assessment (i.e. defences were identified for properties suffering economic risk of flooding for the 1% AEP fluvial event and 0.5% AEP tidal event). As part of the stage 3 assessment, the alignment and location of structural options was refined. Prior to assessing the hydraulic performance of defences as part of the stage 3 assessment, further detailed consideration was given to the location and alignment of defences based on the following:

- Flood depth maps;
- The amount of space available between existing buildings and the river channel;
- The location of existing structures, such as bridges;
- Hydro DEM assessment (specifically for the assessment of storage reservoirs);
- Hydraulic models; and

- Previous project experience.

As the economic benefits of an option are solely based on the economic damages accruing to buildings damaged during a flood event, the indicative alignment, and hence costs, of defences were based upon protecting these damaged buildings. This approach ensured that a more accurate representation of the BCR of a particular option would be achieved. Where applicable, consideration was also given to protecting infrastructure assets which would benefit from defences.

The locations of proposed new structural defences were input to the existing hydraulic models of the rivers to model the hydraulic performance of the structural options (Section 0). Further details on the alignment of defences and hydraulic performance of options for each AU and APSR are provided in Chapters 7 to 12 of the report.

In determining the alignment of defences, no consideration was given to the location of possible underground services, ground conditions, etc. as this is outside the scope of a FRAM Study. Additionally, no consideration was given to protecting lands zoned for development or to specifically protecting agricultural land.

6.1.1. Improvement in channel conveyance

The installation of new culverts and bridges was considered as an option to improve channel conveyance. New culverts and bridges were only considered in urban areas where existing culverts were causing channel constrictions and where other methods to improve conveyance were not considered viable. The alignment and location of proposed culverts and bridges took into consideration;

- Properties at risk; and

  Location and alignment of any existing culverts or bridges.

The location of proposed culverts and bridges sought to minimise disruption to properties and infrastructure. Once the alignment, dimensions and location of the proposed culverts and bridges were identified, the hydraulic performance and impact of the proposed culvert or bridge was assessed using the hydraulic models (Section 0).

Dredging and widening of the river bed and banks was also considered as an option to improve channel conveyance. Based on a review of flood extent data, river cross sections, river bed profiles and water level data, sections of urban area watercourses with reduced conveyance were identified. The hydraulic performance of re-grading and re-profiling sections of urban area watercourses was tested by modifying the relevant hydraulic models (Section 0).

6.1.2. Permanent and demountable structures

Permanent and demountable defence structures are generally located alongside the river channels/coastline and include flood walls, flood embankments and demountable defence structures. Demountable defences refer to lengths of defences that are erected when a flood is forecast and are taken down after the threat of flooding has receded. The permanent defences may also include some localised demountable gates/sections for access. Emphasis was placed on developing smaller scale localised defences that could be constructed to protect a significant number of properties. Extensive defences to protect a small number of properties were generally avoided as they were unlikely to achieve a positive cost benefit ratio.

Where possible permanent and demountable flood defences were set back from the watercourse to allow space for flood waters and to reduce the impact of a flood defence scheme on water levels upstream and downstream of the proposed defence location. Setting defences back from the channel improves access to the rivers and helps minimise the visual impact of a flood defence scheme. The choice of flood defence structure (e.g. flood wall, demountable defence, flood embankment, etc) along the alignment of defences was based on space constraints, visual impact and the results from the hydraulic modelling of options. The costs for flood embankments are less than the costs for flood walls and where possible, flood embankments were used as the preferred permanent defence option. Further information is available in Chapters 7 to 12 of the report.

6.1.3. Flood storage reservoirs

The location of proposed flood storage reservoirs was based on a review of the hydrologically corrected DEM, mapping data and GeoDirectory property data. The HydroDEM was used to identify locations within the study area where significant flood storage could be provided. Mapping data and the GeoDirectory database were used to eliminate areas where the construction of storage reservoirs would result in a significant impact on infrastructure assets and properties. To fully realise the benefits of storage at APSR scale, the reservoir would need to be located reasonably close to the APSR. This criterion was also considered in the identification process.

Once locations were identified, the hydraulic performance of the proposed storage reservoirs was assessed to determine the impact at both AU scale and APSR scale (Section 0). Hydraulic modelling was also used to optimise the size of the flood storage reservoirs necessary to reduce the flood risk downstream.

Modelling of options

6.2.0. Introduction

Once the alignment and location of the defences was chosen, the existing hydraulic models, developed for the rivers, were adapted to represent proposed flood defence structures. The purpose of the hydraulic modelling of options was to determine the impact of proposed defences both within areas being considered and upstream and downstream of areas being considered. This information was used in assessing the performance of an option against the flood risk management objectives. The outputs from the hydraulic modelling of options also provided information which was used to estimate the costs of proposed defence options. As noted earlier, hydraulic modelling was used to assess the impact of the following defence options:

- Improvement in channel conveyance;
- Provision of permanent flood walls/ embankments/ demountable flood defences; and
- Flood storage reservoirs.

Further information on the modelling of options for each AU and APSR is contained in Chapters 7 to 12.

6.2.1. Design standard and freeboard

Table 6-1 provides details on the design standard and freeboard applied to various structural defence options for this study. The design standard is based on standards adopted for the Lee CFRAMS.

Table 6-1 Design standard and freeboard applied to structural defence options.

Defence option	Design standard (level of protection in terms of AEP)	Freeboard (m)	
		Fluvial	Tidal
Walls, demountable defences	1% AEP event fluvial and 0.5% AEP event tidal*	0.3	0.5
Embankments	1% AEP event fluvial and 0.5% AEP event tidal*	0.5	0.8
Culverts and bridges	95%ile flow for 1% AEP MRFS	n/a	n/a
Dredging of river channel and raising of bridges	1% AEP event fluvial and 0.5% AEP event tidal	n/a	n/a
Storage reservoir embankment	1% AEP event fluvial*	0.5	n/a
*Design would also include adaptability of defences for climate change.			

The tidal freeboard was applied to defences in exposed locations along the Fingal-East Meath coastline. In the more sheltered areas, i.e. along river estuaries exposed to both fluvial and tidal flooding, the fluvial freeboard was applied to defences.

6.2.2. Hydraulic model runs

Hydraulic models were run for a number of scenarios, depending on the option being modelled. The results from the model runs were used to determine the impact of the proposed option with the water level results used directly for determining the costs of the proposed option (refer to Section 0).

For permanent defence structures set alongside the river channel, i.e. flood walls and embankments, the hydraulic river models were run for the 1% AEP fluvial event for areas affected by fluvial flooding and for the 1% AEP fluvial and 0.5% AEP tidal events for areas affected by both tidal and fluvial flooding. These model runs are in line with the design standard for defences outlined in Table 6-1. Where the results of this assessment indicated that the design standard resulted in a negative BCR, additional model runs for higher frequency events were undertaken to identify if a positive BCR could be achieved with a lower design standard.

For flood storage reservoirs, a number of model runs were carried out to optimise the storage capacity and reduce the impact of flooding downstream. Where possible, the volume of storage generated was sufficient to eliminate the risk of fluvial flooding downstream.

For culverts and bridges, the model was run for the 1% AEP MRFS fluvial event 95%ile flow with the dimensions of the culverts and bridges adjusted to accommodate this flow without surcharging. The model was then run for the 1% AEP fluvial event for areas affected by fluvial flooding and for the 1% AEP fluvial and 0.5% AEP tidal events for areas affected by both tidal and fluvial flooding to determine the impact on water levels of the increased culvert/bridge capacity.

For the widening and deepening of channels option, the hydraulic river models were run for the 1% AEP fluvial event for areas affected by fluvial flooding and for the 1% AEP fluvial and 0.5% AEP tidal events for areas affected by both tidal and fluvial flooding.

Measures for which no hydraulic modelling was undertaken

For a number of structural and non structural measures the hydraulic performance is difficult to assess at this level of study. These measures include:

- Flood forecasting and warning systems;
- Individual property flood proofing; and
- Proactive maintenance;

Information from a number of other project activities, including the hydrological assessment, flood risk assessment, damage assessment and the flood defence asset database provided useful information in determining the viability and costs for these options. Previous project experience was used in assessing the performance of an option against the flood risk management objectives. Further details on these options are contained in Chapters 7 – 12.

Costing of options

A number of sources of data were used to develop a cost database for calculating the basic costs for each flood risk management measure during the stage 1 assessment. As no national unit cost database is available for Ireland, a database developed as part of the Lee CFRAMS has been used for the costing of measures for this study. The sources of this data range from established unit cost databases (e.g. Environment Agency of England and Wales Unit Cost Database) to Halcrow Barry costs from previous project experience. The database has been updated to include cost data made available by the OPW, FCC and MCC. All of the data in the database has been converted to Euro (Q4 2009); refer to Appendix J for the database.

As part of the stage 3 assessment the outline costs estimated at stage 1 were updated to build up a complete basic construction cost for each option. Details on how the cost build up for the options was undertaken are in Sections 0 to 0.

Calculation of basic costs

The calculation of the basic construction cost involved the use of the cost database to estimate the basic construction costs of the various measures incorporated in an option using outputs from the hydraulic modelling and various other project activities, e.g. FDAD, wherever available.

Proactive maintenance: Proactive maintenance includes costs for maintenance of flood defence structures such as walls and embankments and structures located along the river channel such as bridges and culverts. For the maintenance of culverts, an annual cost rate of € 50,000 for the regular inspection and maintenance of 20 culverts was provided by FCC and used as a basis for determining maintenance costs for these structures.

For defences in the FDAD, the costs for this measure were linked to the length of defences to be maintained and the existing condition of defence assets (wherever this information was available). Depending on the condition of the asset, the residual lifespan was determined based on information in the "National Sea & River Defence Surveys Condition Assessment Manual" published by the Environment Agency, as shown in Table 6-2.

The costs for repairing and maintaining defences were assumed to be 50% of the costs for replacing the structures, as some structures would be repaired rather than replaced. The NPV for replacing and maintaining defences was calculated from the residual lifespan of the defences.

Table 6-2 Residual lifespan based on the condition of defence assets

Asset condition	Residual life (years)
Very Good	67
Good	41
Fair	21
Poor	9
Very Poor	2

The costs for this option also included for the provision of the DAS every 5 years to monitor the performance of defences. These costs were based on the costs for undertaking the DAS as part of the Lee CFRAMS and FEM FRAMS. Additional costs were also included for inspection of defences after a flood event.

Further details on costs for this measure for relevant AUs are in Chapters 7 – 12.

Develop a flood forecasting and warning system: The costs for developing a fluvial flood forecasting and warning system are based on a project completed by Halcrow in 2006 which evaluated a number of flood forecasting schemes for a catchment in Wales. The capital costs for provision of gauges and development of flood forecasting tools are presented in Table 6-3 below.

Table 6-3 Cost data for provision of a flood forecasting system

Fluvial flood forecasting	Unit	Cost (€)
Gauging station	Per station	50,000
Level-to-level correlations	Per model	50,700
PDM rainfall-runoff models only	Per model	118,300
Upstream PDM rainfall-runoff model (with routing model)	Per model	115,227
Downstream PDM rainfall-runoff model (with routing	Per model	104,472

Fluvial flood forecasting	Unit	Cost (€)
model)		
Upstream PDM rainfall-runoff model (with hybrid model)	Per model	133,663
Downstream PDM rainfall-runoff model (with hybrid model)	Per model	124,445
Installation/upgrading rain gauges	per gauge	1,536

In costing fluvial flood forecasting and warning systems for the Fingal East Meath study area, consideration was given to the existing network of river and rain gauges and the time to peak in the watercourses. Further details on these factors are contained in Chapters 7 – 12 with further information of flood forecasting and warning systems in the Preliminary Options Report (Halcrow Barry, 2010).Costs were also included for the operation of these systems over a 50 year lifecycle.

Through the Irish Coastal Protection Strategy Study (ICPSS), low-resolution tidal-surge forecasting capability has been developed around the Irish Coast. The system is a purely tidal-surge forecasting model and would need to be upgraded to provide automated flood warning to people at risk. The costs for this option therefore include costs for upgrading the system to automate dissemination of data and the costs for the operation of the systems over a 50 year lifecycle.

It is noted that the National Flood Forecasting Review Group will make recommendations with regard to the implementation of flood forecasting and flood warning on a national scale and the proposals for a FFWS for each of the AU's identified under this study will be delivered within this context.

Individual property flood proofing costs were based on the outputs from the modelling decision support framework (MDSF) damage assessment results, which give the depth of flooding at each property for a range of AEP events. Where the depth of flooding was greater than 0.6m for the design standard (i.e. 1% AEP fluvial and 0.5% AEP tidal events), individual property flood proofing was not considered viable. The costs for providing individual property flood proofing were calculated for residential and commercial properties separately based on the MCM classification for the buildings. Table 6-4 provides details on the costs for provision of individual property protection at commercial and residential properties and are based on a study recently completed by Halcrow in the UK.

Table 6-4 Costs for provision of individual property protection at commercial and residential properties

Property type	Costs (€)	Unit
Residential	8,000	Per property
Commercial	20,000	Per property

Targeted public awareness and education campaign costs were based on producing flood maps and holding public exhibitions targeted at people at risk of flooding. The costs were based on costs for producing flood maps for this study and varied depending on the size of the AU or APSR and the number of properties at risk. Details of the various costs are in Chapters 7 – 12.

Rehabilitation/improvement of existing defences were based on the following information based on the location of the defences:

- In Duleek, the costs for raising the flood walls were based on the height of the walls to be raised by the unit cost rate for flood walls. For the flood embankments, the additional volume required to raise the embankments to a higher standard of protection was calculated and used to estimate the costs. In both cases it was assumed that the existing foundations of these structures were adequate to accommodate raised defences; and

- At Strand Road in Portmarnock, the costs for rehabilitating the walls were based on the costs of constructing new flood walls as the existing walls do not appear to be formal flood defences (based on site visit notes). The costs for rehabilitating the sluice gate are based on data available in SPONS Civil Engineering and Highway Works Price Book.

Improvement in channel conveyance: A number of measures were covered under this heading (e.g. replacement of culverts, raising bridge decks, widening of river channels) and cost data varied depending on the measure being considered. Information relating to costs for specific measures is covered in Chapters 7 – 12.

Provision of permanent flood walls/embankments: The costs for the provision of walls are dependant on a number of factors including the type, length and height of the wall. The type of wall chosen was dependant on the location of the wall relative to the channel, the proposed height of the wall and whether the wall was required to protect against either fluvial or tidal flooding. Where walls are set back from the channel, the height of wall required will typically be less than where the wall is constructed to the bed of the channel. The length of the walls was determined from the outputs of the hydraulic modelling of the options. The height of the walls was determined from hydraulic model outputs – left/right bank level and bed level. Where defences are set back from the channel the LiDAR data was used to determine the minimum height required. Table 6-5 provides details of the unit cost rate for different wall heights based on the height of the walls.

Table 6-5 Costs for permanent defence walls

Flood Walls	Unit	Unit Cost Rate (€) based on height band			
		< 1.2m	1.2 - 2.1m	2.1 - 5.3m	> 5.3m
Retaining	m	2,358	2,638	3,444	
Retaining and cut off	m	1,380	3,996	4,567	
Retaining and piled	m		4,609	4,024	13,739
Wall raising foundations	m	1,162	1,957		
Wave	m	2,170	1,850		

For defences located in exposed coastal locations, the defences and associated costs outlined in Table 6-6 were considered.

Table 6-6 Costs for coastal defences

Coastal	Unit	Unit Cost Rate (€) per meter of defence
Beach recharge and breakwater	m	7,532
Beach recharge and Groynes	m	4,949
Rock Armour	m	4,779

Coastal	Unit	Unit Cost Rate (€) per meter of defence
Revetment and wall	m	4,580
Breakwater	m	4,571
Beach recharge	m	3,666
Revetment	m	2,615
Sea Wall	m	2,293
Tidal barrier/barrage	m3	4,057
Sand Dune	m	53

For flood embankments, the costs of the embankment are determined by the volume of fill. Embankments were costed with a 1 in 3 side slope. Outputs from the hydraulic modelling of defences (including lengths, left and right bank levels and water levels) were used to determine the fill volume for embankments. Embankment costs are detailed in Table 6-7.

Table 6-7 Costs for defence embankments

Embankment type	Unit	Unit Cost Rate (€) based on volume m^3		
		500-5,000	*5,000 - 15,000*	*>15,000*
Earth embankments	m^3	98	69	36

Provision of demountable flood defence costs were based on a demountable flood defence scheme completed by Halcrow in Ironbridge in England. The costs are based on a pallet barrier type system which is fitted to a retaining structure with cut off. The retaining structure should be no more than 0.5 - 1.0m above ground level to allow for ease of installation of demountables. The costs for construction, operation and storage of these demountable defences are detailed in Table 6-8.

Table 6-8 Costs for construction, operation and storage of demountable defences

Element	Costs rate(€)
Construction of Pallet Barrier demountable flood defence (cost per meter)	771
Operational (costs per meter)	69
Storage (costs per annum)*	16,057

**Note: For small lengths of demountable defences a fixed cost was applied as appropriate and the yearly value was not used.*

Flood storage reservoir costs are based on construction works currently underway on the White Cart Water Flood Prevention Scheme in Scotland. The scheme involves the construction of three flood storage reservoirs of varying sizes and complexity upstream of Glasgow City. An estimate of costs for constructing storage embankments of different sizes was derived from these costs, with details in Table 6-9.

Table 6-9 Costs for provision of storage reservoir embankment

Volume (m^3)	Cost (€) per m^3
<20000	300
20000 - 50000	200
50000 - 75000	100
>75000	75

Lifetime costs

The majority of the measures considered have ongoing costs that also need to be accounted for in the cost estimate for the measure and associated option. These include operation and maintenance costs, replacement of equipment and storage of equipment. To allow the net present value of these costs to be calculated a discount rate of 4% has been applied to the costs throughout the project lifespan (i.e. 50 years). Table 6-10 provides details of the ongoing/lifetime operation costs applied to each of the measures. The NPV maintenance costs for structural options were included under additional costs as detailed in Table 6-11.

Table 6-10 Lifetime operation costs used in the study

Measure	Lifetime costs	Source of costs
Do minimum		
Reduce existing activities	-	N/A
Proactive maintenance	Annual maintenance cost plus additional substantive maintenance/replacement costs every x year's dependant on the condition of the defences (refer to Table 6-2). DAS of defences every 5 years	Environment Agency – residual life of existing defences Halcrow Barry
Non-structural/minor & localised modifications		
Develop a flood forecasting system	Annual operation costs (these vary depending on the size of the area under consideration)	Halcrow Barry
Targeted public awareness and education campaign	Costs for flood mapping and public awareness campaign every 5 years	Halcrow Barry
Individual property protection/flood-proofing	Replacement costs every 25 years	Halcrow Barry
Structural measures		
Rehabilitation, improvement of existing defences	-	N/A
Improvement in channel conveyance	-	N/A
Provision of permanent flood walls/embankments	-	N/A
Provision of demountable flood	Costs for storing demountable	Halcrow Barry

Measure	Lifetime costs	Source of costs
defences	defences and erection of defences on an X yearly basis depending on design standard of permanent defence structure	
Flood storage reservoirs	-	N/A
Relocation of at risk assets (roads, properties, etc)	-	N/A

Additional costs

Additional costs, supplied by the OPW, were added to the basic costs of structural options. The additional costs include, for example, design team fees & expenses, site supervision and allowance for compensation and land acquisition. A list of the additional costs used for the study is detailed in Table 6-11. These additional costs were not applied to non structural options.

Table 6-11 Additional scheme costs to basic construction cost 'C'.

Description of additional costs	Value of additional costs
Basic Construction Cost 'C'	
Contingency	20% of C
Design Team Fees & Expenses For Reinforced Concrete Portion of Works[1]	6% of C
Environmental Consultants	5% of C
Economic Consultants	0.5% of C
Specialist Consultants	2.5% of C
Site Supervision	Based on time cost estimate Clerk of works / Annum = €120,000 Resident Engineer / Annum = €130,000
Allowance for Archaeology	15% of C
Allowance for Environmental Mitigating Measures	6% of C
Allowance for Compensation and Land Acquisition	10% to 12.5% of C
Allowance for Art[2]	
Construction cost up to €2,550,000	1% of C
Construction Cost €2,550,000 to €6,300,000	1% of C, Max €38,000.00
Construction Cost €6,300,00 to €12,700,000	Max €51,000.00
Construction Cost in excess of €12,700,000	Max €64,000.00
NPV Maintenance	C x 1.5% x 22.48

1 Source = Department of Finance Circular Ref:- 11/87
2 Source = Section 4.2 (page 21) of "Public Art: Percent for Art Scheme, General National Guidelines 2004

The additional costs are added to the basic construction cost (C) to give a final cost for implementing a flood risk management option. This final cost was used in determining the BCR of an option (Section 6.5.0).

Benefits of an option

The benefits of an option are based on the economic damages accruing to residential and commercial properties within the study area that will be reduced or removed by the measure(s) that make up that option. Therefore, the benefits of an option will depend on the level of protection provided to these damaged properties. For example, for individual property flood proofing, the benefits afforded will depend of the level of flood risk to the property, the provision of advanced timely warning and the implementation of flood proofing required.

Where options include the construction of structural measures such as walls, demountable defences, embankments and flood storage reservoirs, it has been assumed that they provide 100% protection against the design flood event. Estimation of the economic impact of overtopping of these defences for flood events greater than the design standard has not been considered.

Table 6-12 provides details of the benefits of particular FRM measures and options for the study.

Table 6-12 Assumed benefits of proposed defence options

Measure/option	Benefit (as % of economic risk)	Comment
Reduce existing activities	0%	Assume that reducing existing activities does not offer any benefits
Proactive maintenance	5-10%	Channel maintenance activities including dredging and vegetation removal
	Variable	Maintenance of existing defences (i.e. flood embankment, sluice gate, etc). Maintenance can offer up to 100% benefits depending on what is being protected. Removal of culvert and bridge blockages can provide significant benefits depending on the areas affected by flooding through blockage of culverts
Flood forecasting and warning	20%	Assume flood forecasting and warning provides 20% reduction in damages. (assumption based on flood forecasting being used as an individual measure)
	80%	Assume flood forecasting and warning provides 80% reduction in damages based on assumption that flood forecasting is used in combination with individual property protection

Measure/option	Benefit (as % of economic risk)	Comment
Individual property protection / flood-proofing (IPFP)	10-15%	Assume IPFP fully effective for protected properties (i.e. flood depth <0.6m). Assume 10-15% reduction in damages when not implemented with flood warning.
	80%	Assume IPFP fully effective for protected properties (i.e. flood depth <0.6m). Assume 80% reduction in damages based on assumption that individual property protection provided in combination with flood forecasting
Targeted public awareness and education campaign	5-10%	Targeted public awareness and education campaign will increase awareness of flood risk and measures to reduce flood risk to properties. Assume 5-10% reduction in damages through measures
Sustainable Urban Drainage Systems (SuDS)	10-15%	SuDS are a measure mainly used to reduce the risk from pluvial and drainage flooding. SuDS will reduce the volume of water discharging to a river during a flood event (particularly low order events) however it is difficult to quantify the benefits of this option in providing protection against fluvial/tidal flooding. Assumed benefit of 10 - 15%
Rehabilitation, improvement of existing defences	Variable	Dependant on measure being considered. Refer to stage 1 analysis worksheets for further information.
Improvement in channel conveyance	100%	Assume that improvement in channel conveyance reduces flood risk to properties to zero.
Sediment management	Variable	Dependant on measure being considered. Refer to stage 1 analysis worksheets for further information on the various measures.
Provision of permanent flood walls/embankments/rock armour/revetments	100%	Assume defences provide protection to all properties up to the design standard
Provision of demountable flood defences	100%	Assume defences provide protection to all properties up to the design standard. Assume all defences erected in time with advance warning
Use of overland floodways (e.g. allowing flooding of roads in a	Variable	Dependant on measure being considered. Refer to stage 1 analysis worksheets for further information.

Measure/option	Benefit (as % of economic risk)	Comment
controlled manner)		
Flow diversion (full diversion / bypass channel, flood relief channel, etc.)	100%	Assume measure provides protection to all properties up to the design standard.
Flood storage reservoirs	Variable	Dependant on the available storage and outflows from the storage reservoir.
Beach Recharge/sand dunes	Variable	Beach recharge can achieve up to 100% reduction in economic risk if significant amounts of material are used. Measure is more effective if implemented with other structural measures such as Groynes and flood walls.
Groynes	Variable	Groynes can achieve up to 100% reduction in economic risk if designed effectively. Measure is more effective if implemented with other measures such as beach recharge and flood walls
Breakwater	Variable	Breakwaters can achieve up to 100% reduction in economic risk if designed effectively. Measure is more effective if implemented with other measures such as beach recharge and flood walls
Managed realignment	Variable	Managed realignment can achieve up to 100% reduction in economic risk if designed effectively.
land management	5 - 20%	Land management measures can reduce the peak of a flood event and reduce economic flood risk by up to 20%
Tidal barrier(s)	100%	Assume barrier(s) provide protection to all properties protected up to the design standard
Relocation of at risk assets (roads, properties, etc)	100%	Assume flood risk reduced to zero for all properties relocated from risk zone

6.5.0. Benefit cost ratio

The benefits of an option are made up of the benefits of each individual measure included in that option. They are then compared to the final costs of the option to obtain the BCR.

7. Flood risk management options for the Fingal East Meath study area

Introduction

The results of the stage 1 assessment, contained in the Preliminary Options Report, (December 2010), demonstrated that there were some flood risk management measures that could be applied at study area scale rather than at the smaller spatial scales. The stage 2 assessment resulted in option (1) proactive maintenance and option (2) targeted public awareness and preparedness campaign combined with IPFP being carried forward to stage 3 for the study area.

Stage 3 assessment

The two options carried forward to stage 3 for the study area underwent detailed multi criteria assessment involving the assessment of the performance of each option against the 16 flood risk management objectives. The detailed MCA spreadsheets for each option are included in Appendix E5. Table 7-1 provides a summary of both options with the MCA scores. The results of the SEA are reported on in the SEA Environment Report (Halcrow Barry, 2011).

Table 7-1 Study area options 1 and 2

Assessment units	Fingal East Meath Study Area
Water bodies	Fingal and Meath coastline, Mayne River, Sluice River, Gaybrook Stream, Broadmeadow River, Ward River, Lissenhall Stream, Turvey River, Ballyboghil River, Corduff River, Baleally Stream, Bride's Stream, Jones's Stream, Rush Town Stream, St. Catherine's Stream, Mill Stream, Bracken River, Delvin River, Mosney Stream, Nanny River and Brookside stream
Flood risk management options	(1) Proactive maintenance and (2) Targeted public awareness and preparedness campaign combined with IPFP

Flood Risk (1% fluvial/0.5% tidal AEP event)

A total of 313 properties in the study area are at risk of flooding from the 1% fluvial/0.5% tidal AEP events, of which 295 incur economic damages as a result of that flooding. The results indicate that there are a relatively limited number of locations within the study area that are at significant risk of flooding. The main flood risk occurs along the coastline where some properties are at risk from both fluvial and tidal flooding. Fluvial flood risk can be increased in this area due to difficulties in rivers discharging to the sea during high tides. Flooding occurs on many of the watercourses due to under capacity structures. This flood risk can be exacerbated if structures or trash screens become blocked during flood events. However, the baseline case does not consider the flood risk due to blockage. Seven IRRs have been identified in the study area including two roads, three wastewater treatment works, one wastewater pumping station and one utility operated by Eircom, Bord Gais or ESB.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
248	65	5	6.4	1316	13

Environmental features and receptors at risk or present in the study area

- 51 river water bodies: 9 = high status; 3 = good status; (no deterioration required); 14 = moderate status; 23 = poor status; 3 = bad status (improvements required)
- 4 transitional (i.e. estuarine) water bodies: 4 = moderate status
- 4 coastal water bodies: 2 = high status; 2 = moderate status
- 4 Wastewater treatment works (including waste water pumping station)

- 35 Waste Management Permit Sites
- 22 Section 4 licences and 34 Section 16 licences in the study area
- 13 internationally designated sites and 17 nationally designated sites
- 57 sites on SMR/RPS/RMP registers at risk

Description of option 1

This option involves the development (Meath County Council (MCC)) and enhancement (Fingal County Council (FCC)) of a proactive maintenance regime targeting potential culvert blockage locations along the watercourses in the study area. It should be noted that the ownership and viability of this option is currently under discussion at national level as it places additional duty on Local Authorities which may not have the resources or the legal ability to implement this option. FCC currently carries out maintenance at approximately 20 locations at risk of flooding in Fingal. This involves the cleaning of screens on a two to three week basis, with the frequency increased when heavy rain is forecast. A limited maintenance regime is carried out by MCC. This option would involve including additional culverts as part of the FCC proactive maintenance regime and setting out a proactive maintenance regime for culverts in MCC. Proactive maintenance would involve the removal of debris (vegetation, silt, rubbish) at the entrance and exit of culverts on a regular basis (i.e. monthly) and in advance of, and subsequent to, a flood event. This option would also involve the monitoring of culverts prone to blockages during a flood event. FCC currently uses weather forecast information to identify when a flood is likely. There is an opportunity to link this option to the FFWS identified for the following analysis units (Broadmeadow and Ward, Nanny and Delvin, Mayne and Sluice and Coastal).

Hydraulic modelling indicates that properties in the following locations are at risk due to culvert blockages (based on a comparison of flood maps for the 1% AEP fluvial event against the 70% culvert blockage flood maps for the 1% AEP event): Swords, Dardistown, Balgriffin, Portmarnock Bridge, Warbelstown, Ashbourne, Ratoath, Ballyboghil, Skerries and Bettystown. List of culverts for proactive maintenance by the Local Authorities is presented in Appendix L.

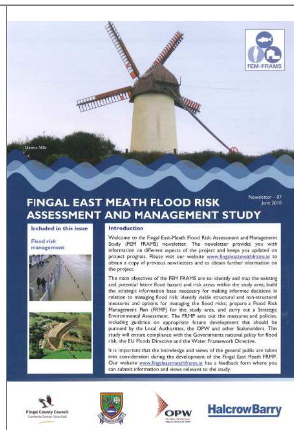
Potential impact on principal overland flow routes and areas of significant natural floodplain storage

As this option is focused on reducing the risk of blockage of trash screens and structures it does not impact on principal overland flow routes other than to reduce out of bank flooding caused by blockage. This option does not involve the construction of any structures in the floodplain and therefore does not in any way affect areas of significant natural floodplain storage.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€1,483k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€1,686k	-25	145	150	75	**345**
BCR	0.88					

Description of option 2



The targeted public awareness and preparedness campaign is necessary to educate the public of the risk of flooding to their properties and the protection methods available to them to reduce potential damage from flood events (i.e. IPFP measures). Information would be disseminated through the distribution of information leaflets, FEM FRAMS website and the provision of public information days.

IPFP involves the use of 'off the shelf' flood defence products to provide individual flood protection to residential and commercial properties. Such products include flood gates, flood barriers, air vent blocks and the installation of non return valves to service pipes. The level of protection afforded by individual property protection is dependant on a number of factors including the uptake, advance warning of flood risk and depth of flooding. For the purposes of assessment, it is assumed that this measure is only applicable when the depth of flooding at a property is less than 0.6m.

The BCR for this option is 0.85 and is based on an assumed 20% reduction in economic risk. The benefits of this option would be significantly greater if the option was provided with a FFWS. Details of the FFWS are detailed in the following Analysis Units (Broadmeadow and Ward, Nanny and Delvin, Mayne and Sluice and Coastal). The BCR for this option when combined with a FFWS is 2.96.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

This option will not alter existing overland flood routes or impact on areas of significant natural flood plain storage.

Multi Criteria Analysis (MCA) Results – option 2

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€3,492k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€4,127k	50	75	0	0	**125**
BCR	0.85 (2.96 with FFWS)	A greater BCR can be achieved if the FFWS options in the analysis units are implemented. Having FFWS will increase the likelihood of IPFP being put in place before the flood event and therefore increase the benefits achieved by this option.				

The results of the stage 3 assessment and the potential implementation of these options are considered further in Chapter 14.

8. Flood risk management options for the Nanny and Delvin AU

Introduction

The results of the stage 1 assessment demonstrated that one option was viable for the Nanny Delvin AU and that only the Duleek APSR had sufficient flood risk to consider potential options. Donacarney and Donacarney Little area, Kentstown (R150/R153 crossing) area, Garristown area, Naul area, the area to the southeast of N2/Hurley crossing and Stamullin area APSRs all had insufficient flood risk to consider specific FRM options within the APSR. Study area or AU scale options may provide some reduction in flood risk to properties at risk in these areas. In addition, some funding may be available to the Local Authority from the OPW Minor works funding programme (for schemes less than €500,000).

Stage 3 assessment

Only one option carried forward to the stage 3 detailed multi criteria assessment involving the assessment of the performance of each option against the 16 flood risk management objectives for both the Nanny Delvin AU and the Duleek APSR. The detailed MCA spreadsheets for these options and more detailed figures are included in Appendix E4. Table 8-1 and Table 8-2 provide a summary of the options with the MCA scores for the AU and APSR respectively. The results and conclusions of the SEA are reported on in the SEA Environment Report (Halcrow Barry, 2011).

Table 8-1 Nanny and Delvin AU option 1

Assessment units	Nanny and Delvin AU
Water bodies	Nanny, Delvin
Flood risk management options	(1) Flood forecasting and warning system for the Nanny River

Flood Risk (1% AEP event)

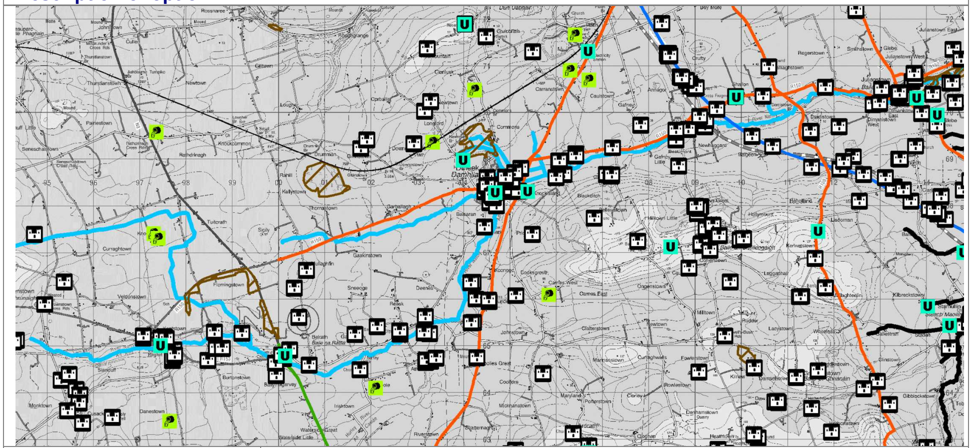
There is limited economic flood risk for the 1% AEP event, with the majority of the risk along the Nanny River. There is a small cluster of properties at risk of flooding at Beaumont Bridge, with the remainder of the risk limited to isolated properties along the rivers. One IRR has been identified in the Nanny and Delvin AU, a utility operated by Eircom, Bord Gais or ESB.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
15	5	1	1.5	485	0

Environmental features and receptors at risk or present in the study area

- 13 river water bodies: 7 = moderate status; 6 = poor status
- 2 Waste Management Permit Sites
- 4 Section 4 licences
- Duleek Commons pNHA; Thomastown Bog pNHA; Balrath Woods pNHA; and Cromwell's Bush Fen pNHA
- 71 sites listed on Meath County Council's Wetland Inventory
- 11 sites on RPS/RMP/SMR at risk

Description of option 1



Legend

- FFWS along River Nanny
- Modelled river centreline

Risk to Critical Infrastructure

- Utilities
- Emergency response/governance
- Airport
- Railway line
- Motorway
- National
- Regional

Risk to Human Health

- High vulnerablity sites

Risk to the Environment

- Potential pollution sources
- Protected areas
- cSAC, SAC, SPA, NHA and pNHA sites

Risk to Cultural Heritage

- Cultural heritage sites

Flood forecasting and warning systems involve the use of mathematical computer models to predict flood water levels based on actual meteorological data and tools to disseminate flood hazard data to people at risk. Further information on the viability of various flood forecasting options are reported on in the Preliminary Options Report. Flood forecasts would be disseminated through a dedicated website and messaging service to provide advance warning to communities.

A FFWS for the Nanny River would provide advance flood warning to properties at risk along the Nanny River including properties in Duleek area APSR and properties in rural areas along the watercourse. The image above shows the Nanny River and flood risk indicators within the catchment of the Nanny River. Those indicators in the floodplain of the Nanny River are likely to benefit from the proposed FFWS. Further details are available in Appendix E4.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

This option would have no impact on either principal overland flow routes or areas of significant natural floodplain storage.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€557,071	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€450,803	200	25	0	0	**225**
BCR	1.24 (4.94 with IPFP)	More benefit can be achieved from FFWS if it is implemented in conjunction with IPFP.				

Table 8-2 Duleek area APSR option 1

Assessment units	Duleek area APSR
Water bodies	Nanny, Paramadden
Flood risk management options	(1) Raising existing defence embankment to a higher standard of protection (1a) Improving existing defences to protect all properties in the Millrace Estate from the 1% AEP event

Flood Risk (1% AEP event)

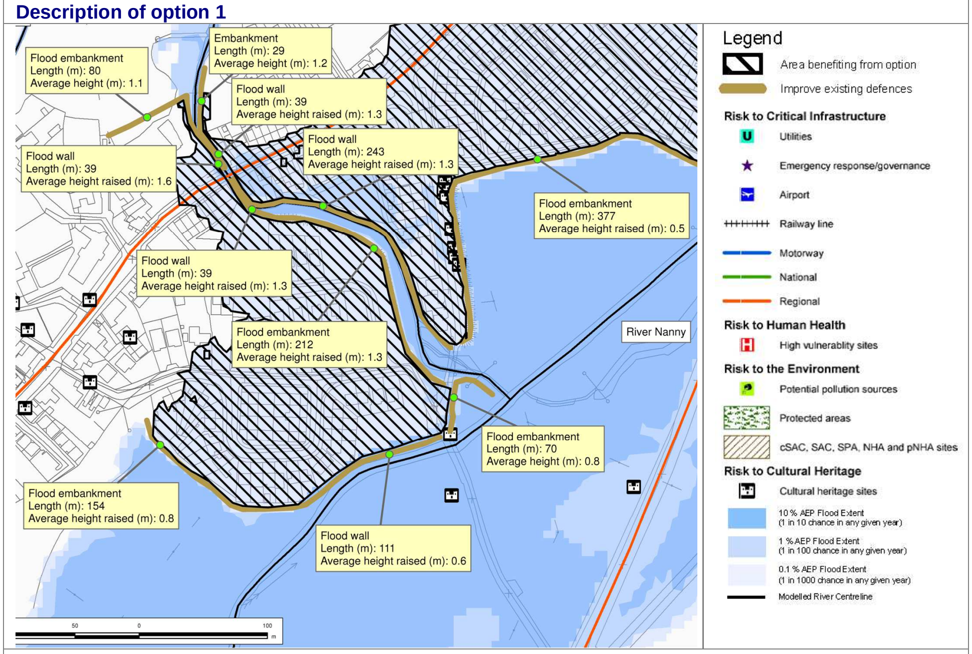
Duleek area APSR is at significant risk of flooding for events greater than the 1% AEP event due to overtopping of the flood defence embankments. The defences along the Nanny River and its tributary, the Paramadden are overtopped by events greater than the 1% AEP. Flooding from the 0.1% AEP affects 191 properties compared to just 5 properties for the 1% AEP event. Due to the significant level of the risk from the 0.1% AEP event, options were considered above the normal 1% AEP standard of protection.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
5 *191 (0.1% AEP)*	0 *0 (0.1% AEP)*	0	0.05	26	0

Environmental features and receptors present or at risk

- 2 river water bodies: 2 = poor status
- Duleek Commons pNHA and
- 26 sites listed on Meath County Council's Wetland Inventory
- 4 sites on RPS/RMP/SMR at risk

Description of option 1



This option involves raising existing flood defence embankments and walls in Duleek to provide protection up to the 0.1% AEP event. Hydraulic modelling indicates that some new defences would also be required as part of this option.

The existing flood defences at Duleek include embankments, walls, a pumping station and channel maintenance works. Hydraulic modelling indicates that these defences provide protection to the majority of properties in Duleek up to the 1% AEP event. The results from the hydraulic modelling indicate that the existing flood embankments would need to be raised by an average of 1.4m and that the existing flood walls would need to be raised by an average of 1.4m for the 0.1% AEP event. This option assumes that existing flood defences are structurally sound to allow them to be raised to a higher standard of protection. Upstream of the bridge on the main street through Duleek, approximately 40m of new flood embankments are required along the left bank and 20m along the right bank of the Paramadden River. The average height of the embankments on the left bank is 1.2m and the average height of embankments on the right bank is 1m. The figure above shows the location where defences would need to be raised in Duleek. Further details are available in Appendix E4.

Hydraulic modelling indicates that there is a negligible impact on water levels along the Nanny River with this option. Along the Paramadden tributary, the construction of new defences and raising of existing defences has an impact on water levels. Water levels are raised by an average of 0.8m along a 0.5km stretch of the river channel. The maximum increase in water levels is 0.93m.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

This option has no impact on overland flow paths or significant natural flood plain storage as it involves modifying an existing flood defence scheme.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€2,934k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€2,747k	225	200	90	-140	**375**
BCR	1.07	Benefits up to the 0.1% AEP considered as proposed option is to protect up to the 0.1% AEP				

Description of option 1a

Option 1a was considered as a variation to option 1 to check if a viable scheme exists to prevent bypassing of existing defences on the Paramadden tributary and flooding of properties in the Millrace Estate for the 1% AEP event. However, the BCR for this option was significantly less than 1 so further assessment was not carried out.

The results of the stage 3 assessment and the potential implementation of these options are considered further in Chapter 14.

9. Flood risk management options for the Ballyboghil and Lusk AU

Introduction

The Ballyboghil and Lusk AU consists of a number of smaller watercourses all draining to the sea. There are six APSRs in total; Rowans Little area, Oldtown area, Ballyboghil area, Turvey Bridge area to the west of Donabate, Donabate area and Lusk area. There is very limited flood risk in the Ballyboghil and Lusk AU with only 5 properties at risk for the 1% AEP and 7 for the 0.1% AEP. The majority of properties at risk are located in the village of Ballyboghil. Whilst overtopping of the river bank occurs from the 10% AEP event, properties in the village are only at risk of flooding from the 2% AEP event or greater (i.e. flooding occurs of the roads and gardens for the 10% AEP but houses only become inundated for the 2% AEP). Study area or AU scale options may provide some reduction in flood risk to properties at risk in these areas. In addition, some funding may be available to the Local Authority from the OPW Minor works funding programme (for schemes less than €500,000).

Stage 3 assessment

No options carried forward to stage 3 for the Ballyboghil and Lusk AU or any of the associated APSRs. Properties at risk within this AU may benefit from study area scale options. Table 9-1 provides a short description of the flood risk in the AU.

Table 9-1 Ballyboghil and Lusk AU

Assessment units	Ballyboghil and Lusk AU
Water bodies	Bracken, Ballyboghil, Corduff, Turvey, Lissenhall, Bride, Jones
Flood risk management options	None

Flood Risk (1% AEP event)

Economic flood risk to properties is limited to a small number of isolated residential and non residential properties along the watercourses in the AU. The majority of flood risk to properties occurs in Ballyboghil but this only occurs for a 2% AEP or greater event. Two IRRs have been identified in this assessment unit, the wastewater treatment works at Ballyboghil and a section of the M1 at Staffordstown.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
5	3	1	1.2	300	0

Environmental features and receptors present or at risk

- 1 WWTW at risk in Ballyboghil area APSR
- 6 Waste Management Permit Sites
- Bog of the Ring pNHA
- 2 sites on SMR/RPS/RMP at risk

10. Flood risk management options for the Broadmeadow and Ward AU

Introduction

The results of the stage 1 assessment demonstrated that one option was viable for the Broadmeadow and Ward AU and that only two APSRs, Ratoath area and Rowlestown East area, had sufficient flood risk to consider potential options. The other APSRs, Dunshaughlin area, Ashbourne area, Owens Bridge area, N2 - Coolatrath Bridge area and Killeek area all had insufficient flood risk to consider specific FRM options within the APSR. Study area or AU scale options may provide some reduction in flood risk to properties at risk in these areas. In addition, some funding may be available to the Local Authority from the OPW Minor works funding programme (for schemes less than €500,000).

Stage 3 assessment

Only one option carried forward to the stage 3 detailed multi criteria assessment involving the assessment of the performance of each option against the 16 flood risk management objectives for each of the Broadmeadow Ward AU, the Ratoath area APSR and the Rowlestown East area APSR. The detailed MCA spreadsheets for these options are included in Appendix E1. Table 10-1, Table 10-2 and Table 10-3 provide a summary of the options with the MCA scores for the AU and APSR respectively. The SEA conclusions and recommendations are reported on in the SEA Environment Report (Halcrow Barry, 2011).

Table 10-1 Broadmeadow and Ward AU option 1

Assessment units	Broadmeadow and Ward AU
Water bodies	Broadmeadow, Ward
Flood risk management options	(1) Flood forecasting and warning system for the Broadmeadow River

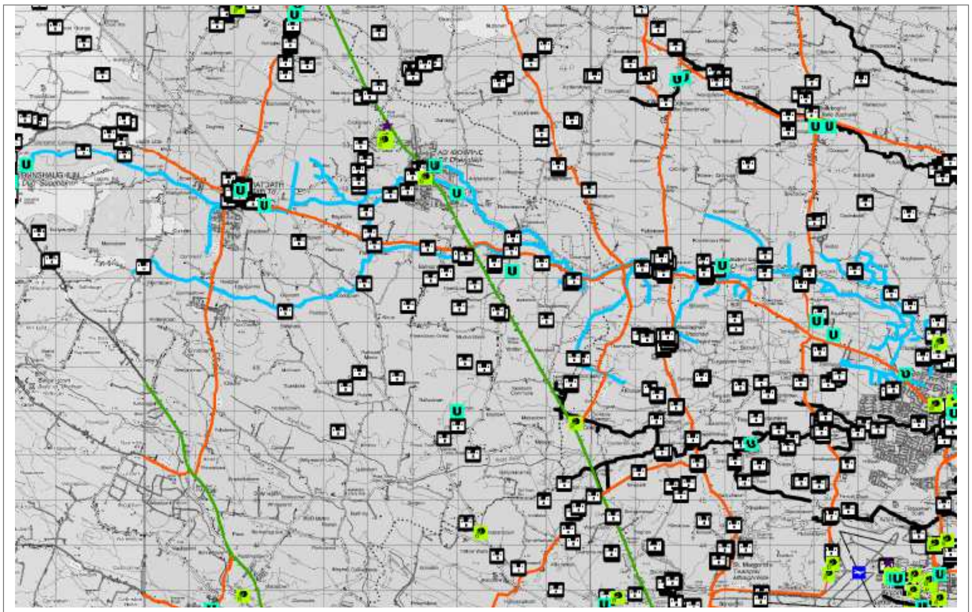
Flood Risk (1% AEP event)
There is limited economic flood risk to properties in the AU for the 1% AEP event with the majority of the risk confined to small clusters of properties at Rowlestown East area APSR and Ratoath area APSR. The remainder of the risk is limited to isolated properties along the rivers. Two IRRs have been identified in the AU, wastewater treatment works at Ashbourne and Toberburr (in Owens Bridge APSR).

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
18	0	2	0.5	150	4

Environmental features and receptors present or at risk

- 25 river water bodies: 4 = high status; 1 = good status; 5 = moderate status; 12 = poor status; 3 = bad status
- 1 Wastewater Pumping Station
- 8 Waste Management Permit Sites
- 4 Section 4 licences
- 13 sites on the SMR/RPS/RMP

Description of option 1



Flood forecasting and warning systems (FFWS) involve the use of mathematical computer models to predict flood water levels based on actual meteorological data and tools to disseminate flood hazard data to people at risk. Further information on the viability of various flood forecasting options are reported on in the Preliminary Options Report. Flood forecasts would be disseminated through a dedicated website and messaging service to provide advance warning to communities.

The image above shows the Broadmeadow River and flood risk indicators within the catchment of this river. Those indicators in the floodplain of the Broadmeadow River are likely to benefit from the proposed FFWS. In terms of at risk properties, a FFWS for the Broadmeadow River would provide advance flood warning to residential and commercial properties at risk in the Ratoath area APSR (9), Ashbourne area APSR (3), Rowlestown East area APSR (2), properties in rural areas along the watercourse (3) and the IRR in Ashbourne. It would not provide any benefit to the remaining at risk property along the Ward River.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

This option has no impact on overland flow paths or significant natural flood plain storage.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€362,954	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€450,803	200	25	0	0	**225**
BCR	0.81 (3.22 with IPFP)	More benefit can be achieved from FFWS if it is implemented in conjunction with IPFP (Study area option 2).				

Table 10-2 Ratoath area APSR option 1

Assessment units	Ratoath area APSR
Water bodies	Broadmeadow
Flood risk management options	(1) Improving channel conveyance by replacing a culvert on the Broadmeadow River at the R125 Ratoath Road and replacing a culvert on a tributary of the Broadmeadow River.

Flood Risk (1% AEP event)

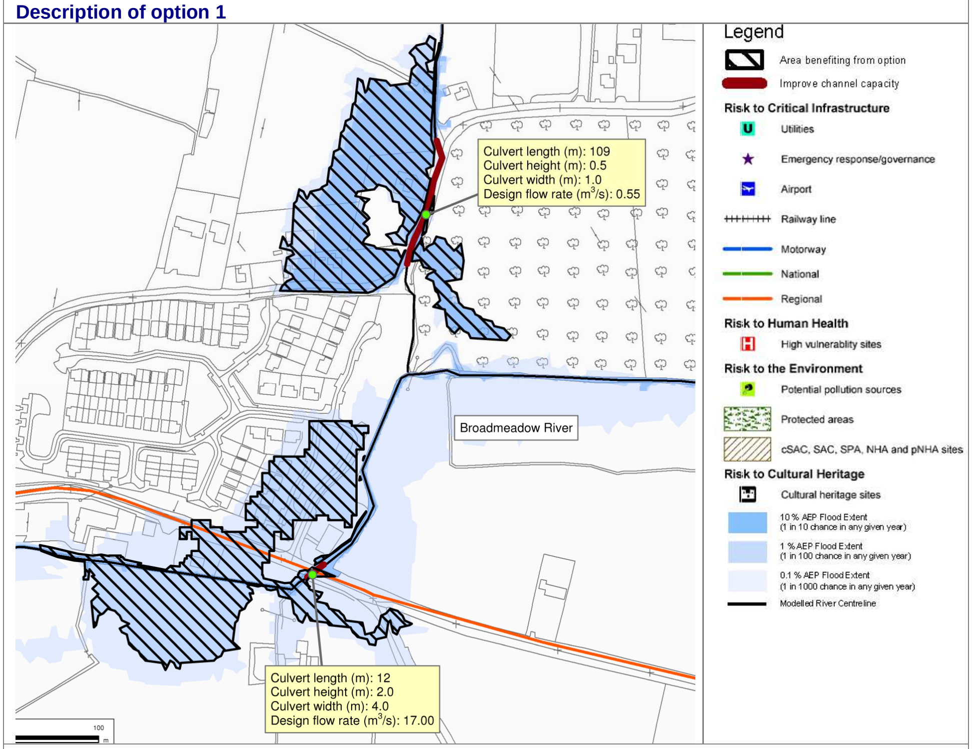
Flood risk in Ratoath Area APSR results form out of bank flooding along the Broadmeadow River primarily due to under capacity culverts under the R125 and along the Broadmeadow tributary to the north of the R125. Flood water spills out of bank upstream of the R123 culvert and floods a number of properties in the housing estate at Moulden Bridge. Existing flood defences (a flood embankment) protect a new housing estate at Somerville in the Ratoath area APSR.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
9	0	0	0.09	2.7	0

Environmental features and receptors present or at risk

- 3 river water bodies: 1 = good status; 2 = bad status

Description of option 1



This option involves replacing two structures where the existing capacity of the structures is insufficient to convey large flows and results in surcharging and spilling of flood waters. The option is slightly amended from the option proposed at Stage 2 following the modelling of this option. The modelling indicates that the proposed embankments identified at stage 2 are not required.

Full and unobstructed conveyance capacity of the re-worked culverts is required for the benefiting areas indicated on the map to benefit from this option. Such conveyance capacity may be significantly reduced through build-up of debris, vegetation or sediment over time, or through temporary blockage of the culverts during flood events and, as such, cannot be guaranteed.

Modelling results indicate that a rectangular concrete culvert of 2m high by 4m wide would be sufficient to reduce flood risk at the R125 crossing. This culvert can convey a flow of 17m^3/s which equates to the 1% AEP MRFS 95%ile flow without surcharging. The replacement culvert on the Broadmeadow River tributary is also designed to convey the 1% AEP MRFS 95%ile flow without surcharging. The dimensions for this culvert are 0.5m high by 1m wide by 109m in length and has a capacity of 0.6m^3/s. Due to the sizing of the culverts the 0.1% AEP flood extent will be significantly reduced. The figure above shows the location where the culvert capacity needs to be increased. Further details are available in Appendix E1. Modelling results indicate that this option will have negligible impact on water levels upstream and downstream of the proposed location for this option. Changes in water levels are localised (i.e. along a 0.4km stretch of the river) to the location of the proposed option. The option results in a decrease in water levels, the maximum of 0.7m occurring on the Broadmeadow River (cross section 4Ba19221U - directly upstream of the R125 crossing) and 0.9m on the Broadmeadow tributary (cross section 4Bax322In).
Potential impact on principal overland flow routes and areas of significant natural floodplain storage
The results of the modelling indicate that existing overland flood flow paths are modified with this option. These existing overland flow paths (northwards across the R125 and southwards from the tributary) are as a result of capacity problems at existing structures and lead to the flooding of properties at Ratoath. The option prevents these overland flow paths through increasing the capacity of the structures. Modelling indicates that the alteration of the flow paths does not increase risk to properties elsewhere. The capacity of the existing culvert on the Broadmeadow tributary results in surcharging of the culvert and attenuation of floodwater on surrounding farm land. The increased culvert capacity as part of this option will prevent flooding of surrounding land and reduce the need for floodplain attenuation.

Multi Criteria Analysis (MCA) Results – option 1							
Benefit Cost Ratio (BCR)		MCA scores					
Benefits of option	€978,175	Technical	Economic	Social	Environmental	**Overall**	
Cost of option	€1,090k	225	135	90	-65	**385**	
BCR	0.91 (0.94 with 0.1% AEP)	Replacement culverts design to pass the 95%ile 1% MRFS without surcharging. This flow is less than the 0.1% AEP current scenario flow and therefore reduction in the 0.1% AEP damage is also achieved, thus increasing the BCR.					

Table 10-3 Rowlestown East area APSR option 1

Assessment units	Rowlestown East area APSR
Water bodies	Broadmeadow
Flood risk management options	(1) Construction of flood defence embankments along left bank of Broadmeadow River tributary upstream of the R125.

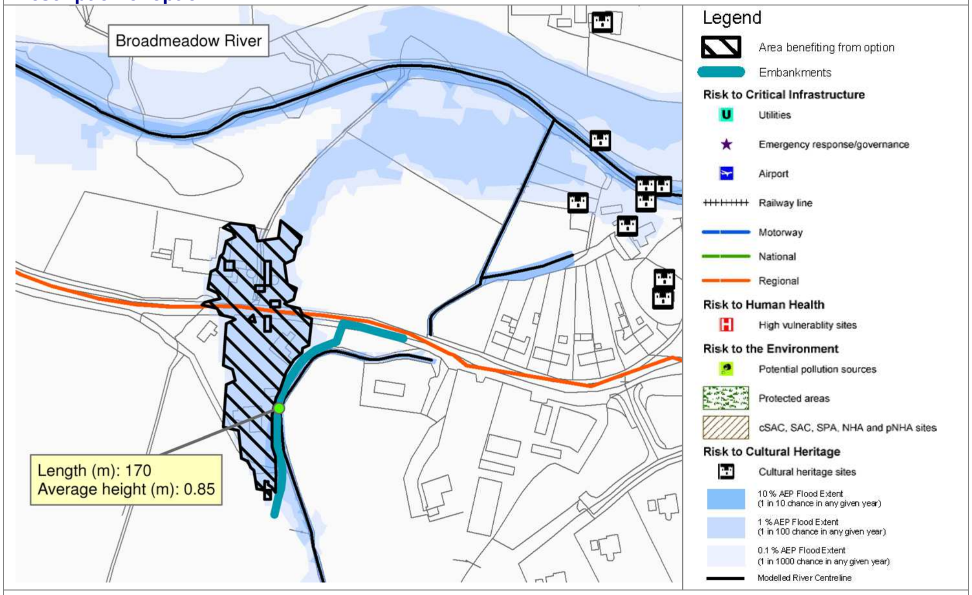
Flood Risk (1% AEP event)
Flood risk in Rowlestown East area APSR is caused by out of bank flooding along the Broadmeadow River primarily due to an under capacity channel upstream of the R125. Two properties are at risk of flooding in this location.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
2	0	0	0.08	5.4	0

Environmental features and receptors present or at risk

- 3 river water bodies: 3 = poor status
- 2 Waste Management Permit Sites
- 3 sites on the SMR/RPS/RMP

Description of option 1



This option involves the construction of a flood defence embankment along the left bank of the Broadmeadow tributary in Rowlestown. Out of bank flows along the left bank results in flooding of two properties. A total of 170m of embankment is required with an average height of 0.85m above ground level including 0.5m freeboard. The figure above shows the location of the proposed embankments. Further details are available in Appendix E1.

Modelling results indicate that this option will have negligible impact on water levels upstream and downstream of the location of the proposed option. Changes in water levels are localised to the vicinity of the proposed option (within 120m upstream and 240m downstream of the embankment). The option results in an increase in water levels with a maximum increase of 0.32m (cross section 4Bap205U).

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The construction of the embankment eliminates the existing overland flood flow path resulting in a localised increase in water levels in the river channel. Modelling indicates that this localised increase in water levels does not increase flood risk to properties elsewhere. There are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€341,628	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€153,301	100	130	90	-95	**225**
BCR	2.23					

The results of the stage 3 assessments and the potential implementation of these options are considered further in Chapter 14.

11. Flood risk management options for the Mayne and Sluice AU

Introduction

The results of the stage 1 assessment demonstrated that one option was viable for the Mayne & Sluice AU and that only the Balgriffin area of the St Margarets, Dublin Airport, Belcamp and Balgriffin areas APSR had sufficient flood risk to consider potential options. Kinsaley Lane area and Ballymacartle area APSRs all had insufficient flood risk to consider specific FRM options within the APSR. Study area or AU scale options may provide some reduction in flood risk to properties at risk in those areas. In addition, some funding may be available to the Local Authority from the OPW Minor works funding programme (for schemes less than €500,000).

Stage 3 assessment for the Mayne & Sluice AU

Only one option carried forward to the stage 3 detailed multi criteria assessment involving the assessment of the performance of each option against the 16 flood risk management objectives for the AU plus two options for the Balgriffin area. The detailed MCA spreadsheet for that option is included in Appendix E3. Table 11-1 and Table 11-2 provide a summary of the options with the MCA scores and SEA conclusions and recommendations.

Table 11-1 Mayne & Sluice AU option 1

Assessment units	Mayne and Sluice AU
Water bodies	Mayne, Sluice
Flood risk management options	(1) Flood forecasting and warning system for the Mayne River

Flood Risk (1% AEP event)

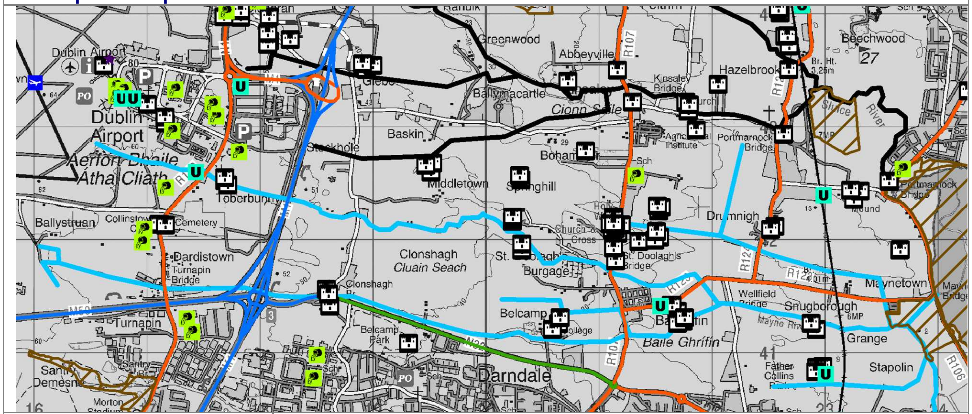
There is limited economic flood risk to properties in the AU for the 1% AEP event with the majority of the risk confined to small clusters of properties at Balgriffin and Streamstown. Elsewhere in the AU, the risk is limited to isolated properties along the rivers. There is one IRR in the AU; approximately 100m of the N32 near Bewleys Airport Hotel in Clonshaugh.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
28	3	0	0.7	31	2

Environmental features and receptors present or at risk

- 2 river water bodies: 1 = high status; 1 = poor status
- 6 Waste Management Permit Sites
- 4 Section 4 licences and 18 Section 16 licences
- Feltrim Hill pNHA
- 6 sites on the SMR/RPS/RMP

Description of option 1



Legend
- FFWS along Mayne River
- Modelled river centreline

Risk to Critical Infrastructure
- Utilities
- Emergency response/governance
- Airport
- Railway line
- Motorway
- National
- Regional

Risk to Human Health
- High vulnerablity sites

Risk to the Environment
- Potential pollution sources
- Protected areas
- cSAC, SAC, SPA, NHA and pNHA sites

Risk to Cultural Heritage
- Cultural heritage sites

Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels, based on actual meteorological conditions, and tools to disseminate flood hazard data to people at risk. Further information on the viability of various flood forecasting options are reported on in the Preliminary Options Report. Flood forecasts would be disseminated through a dedicated website and messaging service to provide advance warning to communities.

A FFWS for the Mayne River would provide advance flood warning to properties at risk along the Mayne River in St Margaret's, Dublin Airport, Belcamp and Balgriffin areas APSR. The image above shows the Mayne River and flood risk indicators within the catchment of the Mayne River. Those indicators in the floodplain of the Mayne River are likely to benefit from the proposed FFWS. Further details are available in Appendix E3.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

This option has no impact on overland flow paths or significant natural flood plain storage.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€185,305	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€450,803	200	25	0	0	**225**
BCR	0.41 (1.64 with IPFP)	More benefit can be achieved from FFWS if it is implemented in conjunction with IPFP (study area option 2).				

Table 11-2 St Margaret's, Dublin Airport, Belcamp and Balgriffin areas APSR option 1 and 1a

Assessment units	Mayne and Sluice AU
Water bodies	Mayne, Sluice
Flood risk management options	(1) Construction of flood defence embankments & walls. (1a) Improve channel conveyance by removing a disused bridge with construction of flood defence embankments & walls.

Flood Risk (1% AEP event)

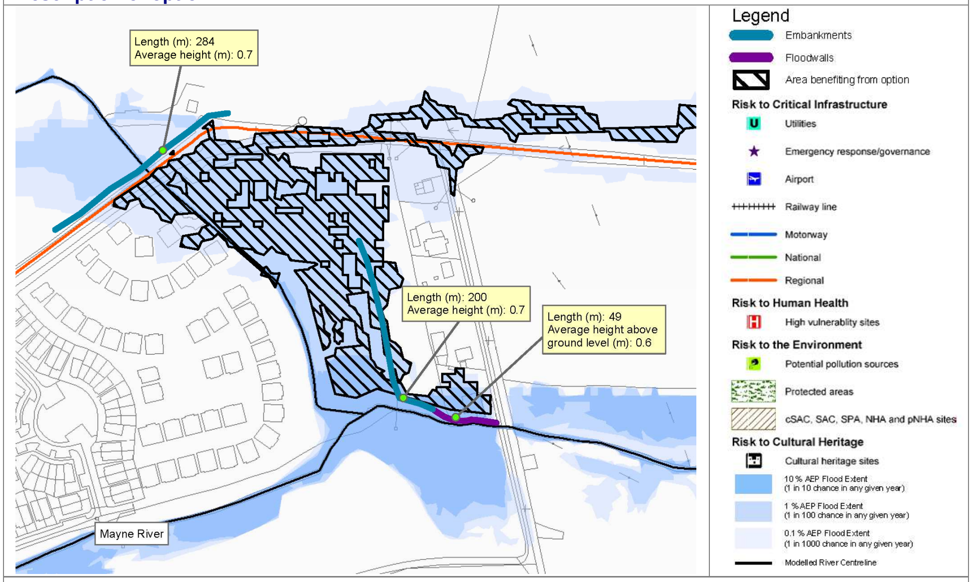
There is limited economic flood risk to properties in the AU for the 1% AEP event with the majority of the risk confined to small clusters of properties at Balgriffin and Streamstown. Elsewhere in the AU, the risk is limited to isolated properties along the rivers. There is one IRR at risk; approximately 100m of the N32 near Bewleys Airport Hotel in Clonshaugh.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
19	2	0	0.7	5	1

Environmental features and receptors present or at risk

- 3 river water bodies: 1 = high status; 2 = poor status
- 6 Section 4 licences and 17 Section 16 licences
- 4 sites on the SMR/RPS/RMP

Description of option 1



This option involves the construction of a flood defence embankment north of the R123 on the Mayne River tributary and the construction of embankments and walls along the left bank of the Mayne River and tributary at Balgriffin. The original option included the replacement of the existing culverts however, hydraulic modelling indicates that replacing the existing culverts is not necessary.

Modelling results indicate that the existing culverts under the R123 and the new development at Balgriffin are sufficient to accommodate the 1% AEP event without surcharging. An under capacity channel north of the R123 results in flood water to spilling southwards across the R123 and flooding the housing development at Balgriffin. A 284m embankment with an average height of 0.7m running east west along the R123 prevents flood water spilling south across the R123. Further downstream, a 200m long embankment with an average height of 0.7m is required on the left bank of the Mayne River and its tributary to prevent out of bank flooding downstream. This embankment is linked to a flood wall on the Mayne River, 50m in length, with an average height of 2.4m (due to space constraints, wall constructed to the bed of the channel). Average height of this wall above ground level is approximately 0.6m.

Modelling results indicate that this option will have some localised impact on water levels upstream and downstream of the proposed location for this option. Upstream of the R123, water levels on the Mayne River tributary are raised by an average of 0.2m along a 250m stretch of the channel. Downstream of the R123, water levels on the Mayne River and its tributary are raised by an average of 0.15m along 430m of river channel. Downstream of the bridge at The Hollow, there are no changes in water levels.

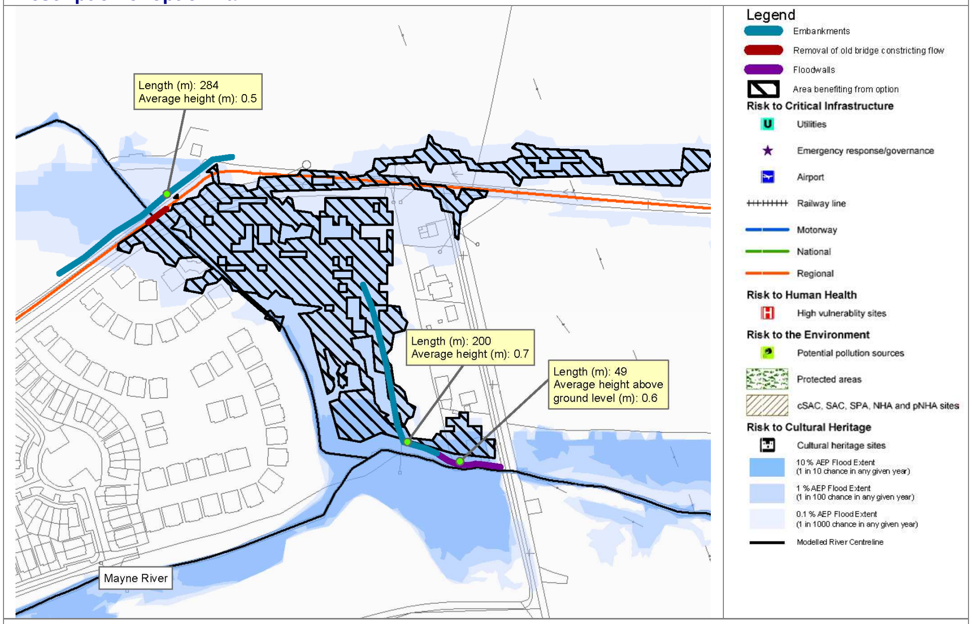
Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The results of the modelling indicate that existing overland flood flow paths are modified with this option. These existing overland flow paths from the Mayne River tributary (southwards across the R123) are as a result of capacity problems at an existing old stone bridge structure and lead to the flooding of properties at Balgriffin. The option prevents these overland flow paths by constructing embankments and walls to protect the properties. There are no areas of significant natural floodplain storage affected by this option but some reduction in floodplain storage does occur.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€955,548	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€809,141	100	130	210	-100	**340**
BCR	1.18					

Description of option 1a



This option involves the construction of a flood defence embankment north of the R123 on the Mayne River tributary and the construction of embankments and walls along the left bank of the Mayne River and tributary at Balgriffin. The option also involves removing an unused bridge structure north of the R123. Hydraulic modelling indicates that this unused bridge increases water levels locally. By removing this bridge structure, the height of embankments to the north of the R123 will be reduced. Hydraulic modelling also indicates that replacing existing culverts at the R123 and housing development at Balgriffin is not necessary as part of this option as they are sufficient to accommodate the 1% AEP event without surcharging.

A 284m embankment with an average height of 0.5m running east west along the R123 is required to prevent flood water spilling south across the R123. Further downstream, a 200m long embankment with an average height of 0.7m is required on the left bank of the Mayne River and its tributary to prevent out of bank flooding downstream. This embankment is linked to a flood wall on the Mayne River, 50m in length, with an average height of 2.4m (due to space constraints, wall constructed to the bed of the channel). The average height of this wall above ground level is approximately 0.6m.

Modelling results indicate that this option will have some localised impact on water levels upstream and downstream of the proposed location for this option. Upstream of the R123, water levels on the Mayne River tributary are lowered by an average of 0.12m along a 120m stretch of the channel. Downstream of the R123, water levels on the Mayne River and its tributary are raised by an average of 0.16m along 430m of river channel. Downstream of the bridge at The Hollow, there are no changes in water levels.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The results of the modelling indicate that existing overland flood flow paths are modified with this option. These existing overland flow paths from the Mayne River tributary (southwards across the R123) are as a result of capacity problems at an existing old stone bridge structure and lead to the flooding of properties at Balgriffin. The option prevents these overland flow paths by removing the bridge structure and constructing embankments and walls to protect the properties. There are no areas of significant natural floodplain storage affected by this option but some reduction in floodplain storage does occur.

Multi Criteria Analysis (MCA) Results – option 1a

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€955,548	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€752,281	100	130	210	-100	**340**
BCR	1.27					

The results of the stage 3 assessment and the potential implementation of these options are considered further in Chapter 14.

12. Flood risk management options for the Coastal AU

Introduction

The results of the stage 1 assessment demonstrated that two options were potentially viable for the Coastal AU and that a number of APSRs had sufficient flood risk to consider potential options: Portmarnock and Malahide areas, Swords area, Rush area, Skerries area and Laytown, Bettystown and coastal area APSRs. The remaining APSRs, Portrane area, Balbriggan area, Gormanston and Gormanston Demesne area, Military Aerodrome (south to Irishtown), Julianstown area and Baldoyle area APSRs all had insufficient flood risk to consider specific FRM options within the APSR. Study area or AU scale options may provide some reduction in flood risk to properties at risk in those areas. In addition, some funding may be available to the Local Authority from the OPW Minor works funding programme (for schemes less than €500,000).

Stage 3 assessment for the Coastal AU

A number of options to manage flood risk in the Coastal AU and APSRs were carried forward to the stage 3 detailed multi criteria assessment involving the assessment of the performance of each option against the 16 flood risk management objectives. The detailed MCA spreadsheets and figures for these options are included in Appendix E2.

Table 12-6 provide a summary of each option with the MCA scores. The SEA conclusions and recommendations are reported on in the SEA Environment Report (Halcrow Barry, 2011).

Table 12-1 Coastal AU options 1 and 2

Assessment units	Coastal AU
Water bodies	Fingal and Meath coastline, Mayne River, Sluice River, Gaybrook Stream, Broadmeadow River, Ward River, Lissenhall Stream, Turvey River, Ballyboghil River, Corduff River, Baleally Stream, Bride's Stream, Jones's Stream, Rush Town Stream, St. Catherine's Stream, Mill Stream, Bracken River, Delvin River, Mosney Stream, Nanny River and Brookside stream
Flood risk management options	(1) Develop a combined fluvial and tidal FFWS. (2) Regular inspection and maintenance of coastal defences including walls, embankments and flap valves.

Flood Risk (1% AEP event)

The Coastal AU is at risk from a number of sources of flooding: tidal flooding only, fluvial flooding only and a combination of tidal and fluvial flooding. There are a number of areas along the Fingal and Meath coast at economic risk for the 1% AEP fluvial event and 0.5% AEP tidal event. The majority of the risk is confined to urban areas along the coast and in particular along the estuaries of the rivers discharging to the Irish Sea. There are a number of locations where the economic risk is directly from coastal flooding from the Irish Sea (e.g. Harbour Road in Skerries area APSR) or from fluvial flooding from the rivers (e.g. Mill Stream in Skerries area APSR). There is one IRR at risk, a WWTW in Julianstown area APSR.

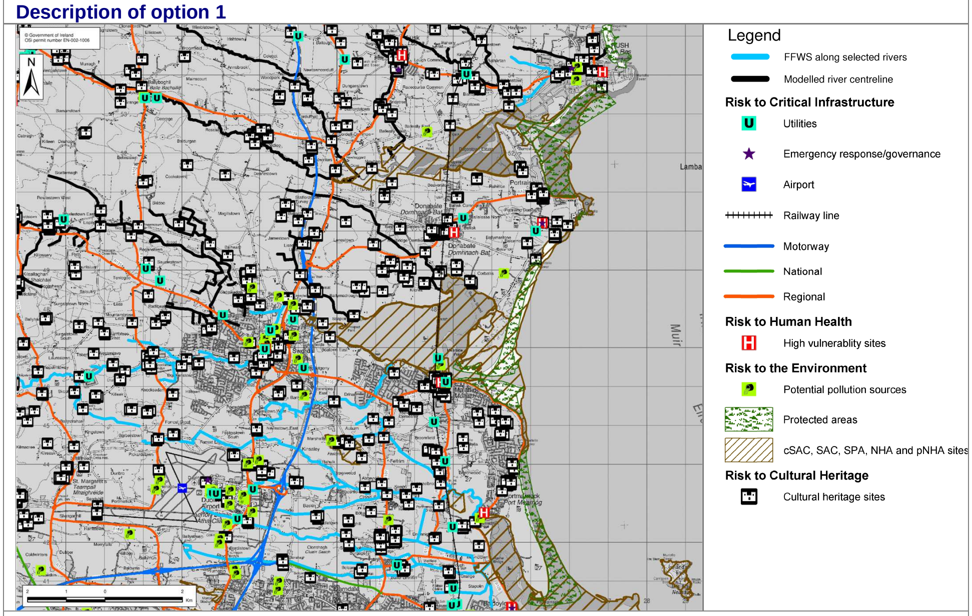
Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
182	54	1	2.5	350	7

Environmental features and receptors present or at risk

- 8 river water bodies: 1 = high status; 2 = good status; 1 = moderate status; 3 = poor status; 1 = bad status

- 4 transitional (i.e. estuarine) water bodies: 4 = moderate status
- 4 coastal water bodies: 2 = high status; 2 = moderate status
- 1 wastewater treatment works
- 13 Waste management permit sites
- 4 Section 4 licences and 15 Section 16 licences
- Boyne Coast and Estuary SAC/pNHA; Boyne Estuary SPA; River Nanny Estuary and Shore SPA; Laytown Dunes and Nanny Estuary; Loughskinny Coast pNHA; Rogerstown Estuary SAC/SPA/Ramsar site/pNHA; Malahide Estuary SAC/pNHA; Broadmeadow-Swords Estuary SPA/Ramsar site; Baldoyle Bay SAC/SPA/Ramsar site/pNHA; Sluice River Marsh pNHA
- 21 sites on Meath County Council's Wetland Inventory, and 92 sites listed on the Coastal Inventory
- 29 sites on the SMR/RPS/RMP

Description of option 1



Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels, based on actual meteorological conditions, and tools to disseminate flood hazard data to people at risk. Further information on the viability of various fluvial flood forecasting options are reported on in the Preliminary Options Report. Flood forecasts would be disseminated through a dedicated website and messaging service to provide advance warning to communities.

Through the Irish Coastal Protection Strategy Study (ICPSS), low-resolution tidal-surge forecasting capability has been developed around the Irish Coast. The system is a purely tidal-surge forecasting model and as part of this option would be developed to generate a combined fluvial and tidal FFWS.

FFWS would be required for the Irish Sea along the Meath and Fingal coastline and for the following rivers: Mill Stream, Rush West Stream, Ward River, Gaybrook Stream and Sluice River (consideration has been given to a fluvial FFWS on the Nanny River, Broadmeadow River and Mayne River as part of the Nanny and Delvin AU and the Mayne and Sluice AU respectively).

The image above shows flood risk indicators along the coast and in catchments where fluvial FFWS are proposed. Those indicators in the coastal and fluvial floodplains where forecasting is proposed are likely to benefit from the proposed FFWS. .

Potential impact on principal overland flow routes and areas of significant natural floodplain storage						
There is no impact on principal overland flow routes and areas of significant natural floodplain storage.						
Multi Criteria Analysis (MCA) Results – option 1						
Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€3,669k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€1,762k	200	25	0	0	**225**
BCR	2.08 (7.29 with IPFP)	Significantly more benefit can be achieved from FFWS if it is implemented in conjunction with IPFP (study area option 2).				
Description of option 2						
A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable it was not considered any further.						

Table 12-2 Portmarnock and Malahide areas APSR options 1 to 5

Assessment units	Portmarnock and Malahide areas APSR
Water bodies	Fingal and Meath coastline, Gaybrook Stream, Broadmeadow Estuary, Sluice River
Flood risk management options	(1) Rehabilitating and raising existing coastal defences at Strand Road (including rehabilitation walls and flapped outfall) and construction of flood defence embankment. (2) Replacement of flapped outfall on Sluice River and construction of flood defence embankments and walls to protect at risk properties at Strand Road. (3) Construction of flood defence embankments and walls to protect at risk properties in Malahide town centre. (4) Construction of flood defence walls and embankments along with rehabilitating and raising of existing coastal defences in Malahide town centre. (5) Construction of demountable flood defences along with embankments to protect at risk properties in Malahide town centre. (5a) Construction of demountable flood defences along with embankments to protect at risk properties in Malahide town centre.

Flood Risk (1% AEP event)

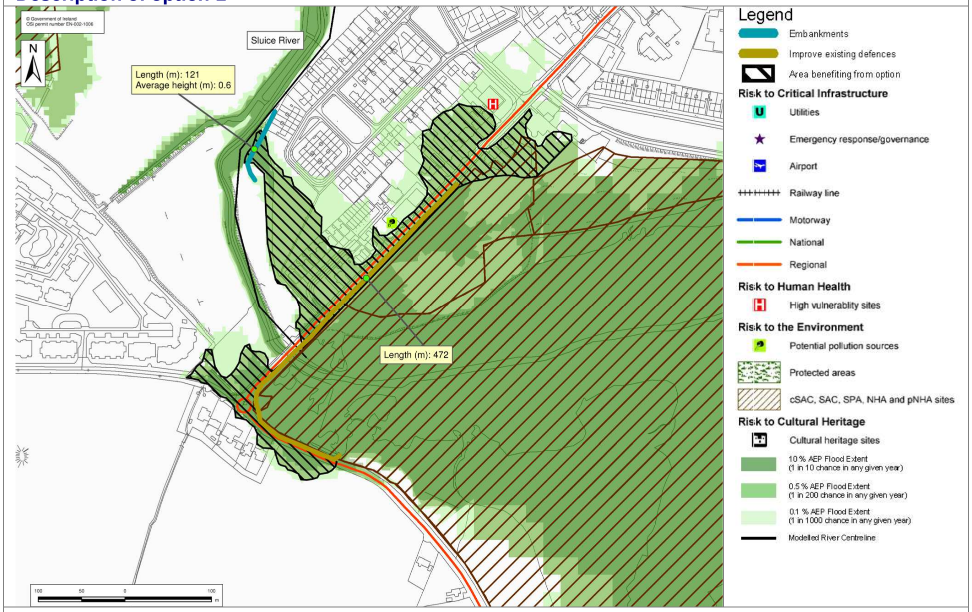
At Strand Road in Portmarnock, 18 properties are at risk from a combination of fluvial (Sluice River) and tidal flooding. In Malahide, the flood risk is from tidal flooding only from the Broadmeadow estuary resulting in 37 properties in Malahide town centre being at risk of flooding. A small number of properties in other locations within the APSR are also at risk of flooding.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
46	16	0	1.0	38	0

Environmental features and receptors present or at risk

- 2 river water bodies: 1 = high status; 1 = poor status
- 2 transitional (i.e. estuarine) water bodies: 2 = moderate status
- 2 coastal water bodies: 2 = moderate status
- 3 Section 16 licences
- Malahide Estuary SAC/pNHA; Broadmeadow-Swords Estuary SPA/Ramsar site; Baldoyle Bay SAC/SPA/Ramsar site/pNHA; Sluice River Marsh pNHA
- 1 site on the SMR/RPS/RMP

Description of option 1



This option involves rehabilitating (i.e. strengthening and raising) 0.5km of existing walls which run alongside the R106 at Strand Road. The option also involves rehabilitating of the flapped gates on the Sluice River at Portmarnock Bridge and the construction of a flood embankment on the left bank of the Sluice River upstream of Portmarnock Bridge.

The existing flood walls and their foundations would be strengthened using structural engineering works to allow walls to provide sufficient flood defence function up to the 0.5% AEP tidal event. The flapped gates on the Sluice River at Portmarnock Bridge prevent the propagation of high tides upstream of this bridge. These gates would be replaced with new flapped gates as part of this option. 120m of flood embankments are required upstream of Portmarnock Bridge. The average height of these embankments is 0.6m and provides protection up to the 1% AEP fluvial event and 0.5% AEP tidal event. Hydraulic modelling indicates that there is no impact on water levels upstream or downstream of Strand Road.

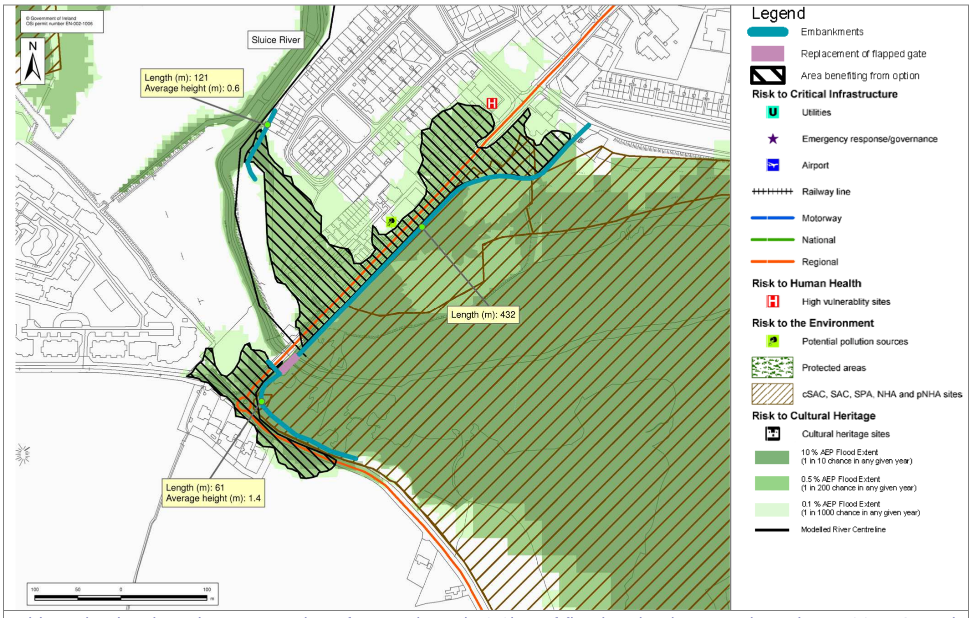
Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The construction of the flood embankment along the left bank of the Sluice River prevents an existing overland flow path (westwards through Hazel Grove and across the R106), however, this would not be considered a principal overland flow route. There are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€1,554k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€1,555k	25	120	210	-260	**95**
BCR	1.0					

Description of option 2



This option involves the construction of approximately 0.6km of flood embankments along the R106 at Strand Road and on the left bank of the Sluice River upstream of Portmarnock Bridge. The option also involves replacing the flapped gates on the Sluice River at Portmarnock Bridge.

Full and unobstructed conveyance capacity of the re-worked flapped gates is required for the benefiting areas indicated on the map to benefit from this option. Such conveyance capacity may be significantly reduced through build-up of debris, vegetation or sediment over time, or through temporary blockage of the flapped gates during flood events and, as such, cannot be guaranteed.

The flapped gates on the Sluice River prevent the propagation of high tides upstream of Portmarnock Bridge. Theses gates would be replaced with new flapped gates as part of this option. Approximately 500m of flood embankments are required along the R106 to protect up to the 0.5% AEP event. The average height of these embankments is 0.8m on the left bank downstream of Portmarnock Bridge and 1.4m on the right bank downstream of Portmarnock Bridge. Upstream of Portmarnock Bridge, approximately 120m of flood embankment are required with an average height of 0.6m. These would provide protection up to the 1% AEP fluvial event and 0.5% AEP tidal event. Hydraulic modelling indicates that there is no impact on water levels upstream or downstream of Strand Road with this option.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The construction of the flood embankment along the left bank of the Sluice River prevents an existing overland flow path (westwards through Hazel Grove and across the R106), however, this would not be considered a principal overland flow route. There are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 2

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€1,554	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€575,481	25	120	90	-260	**-25**
BCR	2.7					

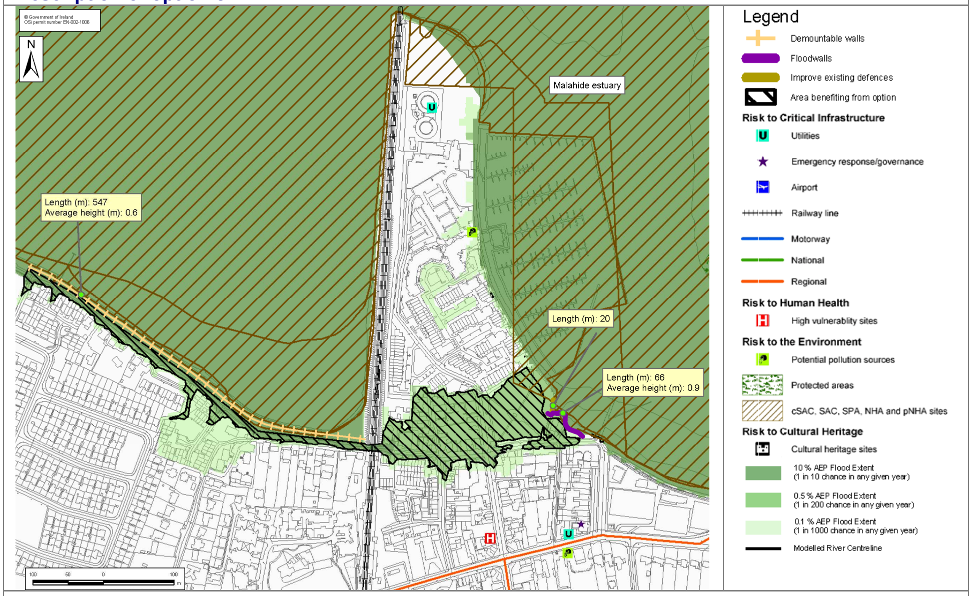
Description of option 3

A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable, this option was not considered any further.

Description of option 4

A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable, this option was not considered any further.

Description of option 5



This option involves the construction of approximately 500m of demountable defences along the coast road to the west of the railway line and 60m of flood walls in Malahide town centre. The option also involves raising a short section of flood wall (approximately 20m) in Malahide.. The option provides protection against tidal flooding up to the 0.5% AEP event. It is noted that this is a significant amount of demountable defences and that the Local Authority and the OPW will need to agree who is responsible for the installation of these demountable defences.

The demountable defences to the west of the railway line prevent flooding of a number of properties along this coast road and cut off the flow path of flood water under the railway underpass and into Malahide town centre. The demountable flood defences would be mounted to a permanent flood defence structure. The average height of demountable defences above ground level would be 1.2m mounted to a permanent wall 0.3m in height above ground. Some localised road raising would be required at the western extremity of the defences to ensure flooding does not propagate along the coast road behind the defences. There would be no impact on water levels in the Broadmeadow estuary with this option.

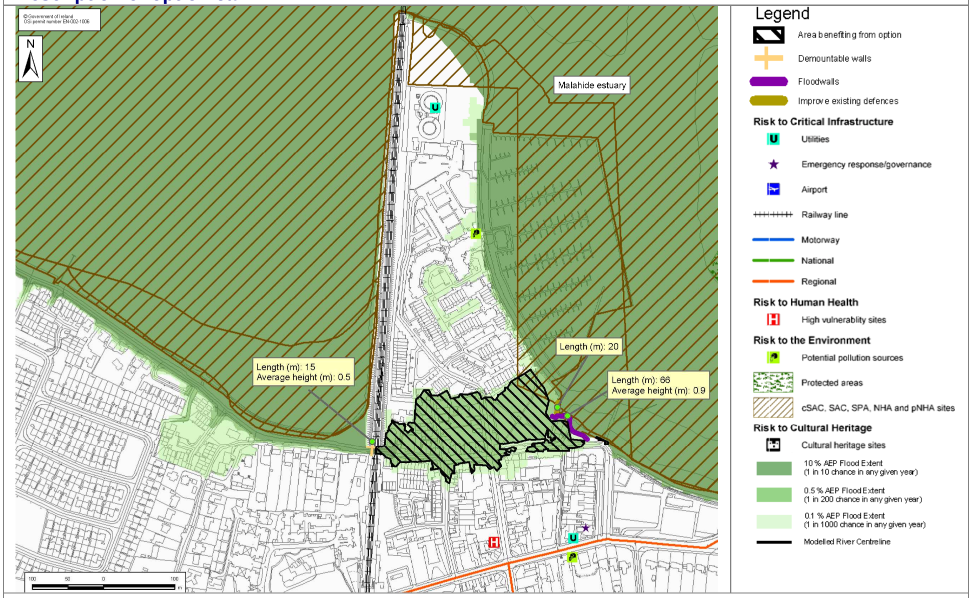
Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The construction of the flood embankment and revetments along the coast road prevents flooding along the coast road, under the railway underpass and into Malahide town centre. There are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 5

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€2,730k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€4,839k	0	180	240	-70	**350**
BCR	0.6 (1.0 with FFWS)	This option requires a FFWS to be implemented. The higher cost/lower BCR includes a specific FFWS with this option. If it is assumed that Coastal AU option 1 is implemented the specific cost for a FFWS for this option can be removed thus increasing the BCR.				

Description of option 5a



This option involves the construction of 60m of flood walls and the raising of a short section of flood wall (approximately 20m) in Malahide town centre. The option also involves the construction of a demountable flood defence across the railway underpass to prevent the propagation of flood waters along the coast road eastwards into Malahide town centre. The option provides protection to properties in Malahide town centre against tidal flooding up to the 0.5% AEP tidal event. It does not reduce the flood risk to properties along the coast road. The 0.5% AEP tidal flood maps indicate that the flood risk along the coast road affects the gardens and driveways of properties and does not result in economic damages to any buildings. It is noted that the Local Authority and the OPW will need to agree who is responsible for the installation of these demountable defences. It is also noted that the permission of Irish Rail may also be required.

A demountable defence across the railway underpass on the coast road would cut off the flow path of flood water under the railway underpass and into Malahide town centre. This option would limit the movement of people and traffic prior to and during a flood event and the traffic management plan would need to consider this issue. Additional investigations would be required to determine if the railway embankment would prevent the ingress of water eastwards into Malahide town centre. This option does not prevent flooding of properties along the coast road.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The construction of the flood embankment and revetments along the coast road prevents flooding along the coast road, under the railway underpass and into Malahide town centre. There are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 5a

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€2,730k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€2,203k	0	180	240	-70	**350**
BCR	1.2 (6.2 with FFWS)	This option requires a FFWS to be implemented. The higher cost/lower BCR includes a specific FFWS with this option. If it is assumed that Coastal AU option 1 is implemented the specific cost for a FFWS for this option can be removed thus increasing the BCR.				

Table 12-3 Swords area APSR options 1 and 2

Assessment units	Swords area APSR
Water bodies	Gaybrook Stream, Broadmeadow River, Ward River, Lissenhall Stream
Flood risk management options	(1) Widening the Gaybrook Stream to reduce fluvial flood risk to properties at Aspen near Kinsaley. (2) Construction of flood defence walls to protect properties at risk from tidal flooding in Swords town centre.

Flood Risk (1% AEP event)

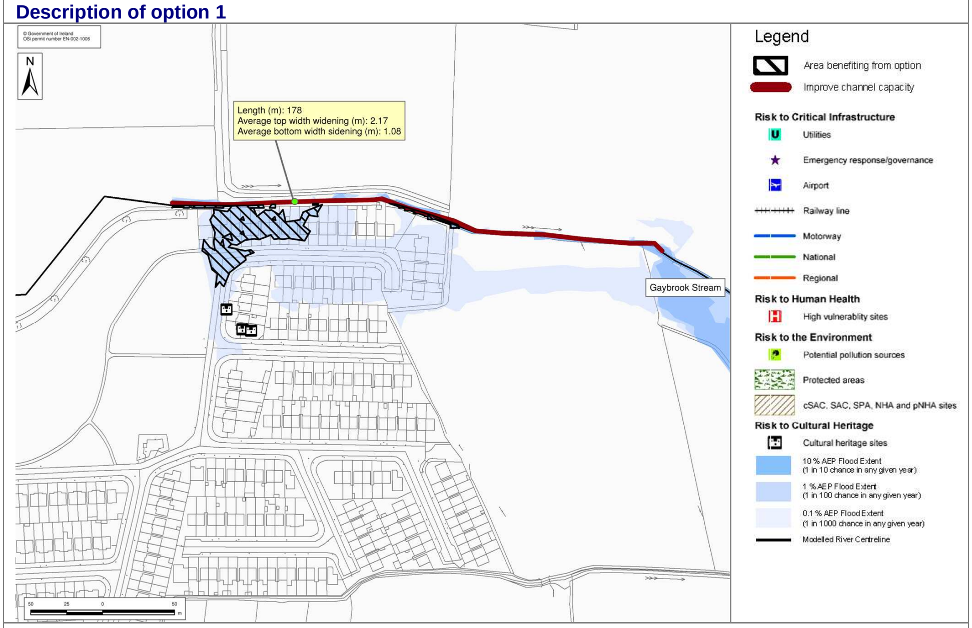
In Swords area APSR, 9 residential properties are at risk of flooding in the Aspen estate from the Gaybrook Stream and 7 non-residential properties (including a fire station) are at risk Swords town centre from the Ward River. The remaining at risk properties are in isolated locations around Swords, including 4 non-residential properties in the Airside Retail Park, which are at risk from the Gaybrook Stream but incur very low economic damages.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
13	15	0	0.12	12	0

Environmental features and receptors present or at risk

- 4 river water bodies: 1 = high status; 2 = moderate status; 1 = poor status
- 1 transitional (i.e. estuarine) water bodies: 1 = moderate status
- 2 Section 4 licences and 7 Section 16 licences
- Malahide Estuary SAC/pNHA; Broadmeadow-Swords Estuary SPA/Ramsar site
- 3 sites on the SMR/RPS/RMP

Description of option 1



This option involves increasing the channel capacity by widening the Gaybrook stream along a 200m length at Aspen. Hydraulic modelling indicates that the top width of the channel would need to be widened by an average of 2m while the bottom width of the channel would need to be widened by an average of 1m between surveyed cross sections 3Ga2306 and 3Ga2128. These channel modifications contain the 1% AEP fluvial event in bank with a 0.3m freeboard (i.e. 1% AEP water levels are 0.3m below top of bank).

Full and unobstructed conveyance capacity of the re-worked channel is required for the benefiting areas indicated on the map to benefit from this option. Such conveyance capacity may be significantly reduced through build-up of debris, vegetation or sediment over time and, as such, cannot be guaranteed.

The results of the hydraulic modelling show that this option modifies water levels locally with an average decrease in water levels of 0.3m along the 200m length of widened channel. Downstream of the channel widening, there is a negligible increase in water levels.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

No principal overland flow routes are modified with this option and there are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€193,440	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€54,166	125	90	90	-110	**195**
BCR	3.6					

Description of option 2

A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable this option was not considered any further.

Table 12-4 Rush area APSR options 1 and 1a

Assessment units	Rush area APSR
Water bodies	St Catherine's Stream, Rush Town Stream, Rush West Stream, Jone's Stream, Rogerstown Estuary
Flood risk management options	(1) Construction of flood defence embankments and walls and replacing culvert along Channel Road to protect at risk properties along the coast and from Rush West stream. (1a) Construction of secondary culvert along Channel Road to protect properties at risk from fluvial flooding along the Rush West stream.

Flood Risk (1% AEP event)

At Rush area APSR, the flood risk is from two separate sources; fluvial flooding from the Rush West Stream and tidal flooding from Rogerstown estuary. The options proposed do not protect 17 properties that area also at risk from tidal flooding. However, the risk from tidal flooding is less than that from fluvial flooding with significantly less economic damages being incurred from tidal flooding only.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
25	2	0	0.6	4	1

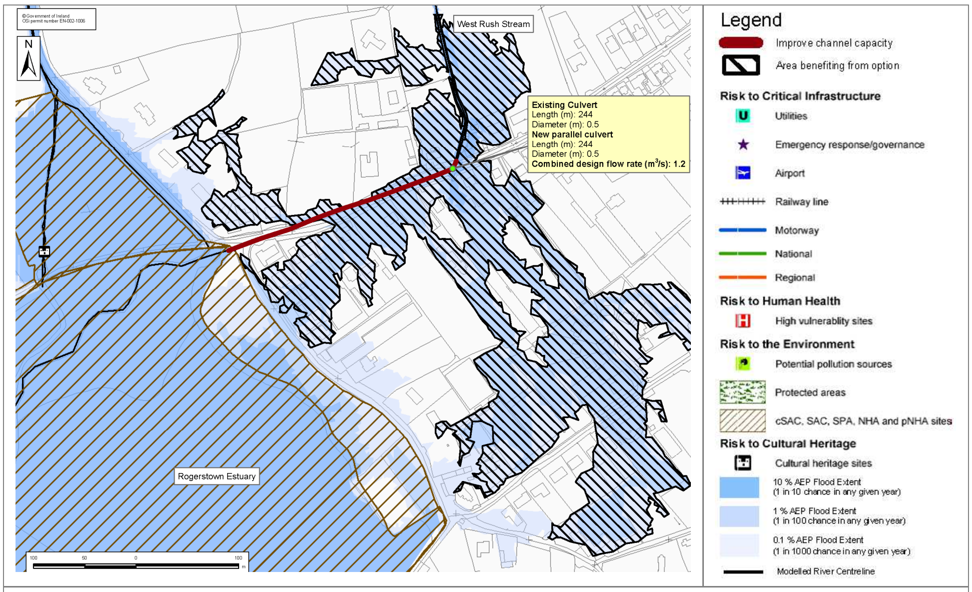
Environmental features and receptors present or at risk

- 1 river water body: 1 = poor status
- 1 transitional (i.e. estuarine) water bodies: 1 = moderate status
- 1 coastal water bodies: 1 = moderate status
- 1 Waste management permit site
- 2 Section 16 licences
- Rogerstown Estuary SPA/SAC/pNHA
- 2 sites on the SMR/RPS/RMP

Description of option 1

A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable, this option was not considered any further.

Description of option 1a



As more economically viable variation of option 1, this option would involve constructing a secondary culvert along side the existing culvert on the downstream end of the Rush West Stream. The capacity of the existing structure is insufficient to convey large flows and results in surcharging and spilling of flood waters and flooding of properties. As the culvert is sized for the 1% MRFS 95%ile flow it can pass the 0.1% AEP fluvial flow without causing any flood damage to property.

Full and unobstructed conveyance capacity of the new and existing culverts is required for the benefiting areas indicated on the map to benefit from this option. Such conveyance capacity may be significantly reduced through build-up of debris, vegetation or sediment over time, or through temporary blockage of the culverts during flood events and, as such, cannot be guaranteed.

Modelling results indicate that a new circular culvert with a diameter of 0.5m when combined with the capacity of the existing structure would be sufficient to reduce fluvial flood risk in Rush. The combined culverts would convey a flow of 1.2m^3/s, which equates to the 1% AEP MRFS 95%ile flow without surcharging.

Modelling results indicate that this option will have some impact on water levels upstream and no impact downstream of the proposed location for this option. Changes in water levels are localised along a 0.3km stretch of the river upstream of the culvert inlet. The option results in an average decrease of 0.36m in water levels upstream of the culvert inlet. The maximum decrease in water levels is 1.0m at the culvert inlet.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The results of the modelling indicate that existing overland flood flow paths are modified with this option. These existing overland flow paths are as a result of capacity problems at the entrance to the existing culvert and lead to the flooding of properties in Rush. The option prevents these overland flow paths through increasing the capacity of the culvert. There are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 1a

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€432,280	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€584,046	225	35	180	-10	**430**
BCR	0.74 (0.9 for 0.1% AEP)	Replacement culverts designed to pass the 95%ile 1% MRFS without surcharging. This flow is less than the 0.1% AEP current scenario flow and therefore reduction in the 0.1% AEP damage is also achieved, thus increasing the BCR.				

Table 12-5 Skerries area APSR options 1 to 6

Assessment units	Skerries area APSR
Water bodies	Fingal coastline, Mill Stream
Flood risk management options	(1) Rehabilitating and raising existing coastal defences at Harbour Road to reduce tidal flood risk. (2) Replacing culverts under roads and railway with larger capacity culverts and widening channel through park to reduce fluvial flood risk to properties at Millar Lane and Sherlock Park. (3) Constructing a flow diversion channel to run in a culvert under the railway and roads at Miller lane and Sherlock Park to reduce fluvial flood risk to properties at Miller Lane and Sherlock Park. (4) Lowering road levels and raising kerb levels along Miller Lane and Sherlock Park to allow controlled flooding along this road and reduce fluvial flood risk to properties. (5) Construction of storage reservoir to the west of railway embankment to provide flood storage upstream of Skerries Area APSR to reduce fluvial flood risk to properties along Miller Lane and Sherlock Park. (6) Construction of storage reservoir to the west of railway embankment to provide flood storage upstream of Skerries Area APSR along with replacing culverts under roads and railway with larger capacity culverts to reduce fluvial flood risk to properties along Millar Lane and Sherlock Park.

Flood Risk (1% AEP event)

For Skerries area APSR, two separate locations are at risk from different sources of flooding. Along Harbour Road, 12 properties are at risk from tidal flooding. A total of 49 residential properties along Millar Lane and Sherlock Park are at risk of fluvial flooding from the Mill Stream.

Properties		Utility assets (No.)	Transport routes (length km)	Land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
59	2	0	1.7	4	0

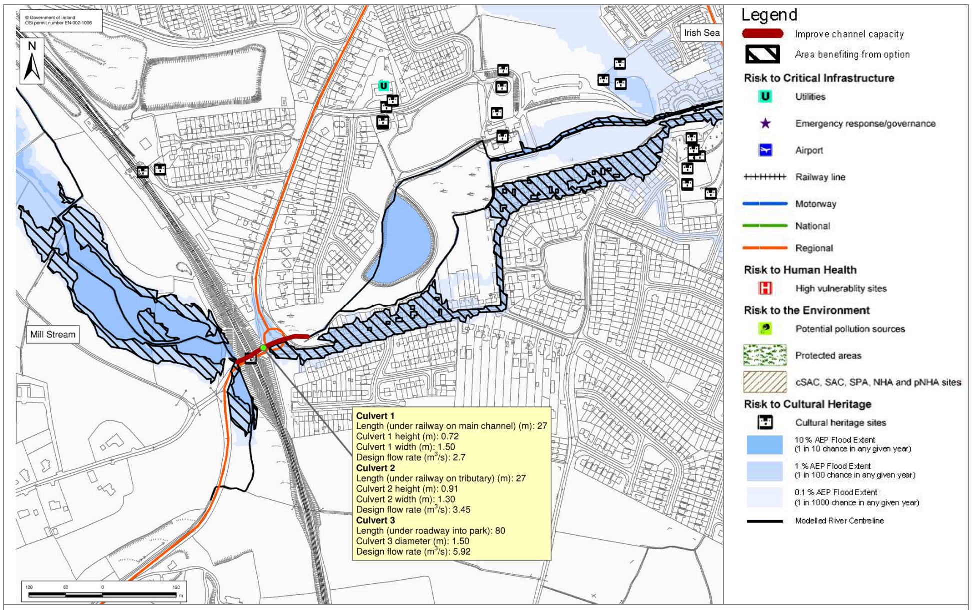
Environmental features and receptors present or at risk

- 1 river water body: 1 = good status
- 1 coastal water bodies: 1 = moderate status
- 1 site on the SMR/RPS/RMP

Description of option 1

A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable, this option was not considered any further.

Description of option 2



This option would involve replacing the existing culverts under the Dublin to Belfast railway line with new larger capacity culverts (which will require consents from Irish Rail). The capacity of the existing culverts is insufficient to convey large flows and results in flood waters ponding on land to the west of the railway embankment and surcharging of existing culverts. This surcharging results in spilling of flood waters along the R127 and floods properties at Millar Lane and Sherlock Park. Hydraulic modelling indicates that it is not necessary to widen and deepen the river channels in the park to accommodate the increased conveyance through the new larger capacity culvert.

Full and unobstructed conveyance capacity of the re-worked channel/culvert is required for the benefiting areas indicated on the map to benefit from this option. Such conveyance capacity may be significantly reduced through build-up of debris, vegetation or sediment over time, or through temporary blockage of the culvert during flood events and, as such, cannot be guaranteed.

The existing culverts under the railway would be replaced with three larger capacity culverts. Hydraulic modelling indicates that the following culverts would be required to convey the 1% AEP MRFS 95%ile flow without surcharging:
- Culvert under the railway on main channel - Box section culvert: Length 27m. Width 1.5m. Height 0.72m
- Culvert under the railway on 15Maa tributary - Box section culvert: Length 27m. Width 1.3m. Height 0.91m
- Culvert under the roadway into the park - Circular culvert: Length 80m. Diameter 1.50m.

Modelling results indicate that this option will have an impact on water levels upstream and downstream of the proposed new culverts. Upstream of the culverts (i.e. to the west of the railway embankment), flood risk to land is reduced with water levels in the Mill Stream lowered by an average of 0.56m along a 650m length of channel. Along the Mill Stream tributary (west of the railway embankment) water levels are reduced by an average of 0.35m along the modelled reach (i.e. 200m). Downstream of the railway, the increased conveyance capacity of the culverts results in an increase in water levels along the Mill Stream. Water levels are raised by an average of 0.21m along 1.1km of river channel. The maximum increase in water levels occurs at cross section 15Ma1123CD where water levels are raised by 0.44m. This increase in water level does not result in out of bank flooding through the park.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The results of the modelling indicate that existing overland flood flow paths are modified with this option. These existing overland flow paths are as a result of capacity problems at the entrance to the existing culverts which results in flood water spilling along the R127 and secondary roads at Millar Lane and Sherlock Park. The option prevents these overland flow paths by increasing the capacity of the culverts. This option also

reduces floodplain storage on lands to the west of the railway embankment. Replacing the existing culverts increases the capacity in the channel system, draining the land flooded to the west of the railway embankment.
u

Multi Criteria Analysis (MCA) Results – option 2

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€1,876k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€1,496k	225	135	180	-35	**505**
BCR	1.3					

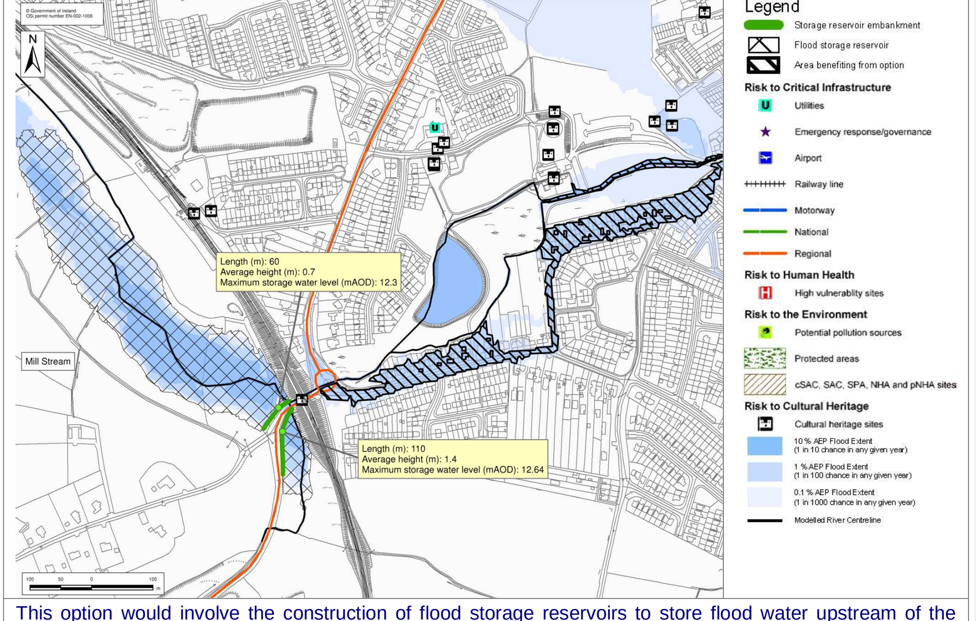
Description of option 3

A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable this option was not considered any further.

Description of option 4

Hydraulic modelling indicates that this is not a viable option. Lowering road levels along Millar Lane and Sherlock Park creates new flow paths and results in flood risk to other areas of Skerries. Therefore, this option is not considered any further.

Description of option 5



This option would involve the construction of flood storage reservoirs to store flood water upstream of the railway embankment and control discharges during a flood event. The controlled discharge would not exceed the capacity of the existing culverts under the road and railway.

Two storage reservoir embankments would be required as follows:

• Storage embankment 1 would be located on the Mill Stream tributary and run alongside the R127. The embankment would tie into the existing railway embankment. A 100m embankment with an average height of 1.4m would be required.

• Storage embankment 2 would be located on the Mill Stream and run alongside a secondary road which joins the R127 near the railway underpass. The embankment would tie into the existing railway embankment. A 60m embankment with an average height of 0.7m would be required.

Both options assume that the railway embankment can be used to impound water. Additional investigations

would be required to determine if the railway embankment would prevent the ingress of water westwards into Skerries. The outflow from both reservoirs would be regulated to the current maximum capacity of the existing culverts which run under the railway and road. Modelling results indicate that this option will have an impact on water levels upstream and downstream of the proposed storage reservoirs. Upstream of the reservoir embankments, flood risk to land (currently zoned as industrial) is increased with water levels in the Mill Stream rising by an average of 0.34m along a 690m length of channel. Along the Mill Stream tributary (west of the railway embankment) water levels rise by an average of 0.65m along the modelled reach (i.e. 200m). Downstream of the railway, the increased storage upstream results in reduced water levels along the Mill Stream. Water levels are lowered by an average of 0.24m along 1.1km of river channel. The maximum decrease in water levels is 0.38m.						
Potential impact on principal overland flow routes and areas of significant natural floodplain storage						
The results of the modelling indicate that existing overland flood flow paths are modified with this option. These existing overland flow paths are as a result of capacity problems at the entrance to the existing culverts which results in flood water spilling along the R127 and secondary roads at Millar Lane and Sherlock Park. The option prevents these overland flow paths by storing the water upstream of the railway embankment. This option also increases floodplain storage on lands to the west of the railway embankment.						
Multi Criteria Analysis (MCA) Results – option 5						
Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€1,876k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€703,994	100	95	180	-50	**325**
BCR	2.7					
Description of option 6						
An additional option was considered which looked at storage reservoirs in combination with improvements in the conveyance capacity of the culverts under the railway. As detailed in Option 5, the proposed storage reservoir embankments are relatively low (maximum height 1.4m) with a controlled discharge not exceeding the capacity of the existing culverts under the road and railway. The proposed storage reservoir embankments are not significantly high to justify constructing the storage reservoir in combination with larger capacity culverts to reduce the embankment height. This option has not been considered any further.						

Table 12-6 Laytown, Bettystown and coastal areas APSR options 1 and 2

Assessment units	Laytown, Bettystown and coastal areas APSR
Water bodies	Meath coastline, Nanny River, Brookside Stream
Flood risk management options	(1) Construction of flood defence embankments to protect properties at risk along the coast and from the Nanny River. (2) Construction of demountable flood defences to protect at risk properties along the coast and from the Nanny River.

Flood Risk (1% AEP event)

The main flood risk in this APSR is to Laytown from combined fluvial and tidal flood risk along the Nanny River estuary.

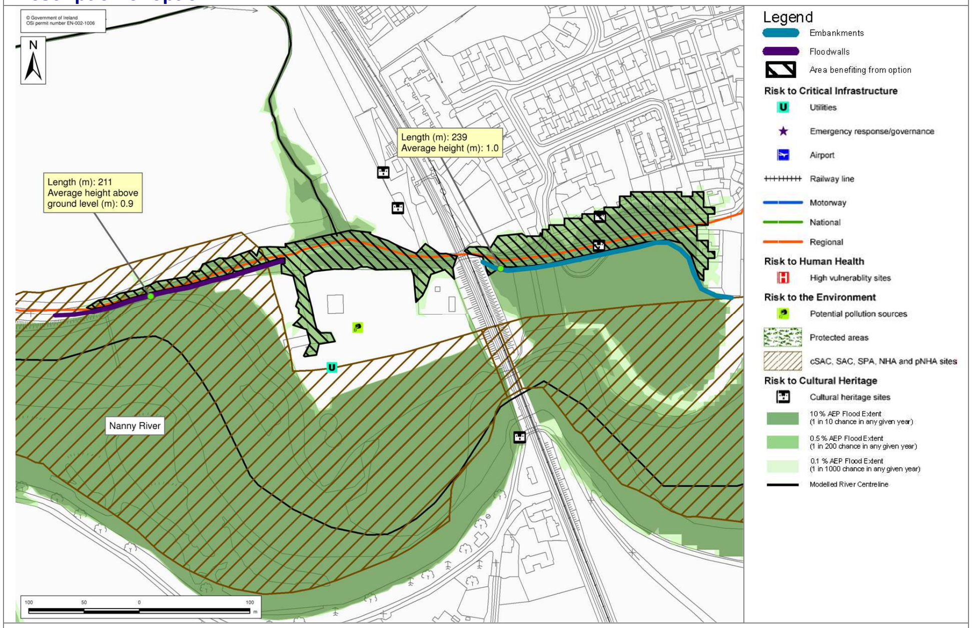
Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Non-residential (No.)				
10	1	0	0.5	11	0

Environmental features and receptors present or at risk

- 2 transitional (i.e. estuarine) water bodies: 2 = moderate status
- 2 coastal water bodies: 2 = high status
- Boyne Coast and Estuary SAC/pNHA; Boyne Estuary SPA; River Nanny Estuary and Shore SPA; Laytown Dunes and Nanny Estuary

- 7 sites listed on Meath County Council's Wetland Inventory, and 37 sites listed on the Coastal Inventory
- 2 site on the SMR/RPS/RMP

Description of option 1



This option involves the construction of flood embankments and walls on the left bank of the River Nanny along the R150 southwest of Laytown. Approximately 210m of flood defence walls are required and, where space is available, the flood walls have been set back from the river bank. Along the R150, there is limited space to set the walls back from the river bank and these walls are constructed to the river bed level. The average height of these walls is 1.0m above the top of bank. Immediately downstream of the railway bridge, approximately 240m of flood embankment are required along the left bank of the Nanny River. This embankment is set back from the channel and has an average height of 1.0m. Hydraulic modelling indicates that there is no impact on water levels upstream or downstream of Laytown with this option.

Potential impact on principal overland flow routes and areas of significant natural floodplain storage

The construction of the flood defence wall along the left bank of the River Nanny prevents an existing overland flow route (eastwards along the R150 which continues under the railway bridge and into Laytown). There are no areas of significant natural floodplain storage affected by this option.

Multi Criteria Analysis (MCA) Results – option 1

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€1,705k	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€,1412k	100	120	180	-260	**140**
BCR	1.2					

Description of option 2

A more detailed review of this option as part of the stage 3 assessment resulted in a BCR of significantly less than 1. As all options need to be economically viable it was not considered any further.

The results of the stage 3 assessments and the potential implementation of these options are considered further in Chapter 14.

13. Individual Risk Receptors

Assessment of potential options for IRRs

The full three stage option assessment process was not used to determine an MCA score for an Individual Risk Receptor (IRR). IRRs tend to be isolated structures and in most cases can be protected by local defences such as a flood embankment. The stage 1 and 2 process was used to identify potential measures and options for managing the risk to IRRs but an alternative, and simpler, approach was adopted for the stage 3 assessment of IRRs. Figure 13-1 shows the locations of the IRRs in the study area.

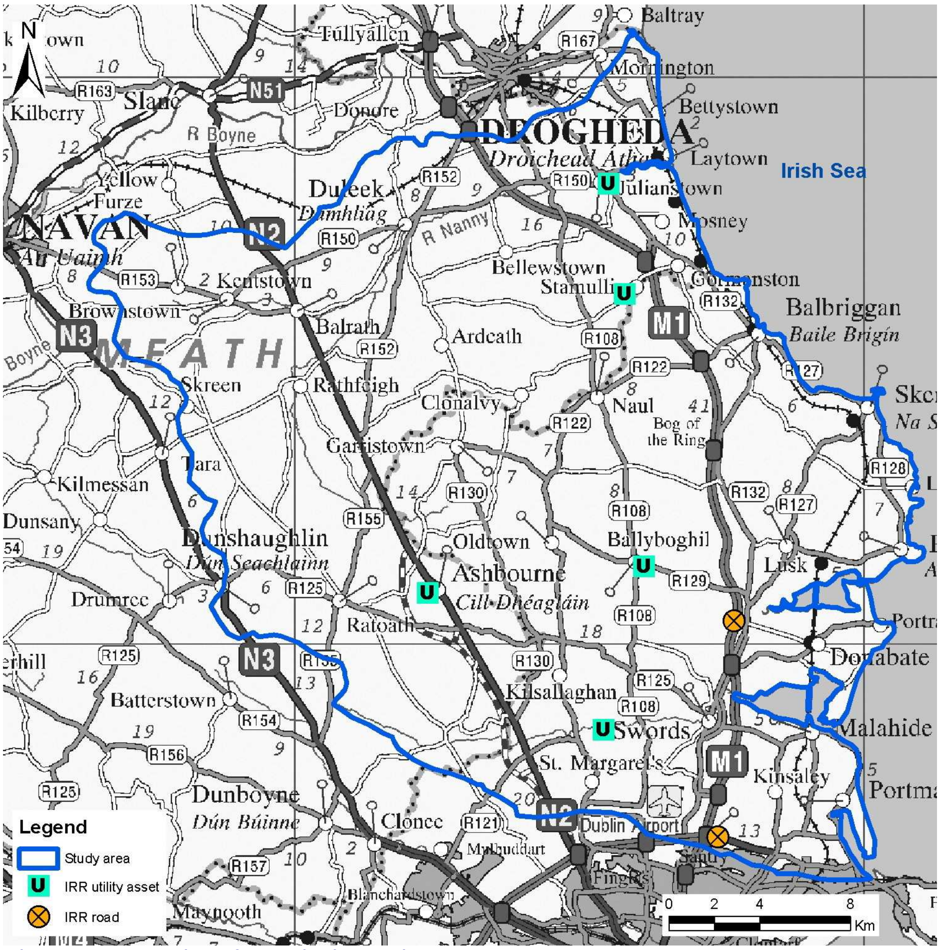


Figure 13-1 Location of IRRs in the study area

The most cost effective option of the potential options identified was selected as the preferred option for each IRR. Relevant environmental issues, constraints and opportunities were considered and reviewed as part of the SEA. These are reported on in the SEA Environmental Report (Halcrow Barry, 2011).

Consideration was also given to proposed options at AU and APSR level which if constructed would provide protection to these IRRs. Consideration may need to be given to protecting these IRRs independently of the AU and APSR defence options given the importance of these assets. A list of potential options to protect these IRRs is provided in Table 13-1. Further information, including alternative options considered, can be found in Appendix G.

Table 13-1 Preferred options for IRRs

Risk receptor	Owner	Location	Likely FRM option	Benefits from APSR/ AU option?
Utility asset at Stamullin	Unknown	Stamullin area APSR	Construction of localised flood defence embankments Or IPFP	No
WWTW at Ballyboghil	Local Authority	Ballyboghil area APSR	Construction of localised flood defence embankments	No
M1 at Staffordstown	NRA	Ballyboghil & Lusk AU	Construction of localised flood defence embankments	No
Wastewater pumping station in Ashbourne	Local Authority	Ashbourne area APSR	Construction of localised flood defence embankments	No
WWTWs at Toberburr	Local Authority	Owens Bridge area APSR	Construction of localised flood defence embankments	No
N32 at Clonshaugh	Local Authority	St Margaret's, Dublin Airport, Belcamp and Balgriffin areas APSR	Construction of localised flood defence embankments	No
WWTWs at Julianstown	Local Authority	Julianstown area APSR	Construction of localised flood defence embankments	No

14. Selection of preferred options

Introduction

The assessments of various measures for the management of flood risk for the Analysis Units (AUs), Areas of Potential Significant Risks (APSRs) and the study area as a whole was undertaken during the stage 1 optioneering process and the results are published in the Preliminary Options Report (refer to Section 0). The identification and assessment of a range of potential flood risk management options for managing both the fluvial and tidal flood risk for the entire study area as well as for the individual AUs, APSRs and IRRs within the FEM FRAM study area are presented in Chapters 7 to 13 of this report.

This chapter provides details on the further work and analysis that was carried out to produce cohesive options for managing the flood risks (both fluvial and tidal) within the AUs, APSRs and the study area as a whole. The options for the IRR were provided in the previous chapter. These cohesive options form a major component of the flood risk management strategy detailed in the draft Fingal East Meath Flood Risk Management Plan (FEM FRMP).

Cohesive options

Introduction

Potential options for the individual AUs, APSRs and the study area as a whole, which have positive MCA scores from the detailed option evaluation process, are listed in Table 14-1.

The options listed in Table 14-1, along with feedback from public consultation and stakeholder involvement, point the way towards the major components of the FEM FRMP, but they required further consideration in terms of consistency, mutuality, dependency etc to produce cohesive options that will effectively manage the flood risk in the study area now and in the future.

Table 14-1 shows that in the majority of locations there is only one viable option. Where there is more than one option, the option with the higher MCA score has been selected as the preferred option (in **bold**). Where two options have equal MCA scores, the option with higher MCA/cost score is selected as the preferred option (in **bold**). The two options for the study area are both shown as preferred options as they are complimentary options rather than alternative options, as discussed below.

When developing cohesive options consideration is given to both spatial and temporal cohesion. This is required to take account of potential impacts of options in different locations and at different spatial scales (e.g. study area scale and analysis unit scale) on each other, as well as the timeline for implementation of different options or the potential dependency of one option on another being implemented (e.g. an option incorporating demountable defences may be dependent on a separate option at a different spatial scale being implemented).

As can be seen in Chapters 7 to 12 and Table 14-1 the majority of options that have come through the options assessment process with a positive MCA score are independent of each other. However, there are a number of options, particularly at study area scale and analysis unit scale, which are mutually beneficial or dependent. This is further discussed in Section 14.1.1.

Future scenarios

As discussed in previous reports and Section 0 two future scenarios (MRFS and HEFS) have been developed and modelled to identify potential increase in flood risk due to climate change. The preferred options have been assessed based on their viability for managing existing risk. However, all options were developed and assessed with a potential increase in flood risk taken into consideration (based on the modelling and mapping of the MRFS). Non-structural options, such as proactive maintenance and FFWS are inherently adaptable to changes in flood risk in the future. Structural options are potentially less adaptable unless future changes in risk are taken into consideration in the design. For structural options that can be adapted in the future (e.g. flood walls, embankments or storage areas) the detailed design should include for foundations that allow raising to protect against future increases in risk. For structural options that are not readily adaptable (e.g. culverts or bridges) the potential future risk is incorporated into the design by ensuring the MRFS flow can pass without surcharging. All options are scored on their adaptability to the two future scenarios as part of the detailed multi-criteria option assessment process described in Chapter 4.

Environmental Assessment

All options have been thoroughly assessed as part of the SEA and AA to ensure that environmental opportunities and constraints are fully considered. Further details on this assessment can be found in the SEA Environmental Report.

Table 14-1: Options with a positive MCA from the detailed options evaluation

(potential options in bold are those proposed to be taken forward to development of cohesive options):

Assessment Unit	Option	MCA Score	BCR
Study Area as a whole	**1. Proactive maintenance** **2. Targeted public awareness and preparedness campaign and individual property flood proofing**	**345** **125**	**0.9** **0.85 (3 with FFWS)**
Nanny and Delvin AU	**1. Flood forecasting and warning system (Nanny River)**	**225**	**1.2 (4.9 with IPFP)**
Duleek (Duleek APSR)	**1. Raising existing defence embankment to a higher standard of protection (to protect up to 0.1% AEP)**	**375**	**1.1**
Boradmeadow & Ward AU	**1. Flood forecasting and warning system (Broadmeadow River)**	**225**	**0.8, (3.2 with IPFR)**
Ratoath (Ratoath APSR)	**1. Improving channel conveyance by replacing a bridge on the Broadmeadow River at the R125 Ratoath Road and replacing a culvert on a tributary of the Broadmeadow River**	**385**	**0.9, (0.9 at 0.1% AEP)**
Rowlestown East (Rowlestown East APSR)	**1. Construction of flood defence embankments along left bank of Broadmeadow River tributary upstream of R125**	**225**	**2.2**
Mayne & Sluice AU	**1. Develop a fluvial FFWS for the Mayne River only**	**225**	**0.4 (1.6 with IPFP)**
Balgriffin (St Margaret's, Dublin Airport, Belcamp & Balgriffin area APSR)	1. Improve channel conveyance by replacing existing culverts together with construction of flood defence embankments & walls upstream of R123 and along left bank of Mayne River and tributary **2. Improve channel capacity by removing an existing unused bridge together with construction of flood defence embankments & walls upstream of R123 and along left bank of Mayne River and tributary**	340 **340**	1.2 **1.3**
Coastal AU	**1. Fluvial & tidal flood forecasting and warning system**	**225**	**2.1 (7.3 with IPFP)**
Strand Road, Portmarnock (Portmarnock & Malahide	**1. Rehabilitating and raising existing coastal defences at Strand Road (including rehabilitation walls and flapped outfall) and construction of flood**	**95**	**1.0**

Assessment Unit	Option	MCA Score	BCR
areas APSR)	**defence embankment**		
Malahide town centre (Portmarnock & Malahide areas APSR)	**1. Construction of demountable flood defences at underpass along with embankments to protect at risk properties in Malahide town centre** 2. Construction of demountable flood defences along coast road with embankments to protect at risk properties in Malahide town centre	**350** 350	**1.2 (6.2 with FFWS)** 0.6 (0.9 with FFWS)
Aspen (Swords) (Swords area APSR)	**1. Improve channel conveyance by widening and deepening of the Gaybrook Stream to reduce fluvial flood risk to properties at Aspen near Kinsaley**	**195**	**3.6**
Rush (Rush area APSR)	**1 Construction of secondary culvert along Channel Road to protect properties at risk from fluvial flooding along the Rush West stream.**	**430**	**0.7 (0.9 at 0.1% AEP)**
Skerries (Skerries area APSR)	**1. Improve channel conveyance by replacing culverts under roads and railway with larger capacity culverts and widening channel through park to reduce fluvial flood risk to properties at Millar Lane and Sherlock Park** 2. Construction of storage reservoir to the west of railway embankment to provide flood storage upstream of Skerries Area APSR to reduce fluvial flood risk to properties along Miller Lane and Sherlock Park	**505** 325	**1.3** 2.7
Laytown (Laytown, Bettystown & coastal area APSR)	**1. Construction of flood defence embankments to protect properties at risk along the coast and from the Nanny River**	**140**	**1.2**

14.1.1. Discussions on study area options

Proactive maintenance

Flooding occurs on many of the watercourses due to under capacity structures, which can be exacerbated if structures or trash screens become blocked during flood events. Proactive maintenance would involve the removal of debris (vegetation, silt, rubbish) at the entrance and exit of culverts on a regular basis and in advance of, and subsequent to, a flood event. It would also involve the monitoring of culverts prone to blockages during a flood event. As this option is focused on reducing the risk of blockage of trash screens and structures it does not impact on principal overland flow routes other than to reduce out of bank flooding caused by blockage. This option can be independent of all other options but greater efficiency could be achieved if it is linked with a flood forecasting and warning system. By using a flood forecasting and warning system with specific trigger levels for flood warnings at different culverts resources could potentially be more effectively used and time spent clearing trash screens when flooding is not likely to occur could be reduced.

It should be noted that the ownership of this option needs to be agreed at national level between the Local Authorities and the OPW.

Targeted public awareness and preparedness campaign and individual property flood proofing

The targeted public awareness and preparedness campaign is necessary to educate the public of the risk of flooding to their properties and the protection methods available to them to reduce potential damage from flood events. The individual property flood proofing involves the use of 'off the shelf' flood defence products to provide individual flood protection to residential and commercial properties. Such products include flood gates, flood barriers, air vent blocks and the installation of non return valves to service pipes. The benefit of this option can be greatly increased if it is linked to a flood forecasting and warning system. While IPFP can be put in place based on local knowledge and experience of when flooding may occur, it is much more likely to reduce significant damage to property on a wider scale if property owners can be formally warned when a flood may occur. This option can be implemented in the short term and provide protection to properties that may be protected by a structural option in the longer term.

14.1.2. Discussions on analysis unit options

Flood forecasting and warning system (FFWS)

Flood forecasting and warning systems involves the use of mathematical computer models to predict flood water levels based on actual meteorological data and tools to disseminate flood hazard data to people at risk. Details on the viability of various flood forecasting options are presented on the Technical Note on Flood Forecasting and Warning System in Appendix E of the Preliminary Options Report (HalcrowBarry, 2010). A FFWS option has been found as the preferred option for the Nanny River (Nanny Delvin AU), Broadmeadow River (Broadmeadow Ward AU), Mayne River (Mayne Sluice AU) and the Coastal AU. A flood forecasting and warning system is a very effective method of identifying weather events that may cause flood hazard and damage to property. In particular, it is a very useful tool for emergency planning. As discussed above the benefit of a flood forecasting and warning system can be greatly increased if it is linked to options at the study area scale. In addition, the implementation of a FFWS system could benefit options at APSR scale, for example the preferred option for

Malahide Town Centre incorporates the use of demountable defences which require flood warning to be effective.

It is noted that FCC currently uses weather forecast information to identify when a flood is likely.

14.1.3. Discussions on APSR options

The majority of the preferred options at APSR scale can be implemented independently of any other option and will not impact on options in other locations or at different spatial scales. However, there are two locations where implementation of the preferred option will not be implemented in the short term or where the option is dependent on another option being in place.

Duleek Area APSR – Raising defences to greater than 1% AEP

This option involves raising existing flood defence embankments and walls in Duleek to provide protection up to the 0.1% AEP event. While the standard of protection is the 1% AEP this study has identified a high level of residual risk in Duleek when looking at the 0.1% AEP. Based on this it is considered that there may be some economic benefit in giving increased protection to Duleek. The option for increasing protection to properties in Duleek shall not be considered for implementation in the short term but shall be monitored and reviewed in the next cycle of the CFRAM process in 2015. The responsibility for this shall be with the OPW.

Malahide Town Centre – Construction of demountable flood defences at underpass along with embankments to protect at risk properties in Malahide town centre

This option incorporates the use of demountable flood defences to prevent tidal flooding of a significant number of properties in Malahide Town Centre. While costs of incorporating a tidal flood forecasting system in the option have been considered (giving a BCR of 1.2) significantly greater benefit can be achieved if this option is linked with the Coastal AU tidal flood forecasting and warning option (BCR of 6.2).

Additional considerations

It should be noted that this is a strategic study and that further investigation of all the preferred options from this study from a technical, economic and environmental viewpoint would be required at detailed design stage. This is particularly important for options with BCR values close to or less than 1 to ensure that any options that are implemented are economically viable.

Components of the FEM FRMP

The discussions in Section 0 above lead to list of preferred options to be pursued, or components of the FEM FRMP, as indicated in Table 14-2. Figure 14-1 shows the locations of these preferred options.

Full details of the catchment flood risk management strategy can be found in the Fingal East Meath Flood Risk Management Plan.

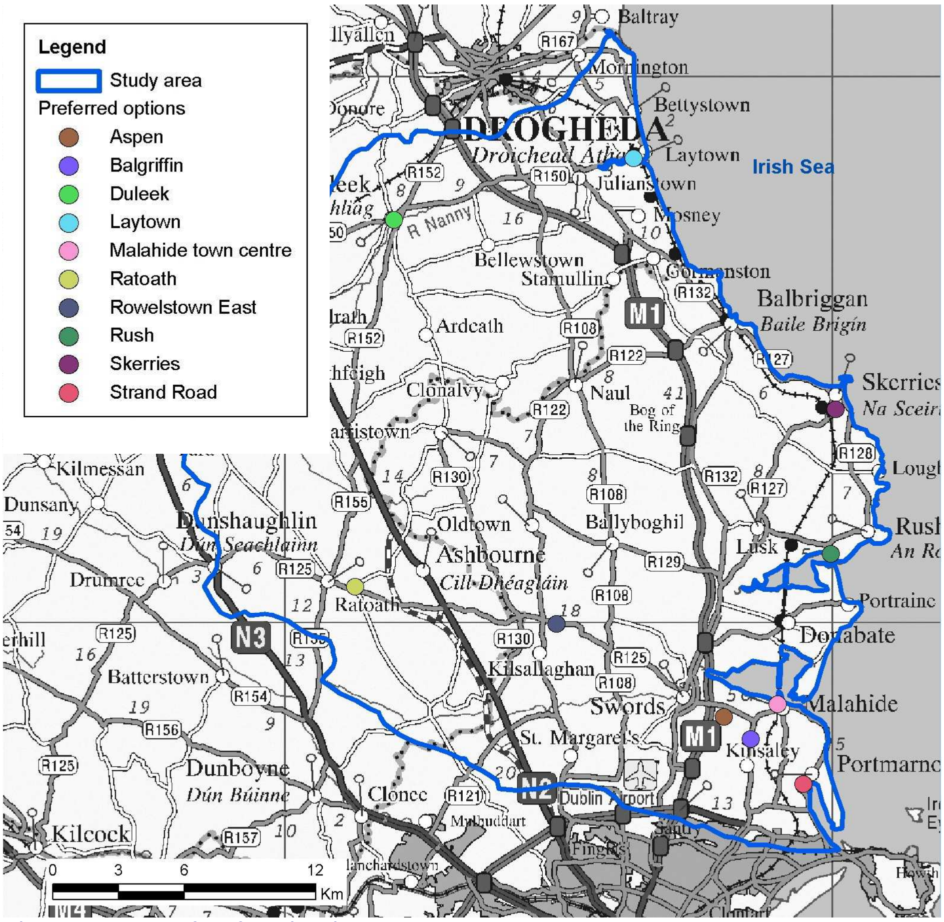


Figure 14-1 Map of preferred options

In addition to the preferred options in Table 14-2, the strategy will also consider:

- Planning and flood risk management;
- Requirement for additional monitoring of rainfall and flows in the study area;
- Better collection of flood event data;
- Potential for localised works under the OPW Minor Works Scheme;
- Influence of the OPW arterial drainage (channel maintenance) works on flood risk;
- Implementation, monitoring, review and evaluation of preferred options and other relevant actions, plans and policies.

Full details of the catchment flood risk management strategy can be found in the Fingal East Meath Flood Risk Management Plan (FRMP).

Table 14-2 Components of the FEM FRMP

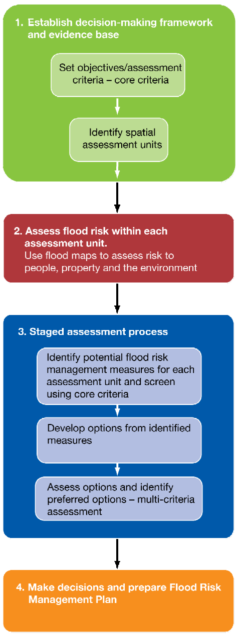
Assessment Unit	Option	MCA Score	BCR	Cost €million	Comments
Study Area as a whole	Proactive maintenance Targeted public awareness and preparedness campaign and individual property flood proofing	345 125	0.88 0.85 (2.96 with FFWS)	1.7 4.1	Both of these options ranked equally as they are completely independent and both be implemented.
Nanny and Delvin AU	Flood forecasting and warning system (Nanny River)	225	1.24 (4.94 with IPFP)	0.5	System to be compatible with the FCC/MCC telemetry system.
Duleek (Duleek APSR)	Raising existing defence embankment to a higher standard of protection (to protect up to 0.1% AEP)	375	1.07	2.8	Recommended option included in the Plan but for potential longer term implementation.
Boradmeadow & Ward AU	Flood forecasting and warning system (Broadmeadow River)	225	0.81 (3.22 with IPFR)	0.5	System to be compatible with the FCC/MCC telemetry system.
Ratoath (Ratoath APSR)	Improving channel conveyance by replacing a bridge on the Broadmeadow River at the R125 Ratoath Road and replacing a culvert on a tributary of the Broadmeadow River	385	0.9 (0.94 at 0.1% AEP)	1.1	Further work to determine if positive BCR can be achieved.
Rowlestown East (Rowlestown East APSR)	Construction of flood defence embankments along left bank of Broadmeadow River tributary upstream of R125	225	2.23	0.2	
Mayne & Sluice AU	Develop a fluvial FFWS for the Mayne River only	225	0.41 (1.64 with IPFP)	0.5	System to be compatible with the FCC/MCC telemetry system.
Balgriffin (St Margaret's, Dublin Airport, Belcamp & Balgriffin area APSR)	Improve channel conveyance by removing old bridge structure combined with construction of flood defence embankments & walls upstream of R123 and along left bank of Mayne River and tributary	340	1.27	0.8	
Coastal AU	Fluvial & tidal flood forecasting and warning system	225	2.08 (7.29 with IPFP)	1.8	System to be compatible with the FCC/MCC telemetry system.

Assessment Unit	Option	MCA Score	BCR	Cost €million	Comments
Strand Road, Portmarnock (Portmarnock & Malahide areas APSR)	Rehabilitating and raising existing coastal defences at Strand Road (including rehabilitation walls and flapped outfall) and construction of flood defence embankment	95	1.0	1.6	
Malahide town centre (Portmarnock & Malahide areas APSR)	Construction of demountable flood defences at underpass along with embankments to protect at risk properties in Malahide town centre	350	1.2 (6.2 with FFWS)	0.4	Traffic management required when demountable defences in place.
Aspen (Swords) (Swords area APSR)	Improve channel conveyance by widening and deepening of the Gaybrook Stream to reduce fluvial flood risk to properties at Aspen near Kinsaley	195	3.57	0.1	
Rush (Rush area APSR)	Construction of secondary culvert along Channel Road to protect properties at risk from fluvial flooding along the Rush West stream.	430	0.74 (0.88 at 0.1% AEP)	0.6	Further work to determine if positive BCR can be achieved.
Skerries (Skerries area APSR)	Improve channel conveyance by replacing culverts under roads and railway with larger capacity culverts and widening channel through park to reduce fluvial flood risk to properties at Millar Lane and Sherlock Park	505	1.25	1.5	Consultation with Irish Rail required during the detailed design phase of this measure.
Laytown (Laytown, Bettystown & coastal area APSR)	Construction of flood defence embankments to protect properties at risk along the coast and from the Nanny River	140	1.21	1.4	Detail design stage to look at access to the car park. Costing included provision for drainage works behind the new embankments.

15. Summary and recommendations

Summary

As discussed previously, a staged decision making process has been implemented to ensure that the assessment of flood risk management measures and options is evidence-based, transparent, and inclusive of stakeholder and public views. This process is shown in the flowchart on the right (with bigger version in Figure 2-4).



The Preliminary Options Report identified a list of potential measures that were carried forward to this draft Final Report. The activities reported on in this draft Final Report are the development of options from the identified measures; the assessment of these options; and the identification of the preferred options.

All of this information, including the results of the additional studies, investigations and the consultation process, will feed into the final deliverable the Flood Risk Management Plan (FRMP).

The assessment of flood risk in the study area indicates that the majority of the flood risk to properties is along the Fingal and Meath coastline and estuaries where areas are at risk from both fluvial and coastal flooding. The majority of the IRRs at risk are waste water treatment facilities (waste water treatment plants and pumping stations) and two National Roads.

The preferred options are as detailed in Table 15-1 and Table 15-2 on the following pages.

Table 15-1 Preferred options identified for the study area, AUs and APSRs

Spatial scale	Preferred Options
Study area	
Study area	Development (Meath) and enhancement (Fingal) of a **proactive maintenance regime** targeting potential culvert blockage locations.
	Targeted public **awareness and education** campaign and **individual property flood proofing**.
Analysis Unit (AU)	
Nanny & Delvin (N&D)	Develop a fluvial **FFWS** for the **Nanny River**
Broadmeadow & Ward (B&W)	Develop a fluvial **FFWS** for the **Broadmeadow River**
Mayne & Sluice (M&S)	Develop a fluvial **FFWS** for the **Mayne River**
Coastal (C)	Develop a combined fluvial and tidal **FFWS**
Area of Potential Significant Risk (APSR)	
Duleek area (N&D AU)	**Raising existing defence** embankment to a higher standard of protection (to protect up to 0.1% AEP). (For potential longer term implementation)
Ratoath area (B&W AU)	**Improving channel conveyance** by replacing a bridge on the Broadmeadow River at the R125 Ratoath Road, and replacing a culvert along a tributary of the Broadmeadow River with a larger capacity culvert
Rowelstown East area (B&W AU)	Construction of flood defence embankments along left bank of Broadmeadow River tributaries upstream of R125
St.Margaret's, Dublin Airport, Belcamp & Balgriffin areas (M&S AU)	**Balgriffin: Improving channel conveyance** by removing old bridge structure combined with construction of flood defence embankments and walls upstream of R123 and along left bank of Mayne River
Portmarnock & Malahide areas (C AU)	**Portmarnock: Rehabilitating and raising** existing coastal defences at **Strand Road** (including rehabilitation of flapped outfall) and construction of flood defence **embankment**.
	Malahide town centre: Construction of demountable flood defences at underpass along with embankments to protect at risk properties in Malahide town centre.
Laytown, Bettystown & Coastal area (C AU)	Construction of flood defence **embankments** to protect properties at risk along the coast and from the **Nanny River**.
Swords area (C AU)	Improve channel conveyance by **widening and deepening** of the Gaybrook Stream to reduce fluvial flood risk to properties at **Aspen near Kinsaley**.
Rush area (C AU)	Improve conveyance by constructing secondary **culvert** along **Channel Road** to protect properties at risk from fluvial flooding along the West Rush stream.
Skerries area (C AU)	Improve channel conveyance by **replacing culverts** under roads and railway with larger capacity culverts, and **widening** channel through park to reduce fluvial flood risk to properties at **Miller Lane and Sherlock Park**.

Table 15-2 Preferred options for IRRs

Risk receptor	Location	Likely FRM option
Utility asset at Stamullin	Stamullin area APSR	Construction of localised flood defence embankments or IPFP
WWTW at Ballyboghil	Ballyboghil area APSR	Construction of localised flood defence embankments
M1 at Staffordstown	Ballyboghil & Lusk AU	Construction of localised flood defence embankments
Wastewater pumping station in Ashbourne	Ashbourne area APSR	Construction of localised flood defence embankments
WWTWs at Toberburr	Owens Bridge area APSR	Construction of localised flood defence embankments
N32 at Clonshaugh	St Margaret's, Dublin Airport, Belcamp & Balgriffin areas APSR	Construction of localised flood defence embankments
WWTWs at Julianstown	Julianstown area APSR	Construction of localised flood defence embankments

Recommendations

The option assessment process has provided the components for the development of a long term sustainable strategy for managing flood risk in the Fingal East Meath study area. Data collection and analysis has been a key process at each stage of the FEM FRAMS leading to the development of options. Analysis of this data has established limitations and deficiencies in a number of datasets used throughout the study. A summary of specific actions relating to improving these datasets for the FEM FRAMS and nationally is detailed below. Further project specific recommendations are contained within the relevant project reports.

Hydro-meteorological data collection network

One of the main difficulties for the hydrological analysis for the study area has been the unavailability of recent hydrometric data in the river catchments. Only two out of the 12 hydrometric stations were in operation, whereas all other stations were closed during the period 1995-2001. The closed hydrometric stations therefore missed the opportunities of recording useful information on the recent significant flooding incidents in the study area, which would have provided valuable information for the calibration of the hydraulic models. Although the EPA has installed data loggers at two stations in November/December 2009, other gauges are still closed.

Therefore, in addition to continuing the currently operating four stations, namely, the one on the Nanny River (Station 08011), on the Broadmeadow River (Station 08008), on the Delvin River (Station 08002) and on the Garristown Stream (Station 08010), the hydrological study included the following priority list of gauging stations for reinstallation in the study area:

- Immediate re-installation of the gauge on the Ballyboghill River (Station 08012 – by FCC);

- Re-installation of another three gauges, namely, the Sluice (Station 08005 – by FCC), the Ward (Station 08009 – by FCC) and the Broadmeadow (Station 08007 – by MCC) rivers as a first priority;
- Re-installation of further four stations, namely, the Mayne (Station 08006 – by FCC), the Broadmeadow (Station 08003 – by FCC), the Ward (Station 08004 – by FCC) and the Mill Stream (Station 08014 – by FCC) as a second priority.

The EPA clarified on the 31st January 2011 that both the Sluice and the Mayne rivers are now considered to be in Hydrometric Area 09. The EPA further noted that the station numbers for the hydrometric stations in the Mayne and Sluice will be changed in the next release of the hydrometric register. Accordingly, the hydrometric station Kinsaley Hall on the Sluice River will change from 08105 to 09105 and the Hole In Wall (Mayne River) will change from 08106 to 09106.

In addition, consideration should be given to the needs of a flood forecasting system when deciding on the gauges to be installed.

Flood mapping

As there are no national standards or policy in Ireland to cover flood mapping in the tidal/fluvial transition area, a national policy is required to be implemented by the OPW on joint probability for catchments in Ireland.

Defence Asset Survey

- The earth embankment and concrete walls at Duleek along the left bank of the River Nanny and both banks of the Paramadden tributary should be surveyed and included in the Defence Asset Database.
- Information on coastal defences along the Fingal coastline within the FDAD was sourced from the DCFPP. This information was reviewed and, in some locations updated, then transferred into the FDAD. It is recommended that these defences are included in future survey work proposed for the next update of the FDAD.
- For future projects, it is recommended that a more thorough investigation of defences to be surveyed as part of the DAS should be undertaken at the start of the project. This investigation would identify flood defences which provide flood protection (i.e. the flood defence scheme in Duleek) and reduce the extent of natural river channels and banks which form a large proportion of the data in the FEM FRAMS FDAD.

Property database

The property database developed for the FEM FRAMS was based on the An Post GeoDirectory and OSi mapping. There are a number of improvements that could be made to increase the accuracy of this database for future studies:

- The GeoDirectory address point data lacked information relating to non residential building classifications. This required a manual check and update of the database to include these non residential buildings. It is recommended that this non residential building classification is passed onto An Post so that it is included in future versions of the database;

- The floor area of buildings was determined from building polygon data generated from OSi landline data from 2005 and 2007. Due the level of residential and commercial development in the study area, a large proportion of buildings could not be assigned actual floor areas as no building polygon data was available. It is recommended that for future studies, the latest landline data is obtained for the study area.

Option appraisal

A number of improvements could be made to the option appraisal process for future revisions of the study:

- The size and number of APSRs should be reviewed and the flood risk to areas identified as being APSRs should be significant (no flood risk was identified in a significant number of APSRs in the FEM FRAM study area). It should also be ensured that APSRs do not extend over large urban areas incorporating different urban centres (e.g. Portmarnock & Malahide APSR) and different areas of flood risk. In addition, the current scope of services and methodology for determining economic damage to properties and assessing the viability of options, it is not appropriate for FRAM studies to be developing measures/options for small clusters of properties (e.g. Rowlestown East APSR). The data used is not sufficiently detailed to look at flood risk at such a small scale. ;

- It is recommended that a review is undertaken of the usefulness of the indicator datasets for each objective and sub-objective for determining the baseline against which options are appraised;

- The valuations of residential and non-residential properties are required to determine the capping values for economically damaged buildings. Estimating current market values of non-residential properties was difficult and a number of methods for estimating the value of these properties were used. It is recommended that further work is undertaken to estimate more accurate capping values for non-residential properties;

- Costs for flood risk management measures were primarily based on UK project costs. The majority of Irish data is not in a format that can be readily used to determine the costs for flood risk management measures. It is recommended that a database of costs for Irish projects is developed in a format that is easily useable (i.e. similar to the EA unit cost database);

- The threshold level of all properties in the flood risk areas should be surveyed so that more accurate determination of the depth of flooding and hence the economic damage can be made. This is relevant to this study area due to the limited nature of flood risk and the relatively isolated clusters of properties at risk; and

Environmental considerations

- It is recommended that further work is undertaken to determine the precise location/likely location of various Annex I and II species of the Habitats Directive. This can be through direct surveys and investigations and through the collation of information from previous studies. This information should be included in a national database.

- Further work is required to amend and make more effective the current cultural vulnerability assessment methodology and this should be circulated to the local authority's heritage officer for comment.

- All projects and flood mitigation works completed, including construction operation and maintenance, future iterations or reviews of the study, including environmental reports, based on the recommendations from this study,

    - must comply with all current Environmental Legislation (e.g. Habitats Directive, SEA directive, Birds and Natural Habitats Regulations etc.) and undergo, where required, an Environmental Impact Assessment, an Environmental Impact Statement, and an Appropriate Assessment to ensure the protection of water quality, biodiversity, landscape character, natural and cultural heritage, infrastructure and habitats with mitigation measures set and monitored on a project basis.

    - be assessed for potential in combination effects, considering in particular the likely effects of multiple small scale works and additional/combined effects of other relevant plans, programmes or projects on the integrity of Natura 2000 sites. All Appropriate assessment, Natura Impact studies and proposed mitigation measures where required, should be completed in consultation with the National Parks and Wildlife service

    - will be reviewed on an individual basis and in combination with other plans and projects to ensure that the designated national and European conservation sites are protected with their integrity ensured during the implementation of the plan or works proposed.

    - must include objectives for the protection of NHA's, national parks, national reserves, wildfowl sanctuaries, refuges for flora and fauna, species protected under the wildlife act, wetlands providing flood protection as per the national biodiversity plan, and also that no invasive species are dispersed or spread through construction best practice and proper disposal of construction waste.

    - take account of the policies and objective set out in the appropriate County Development Plans, Green infrastructure Strategies, Landscape Character Plans, land use plans including cumulative environmental sensitivity/vulnerability maps, and Brú na Boinne World Heritage Plan, National Biodiversity Plans, or any other relevant environmental plans

    - will be managed and carried out in compliance with the national waste legislation where relevant and appropriate.

    - ensure full compliance, with the requirements of the Directive on the assessment of the effects of certain plans and programmes on the environment – The SEA Directive and the associated Planning and Development (Strategic Environmental Assessment) Regulations..

    - must consider the Malahide and Balbriggan/Skerries Shellfish Growing Areas Pollution Reduction Programmes, with the areas protected and taken into account for potential effects in any structural flood alleviation works considered.

- The 6 year review, or any other mid-term review, of the FRAM studies or any flood mitigation works, existing defence remediation works completed on the basis of the recommendations from the FRAM study
    - shall review the environmental requirements of the SEA or Habitats Directive for the Strategic Environmental Assessment and the Appropriate Assessment, assessing works completed or any new relevant information.
    - re-assess the data gaps and technical deficiencies for new information which could be used, with an assessment of the SEA ER and the Appropriate assessment of the effects of any new data sets that become available.
    - undergo an assessment of cumulative in-combination effects with other plans, projects and/or schemes, and shall put in place the necessary mitigation measures, if required, to be agreed with the necessary parties.
- For any structural works, environmental management plans should be established for each specific project, as required, arising out of the implementation of the plan, to take account of and assess the potential impacts on water quality, biodiversity, landscape character, natural and cultural heritage, infrastructure and habitat during construction, maintenance and operation of the proposed flood mitigation scheme.
- All land use plans, Local area plans, county development plans, landscape character plans, assessment of future land zoning, and planning applications for all developments must take account of the recommendations of and be informed by the FEMFRAM study and shall implement The Planning System and Flood risk Management Guidelines for Planning Authorities including the appendices as appropriate.
- All proposed flood mitigation works, revisions to the current study or measures associated with the Plan must comply with the requirements of the Water Framework Directive (WFD) including Article 4.7

The EU's Common Implementation Strategy for the Water Framework Directive (2000/60/EC)(WFD) – Guidance Document No. 20, in particular Section 3.5 Key Issues for Article 4.7, provides useful information.

- The associated Programme of Measures set out in the Eastern River Basin District River Basin Management Plan and the extent to which they are compatible with the objectives of the Floods Directive should be assessed for all future FRAM studies and any revisions to the current study.
- All existing and proposed critical Infrastructure such as water treatment and waste water treatment infrastructure should be protected in accordance with The Planning System and Flood risk Management Guidelines for Planning Authorities including the appendices

Implementation of the National CFRAM programme

- Details of the implementation of the National CFRAM programme and how it integrates with individual FRM Plans should be confirmed and made available to the public;

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- The database showing the location of utility assets (electricity, telecom, gas etc) was provided by the OPW. However, this database, on the request of the utility operator, did not include the details of the type of utility asset. This needs to be discussed further with the utility operators as the type of utility asset has significant benefits when considering emergency planning; and
- The number and type of flood maps required and the end use should be reviewed. There are over 1,300 A3 maps required for the FEM FRAMS project. In particular one issue that has arisen was in relation to the requirement for separate fluvial and tidal maps. This can be confusing and most users (Planners and the general public) will only look at one map which may not provide the details of the worse case scenario for a particular site. The separate maps are only useful for emergency planning for actual flood events.
- The eastern CFRAM study will undertake a review of the FEM FRAM Study, the Dodder Study and the Tolka Study and the available material for Unit of Management HA08, incorporating the findings, recommendations and proposed measures into the overall Eastern CFRAM Study Flood Risk Management Plan.
- Any recommendations in respect of flood mapping and modelling made by the Eastern CFRAM Study will be carried out during the first review of the FRAM study.
- Modelling and mapping from Eastern CFRAM Study should take precedence over the FEM-FRAM Study where there are overlaps

Monitoring, review and evaluation

This FEMFRAM study will be reviewed on a six-yearly cycle, by the OPW and the relevant Local Authorities, as part of the Eastern River Basin District CFRAM Study. For the review to be effective, systems will be set up to provide data with which to assess performance in relation to the original Plan content and the information on which it is based.

Review and monitoring will be an on-going exercise and lessons learnt will be taken account of in the national CFRAMS/FRMP programme. Lessons learnt will be acted on once they are confirmed and not held back until a six-yearly review.

Maintenance

Proactive maintenance forms an integral part of any flood mitigation/prevention programme. The ownership of this option needs to be agreed at national level between the Local Authorities and the OPW

FEMFRAM Study Documents

- Final Report
- Flood risk Management Plan
- AA Screening Report
- Environmental Scoping Report
- SEA Environmental Report
- Hydraulics Report
- Hydrology Report
- Inception Report
- Preliminary Options Report

Technical Notes were prepared on the following aspects of the study

- Sluice River Technical Note
- Review of EPA rating at GSs 08002, 08003, 08005, 08007, 08009, 08010 & 08012 and OPW rating at GSs 08008 & 08011
- Joint Probability Analysis
- Flood Forecasting Options
- Groundwater flood hazard technical note
- Pluvial flood risk assessment technical note
- Fluvial Geomorphology Broad Scale Assessment
- Strategic Sustainable Urban Drainage Systems (SUDS) _V5
- Balbriggan Urban River Modelling
- Balleally River Modelling
- Bracken River Modelling
- Broadmeadow River water levels
- Hydrometric data of Stns 08004, 08006 & 08014
- Defence failures
- Blockage scenario
- Fluvial Geomorphology Broad Scale Assessment
- Cuckoo Stream Technical Note
- Cuckoo Stream Attenuation Technical Note
- Rush Stream Technical Note
- River Mayne
- Gaybrook River Modelling
- Rush's Bride's and Jone's streams River Modelling
- Joint Probability Analysis
- Generation of Tidal Boundaries
- Annual maximum flows at Hydrometric Stations on the Delvin River Stn 08002-Naul and Ward River: Stn 08009-Belheary
- Hydrology GIS work – FSSR boundaries Method Example

Interim Works Since draft Flood Risk Management Plan

Ballyboghil & Turvey Rivers

The FEMFRAM study mapped the Turvey River as receiving flows from the Ballyboghil River in extreme events, cross catchment flows. The presence of embankments constructed during the M1 motorway contract was not included in the hydraulic model due to the topographical survey boundary for each river not overlapping. There is also a slight location error associated with the river centreline used.

A review of the flood maps for both rivers is required, that includes the embankments, to produce maps that show the correct flood extents including cross catchment flows, if any.

Gaybrook Stream (in the vicinity of Aspen near Kinsaley)

The works recommended in the FEMFRAM study are now complete.

Since the completion of the options report a single culvert on the gaybrook stream, located to the east of Aspen Drive, was replaced with twin 1050mm culverts. FEMFRAMs modelled the culvert as a single culvert. The mapping for this stream should now be reviewed based on the presence of the twin 1050mm culverts and completed channel widening.

Rolestown East (Broadmeadow river Tributary)

The options report recommendation was reviewed, due to difficulties constructing the preliminary proposals, with an alternative flood mitigation solution designed and now constructed. The flood mapping for the area should be reviewed based on the completed works.

The Sluice River

The Grange area of Malahide has been subject to a number of flood events, most recently in August 2008 and October 2011. Flood mitigation works required to alleviate the risk of flooding to the area were constructed in 2013.

The Grange in Malahide forms part of the Sluice catchment, which was modelled as part of the FEMFRAM study and showed significant areas of flooding for the various AEP's. The Grange area did not form part of the FEMFRAM study.

As well as providing flood alleviation to the Grange in Malahide the completed works have the potential to reduce the flood extents to the Sluice River. The flood mapping for the Sluice River should be reviewed based on the completed works.

Climate Change

The future scenario sea level rise should be reviewed in line with current best practice at the time of the review

Glossary of terms

Analysis Unit (AU) These cover large spatial scale and are large sub-catchments or areas of tidal influence.

Annual Exceedence Probability (AEP) Historically, the likelihood of a flood event was described in terms of its return period. For example, a 1 in 100 year event could be expected to be equalled or exceeded on average once every 100 years. However, there is a tendency for this definition to be misunderstood. There is an expectation that if such an event occurs, it will not be repeated for another 100 years. However, this is not the case; to try to avoid the misunderstanding, flood events are expressed in terms of the chance of them occurring in any year. This can be stated in two ways, namely a percentage or a probability. Taking the above example, we would say that this event has a one per cent, or 1 in 100, chance of being equalled or exceeded in any year.

Area of Potential Significant Risk These are existing urban areas with quantifiable flood risk.

Assessment Unit Define the spatial scale at which flood risk management options are assessed. Assessment Units are defined on four spatial scales ranging in size from largest to smallest as follows: catchment scale, Analysis Unit (AU) scale, Areas of Potential Significant Risk (APSR) and Individual Risk Receptors (IRR).

Average Annual Damages (AAD) Depending on its size (or severity), each flood will cause a different amount of flood damage. The average annual damage is the average damage in euros per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events).

Benefit Cost Ratio (BCR) A benefit cost ratio is the ratio of the benefits of a flood risk management option, expressed in monetary terms, relative to its costs.

Benefits Those positive quantifiable and unquantifiable changes that a plan will produce, including damages avoided.

Catchment A surface water catchment is the total area of land that drains into a watercourse.

Catchment Flood Risk Management Plan (CFRMP) is a large-scale strategic planning framework for the integrated management of flood risks to people and the developed and natural environment in a sustainable manner.

Digital Terrain Model (DTM) A DTM represents the topography (elevation) of the ground.

Estuary A semi-enclosed coastal body of water with one or more rivers or streams flowing into it, and with an open connection to the sea

Flood An unusual accumulation of water above the ground caused by high tide, heavy rain, melting snow or rapid runoff from paved areas. In this study a flood is marked on the maps where the model shows a difference between ground level and the modelled water level. There is no depth criterion, so even if the water depth is shown as 1mm, it is designated as flooding.

Flood defence A structure (or system of structures) for the alleviation of flooding from rivers or the sea.

Flood depth maps Illustrate the estimated flood depths for areas inundated by a particular flood event. This provides useful information on potentially dangerous areas of deep flood waters during a flood event.

Flood extent maps Show the estimated area inundated by a flood event of a given AEP event. The flood extents have no depth criterion, so even if the water depth is shown as 1mm, it is designated as flooding.

Flood hazard Refers to the frequency and extent of flooding to a geographic area.

Flood hazard maps Show the harm or danger which may be experienced by people from a flood event of a given annual exceedance probability, calculated as a function of depth and velocity of flood waters.

Flood risk Refers to the potential adverse consequences resulting from a flood hazard. The level of flood risk is the product of the frequency or likelihood of flood events and their consequences (such as loss, damage, harm, distress and disruption).

Flood Risk Management (FRM) The activity of understanding the probability and consequences of flooding, and seeking to modify these factors to reduce flood risk to people, property and the environment. This should take account of other water level management and environmental requirements, and opportunities and constraints. It is not just the application of physical flood defence measures.

Flood Risk Management Measure Structural and non-structural interventions that modify flooding and flood risk either through changing the frequency of flooding, or by changing the extent and consequences of flooding, or by reducing the vulnerability of those exposed to flood risks.

Flood Risk Management Objectives These provide a basis by which the flood risk management options are assessed. Each objective and sub-objective has an indicator, minimum target and aspirational target. Options are scored on how well they perform in meeting the minimum and aspirational targets.

Flood Risk Management Option Can be either a single flood risk management measure in isolation or a combination of more than one measure to manage flood risk.

Flood velocity maps Show the speed of the flood water for a particular flood event using graduated colours. The maps provide information on fast flowing flood waters which are potentially dangerous.

Flood Warning To alert people of the danger to life and property within a community.

Floodplain Any area of land over which water flows or is stored during a flood event or would flow but for the presence of flood defences.

Fluvial Pertaining to a watercourse (river, stream or lake).

Geographical Information System (GIS) A GIS is a computer-based system for capturing, storing, checking, integrating, manipulating, analysing and displaying data that are spatially referenced.

Geomorphology The science concerned with understanding the form of the Earth's land surface and the processes by which it is shaped, both at the present day as well as in the past.

Groundwater Water occurring below ground in natural formations (typically rocks, gravels and sands). The subsurface water in the zone of saturation, including water below the water table and water occupying cavities, pores and openings in underlying soils and rocks.

Habitats Directive European Community Directive (92/43/EEC) on the Conservation of Natural Habitats and of Wild Flora and Fauna and the transposing Irish regulations (The European Union (Natural Habitats) Regulations, SI 94/1997 as amended).. It establishes a system to protect certain fauna, flora and habitats deemed to be of European conservation importance.

High End Future Scenario (HEFS) Represents extreme changes in drivers of flooding, such as climate change and land use change, by 2100.

Hydraulic Computer Model Software tool to solve advanced mathematical equations, based on a variety of parameters, to provide an estimate on water levels, flows and velocities in a watercourse.

Hydrograph A graph showing changes in the discharge (flow) of a river over a period of time

Impermeable Used to describe materials, natural or synthetic, which have the ability to resist the passage of fluid through them.

Individual Risk Receptors (IRR) Essential infrastructure assets such as a motorway or potentially significant environmentally polluting sites.

Inundation To cover with water - especially flood waters.

ISIS 1D/2D hydraulic computer modelling software developed by Halcrow Group Ltd

Land Management Various activities relating o the practice of agriculture, forestry, etc.

Land Use Various designations of activities, developments, cropping types, etc, for which land is used.

LiDAR Light Detection and Ranging (LiDAR) is an airborne topographical mapping technique that uses a laser to gather information on the shape and height of the ground.

Mid Range Future Scenario (MRFS) This is a future flood risk management scenario and considers the more likely estimates of changes to the drivers that can influence future flood risk in the Lee catchment by 2100.

Modelling and Decision Support Framework (MDSF) MDSF is a GIS-based decision support tool developed to assist the CFRMP process through automation of parts of the analysis.

Natura 2000 European network of protected sites which represent areas of the highest value for natural habitats and species of plants and animals which are rare, endangered or vulnerable in the European Community. The Natura 2000 network will include two types of area. Areas may be designated as Special Areas of Conservation (SAC) where they support rare, endangered or vulnerable natural habitats and species of plants or animals (other than birds). Where areas support significant numbers of wild birds and their habitats, they may become Special Protection Areas (SPA). SACs are designated under the Habitats Directive and SPAs are classified under the Birds Directive. Some very important areas may become both SAC and SPA.

Natural Heritage Area An area of national nature conservation importance, designated under the Wildlife Act 1976 (as amended), for the protection of features of high biological or earth heritage value or for its diversity of natural attributes.

Non structural options include flood forecasting and development control to reduce the vulnerability of those currently exposed to flood risks and limit the potential for future flood risks.

Permeable Able to be penetrated by water.

Programme of Measures A list or timetable of intended actions.

Protected Structure A structure that a planning authority considers to be of special interest from an architectural, historical, archaeological, artistic, cultural, scientific, social, or technical point of view

Ramsar site Wetland site of international importance designated under the Ramsar Convention on Wetlands of International Importance 1971, primarily because of its importance for waterfowl.

Return Period The average interval in years between events of similar or greater magnitude (e.g. a flow with a return period of 1 in 100 years will be equalled or exceeded on average once in every 100 years). However, this does not imply regular occurrence, more correctly the 100 year flood should be expressed as the event that has a 1 per cent probability of being met or exceeded in any one year, expressed as the annual exceedance probability.

Riparian Relating to the strip of land on either side of a watercourse.

Riverine Pertaining to a watercourse (river or stream) and its floodplain.

Run-off That part of rainfall which finds its way into streams, rivers etc and flows eventually to the sea, as surface flow or sub-surface flow.

Rural Area Watercourses (RAW) are in areas where the flood risk was, at the outset of the Study, considered to be moderate.

Scenario A possible future situation, which can influence either catchment flood processes or flood responses, and therefore how successful flood risk management policies/measures can be. Scenarios are usually made up of a combination of the following: urban development (both in the catchment and river corridor); change in land use and land management practice (including future environmental designations); or climate change.

Special Area for Conservation (SAC), Candidate Special Area for Conservation (cSAC) A SAC are internationally important site, protected for its habitats and non-bird species. It is designated, as required, under the EC Habitats Directive. A cSAC is a candidate site, but is afforded the same status as if it were confirmed.

Special Protection Area (SPA) A SPA is a site of international importance for breeding, feeding and roosting habitat for bird species. It is designated, as required, under the EC Birds Directive.

Steering Group The Steering Group oversees the production of the FEM FRMP and is expected to comprise key staff from FCC, MCC and the OPW together with key staff from other major stakeholders, where appropriate.

Storm surge Caused by low pressure systems which force the ocean surface to rise higher than the normal sea level.

Structural options involve the application of physical flood defence measures, such as flood walls and embankments, which modify flooding and flood risk either through changing the frequency of flooding, or by changing the extent and consequences of flooding.

Surface Water Water in rivers, estuaries, ponds and lakes.

Sustainability A concept that deals with mankind's impact, through development, on the environment. Sustainable development has been defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987). Sustainability in the flood risk management context could be defined as the degree to which flood risk management options avoid tying future generations into inflexible or expensive options for flood defence. This usually includes consideration of other defences and likely developments as well as processes within a catchment.

The Office of Public Works (OPW) The lead agency with responsibility for flood risk management in Ireland

Tidal Related to the sea and its tide

Topography Physical features of a geographical area.

Water courses Water features include rivers, lakes, ponds, canals, harbours and coastal waters.

Water Framework Directive (WFD) EU Water Framework Directive 2000/60/EC sets out a system for the integrated and sustainable management of catchments so that the ecological quality of waters is maintained in at least a good state or is restored. The Directive lays down a six-yearly cycle of catchment planning.

References

An Post GeoDirectory 2008

Bruen, M. Climate change: Flooding impacts desk-study/Summary of projections. 2003.

Bruen, M. Gebre, F. An investigation of the Flood Studies Report ungauged catchment method for Mid-Eastern Ireland and Dublin. 2005.

Cawley, A M., Cunnane, C. Comment on Estimation of Greenfield Runoff Rates. 2003.

Centre of Ecology and Hydrology. Flood Estimation Handbook Vol 1-5**.** 1999.

Chen, Y., Numerical Modelling of Solute Transport Processes Using Higher Order Accurate Finite Difference Schemes, Ph.D. Thesis, University of Bradford. 1992.

Chow, V T, Maidment, D R, Mays, L W. Applied Hydrology. 1988.

Chow, V.T., Open Channel Hydraulics, McGraw-Hill. 1959.

CIRIA. The Beach Management Manual, CIRIA R153. 1996.

CMRC. Developing monitoring protocols for spatial policy indicators. LOSPAN Phase 2 report. 2001

Corine 2006. Ireland Land Cover Update**.** 2006.

Cunnane, C. Lynn, M A. Flood Estimation Following the Flood Studies Report**.** The Institution of Engineers Ireland. 1975.

Defra (UK) R & D Technical Report. Flood Risks to People Phase 2 (FD2321). 2005.

Defra (UK) R & D Technical Report. Joint Probability – Dependence Mapping and Best Practice (FD2308**)**. 2006.

DEHLG and OPW, 2009. The Planning System and Flood Risk Management; Guidelines for Planning Authorities (including Technical Appendices), 2009.

DEHLG. Implementation of SEA Directive 2001/42/EC; Assessment of the Effects on Certain Plans and Programmes on the Environment Guidelines for Planning Authorities, The Stationary Office, Dublin. 2004.

Department of Agriculture, Food and Forestry. Growing for the Future - A Strategic Plan for the Development of the Forestry Sector in Ireland**.** 1996.

Department of Arts, Heritage, Gaeltacht and the Islands The National Biodiversity Plan. 2002

Department of Environment, Food and Rural Affairs (UK). FCDPAG1 Flood and Coastal Defence Project Appraisal Guidance: overview. 2001.

Department of Environment, Food and Rural Affairs (UK). FCDPAG3 Flood and Coastal Defence Project Appraisal Guidance: economic appraisal. 2001.

Department of Environment, Food and Rural Affairs (UK). FCDPAG4 Flood and Coastal Defence Project Appraisal Guidance: approaches to risk. 2001.

Department of Environment, Food and Rural Affairs (UK). Flood and Coastal Defence Appraisal Guide FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts. 2006.

Dublin City Council. Greater Dublin Strategic Drainage Study (GDSDS), Regional Drainage Policies – Technical Document. 2005

Environment Agency (UK). Catchment Flood Management Plan Guidance – Future Scenario. 2006.

Environment Agency (UK). Catchment Flood Management Plan Processes and Procedures Guidance. Volume 2.

Environment Agency (UK). Extension of Rating Curves at Gauging Stations; Best Practice Guidance Manual. 2003.

Environment Agency (UK). National Sea & River Defence Surveys Condition Assessment Manual.2004

Environment Agency (UK). SEA Guidance, Strategic Environmental Assessment (SEA) internal plans and strategies: Operational instruction 246-04, 2009

EPA. Consultation Draft of the GISEA Manual. 2009

EPA. Development of Strategic Environmental Assessment (SEA) Methodologies for Plans and Programmes in Ireland. Synthesis Report and associated Final Report. 2003

EPA. Strategic Environmental Assessment – SEA Pack. 2008

European Commission. Action Plan: Halting the loss of biodiversity by 2010 and beyond. 2006

European Commission. Implementation of Directive 2001/42 on the Assessment of the Effects of Certain Plans and Programmes on the Environment, European Commission. 2003

Fletcher, C.A., Computational Techniques for Fluid Dynamics.. Vol. II, Specific Techniques for Different Flow Categories, 2nd ed., Springer-Verlag, Berlin, 1991.

Flood Hazard Research Centre. The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques Multi Coloured Manual. 2005

Foresight. Future Flooding. Office of Science and Technology. 2004.

Forest Service. Code of Best Forest Practice – Ireland. Department of the Marine and Natural Resources. 2000

Goodbody Economic Consultants A Review of Cost Benefit Procedures for Flood Relief Schemes. 2001

Government of Ireland. Ireland: National Development Plan 2007-2013: transforming Ireland: a better quality of life for all. Stationery Office, Dublin. 2007

Halcrow Barry. Fingal East Meath Flood Risk Assessment and Management Studies - Tender Documents – Channel Structure and Defence Assets Geometry Survey. 2008.

Halcrow Barry. Fingal East Meath Flood Risk Assessment and Management Study, Inception Report. 2008

Halcrow Barry. Fingal East Meath Flood Risk Assessment and Management Study, Preliminary Hydrology Report, 2009

Halcrow Barry. Fingal East Meath Flood Risk Assessment and Management Study, Hydrology Report, 2010

Halcrow Barry. Fingal East Meath Flood Assessment and Management Study, Environmental Scoping Report. 2009

Halcrow Barry. Fingal East Meath Flood Risk Assessment and Management Study, Hydraulics Report, 2011

Hosking, J. R. M. Wallis, J.R. Regional Frequency Analysis. An Approach Based on L-Moments**.** 1997.

Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R. and Hill, S Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp. 2002

Hydro-Logic Ltd. Review of Flood Flow Ratings for Flood Studies Update. OPW. 2006

IPCC. Climate Change 2007: The Physical Science Basis - Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 2007.

Irish Climate Analysis and Research Units (ICARUS). Implications of the EU Climate Protection Target for Ireland**.** Environmental Protection Agency. 2007.

Irish Committee on Climate Change. Ireland and the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Royal Irish Academy. 2007.

Irish Committee on Climate Change. 3rd Scientific Statement. Climate and Sea Level Change.

Irish Government. National Development Plan 2007 – 2013. 2007.

Irish Government. National Spatial Strategy. 2001.

Joint Defra/EA Flood & Coastal Erosion Risk Management R&D Programme (UK). Review of impacts of rural land use and management on flood generation. Impact study report**.** R&D Technical Report FD2114/TR. 2005.

Kirby, A M and Ash, J R V Fluvial Freeboard Guidance Note, R&D Technical Report W187, Environment Agency. 2000

Link, P.M. and Tol, R.S.J. Possible economic impacts of a shutdown of the thermohaline circulation: an application of FUND. Portuguese Economic Journal 3: 99–114. 2004.

McGrath, R. Nishimura, E. Nolan, P. Semmler, T. Sweeney, C. and Wang, S. Climate Change: Regional Climate Model Predictions for Ireland**.** Environmental Protection Agency. 2005.

McGrath, R. Nishimura, E. Nolan, P. Venkata, R. Semmler, T. Sweeney, C. and Wang, S. Community Change Consortium for Ireland. Annual Report 2004**.** 2004.

Mills, P. P. Generation of a Hydrologically Corrected Digital Elevation Model for the Republic of Ireland. 2002.

Murphy et al. Irish National Hydrology Seminar 2006. Water Resources in Ireland & Climate Change**.** 2006.

NERC (National Environment Research Council). Flood Studies Report. 1975.

Office of Public Works. Report of the Flood Policy Review Group**.** 2004.

Office of Public Works. Design considerations of possible climate change for flood risk management practice. 2006.

RPS Consulting Engineers. Irish Coastal Protection Strategy Study -Phase III Work Packages 2, 3 & 4A Extreme Flood Outline Floodplain Mapping & Erosion Risk Assessment Dalkey Island to Omeath.O Department of Agriculture, Fisheries and Food. 2008

Office of the Deputy Prime Minister (UK). A Practical Guide to the SEA Directive. 2005

Peter Bacon and Associates. A review and appraisal of Ireland's forestry development strategy**.** 2004.

Rahmstorf, H. A Semi-Empirical Approach to Projecting Future Sea-Level Rise**.** Science 315:368-370. 2007.

Scott, P & Marsden, P Development of Strategic Environmental Assessment (SEA) Methodologies for Plans and Programmes in Ireland (2001-DS-EEP-2/5). Synthesis Report. Report prepared for the Environmental Protection Agency by ERM Environmental Resources Management Limited. 2003.

Shennan, I. and Horton, B. Holocene land- and sea-level changes in Great Britain**.** Journal of Quaternary Science 17: 511-526. 2002.

CDM. River Basin District Management Plan for Eastern River Basin District (ERBD). 2008

Spon's Civil Engineering and Highway Works Price Book. 2006

Sweeney, J. Fealy, R. Downscaling global climate models for Ireland: providing future climate scenarios. ICARUS. 2006.

Sweeney, J. Brereton, T. Byrne, C. Charlton, R. Emblow, C. Fealy, R. Holden, N. Jones, M. Donnelly, A. Moore, S. Purser, P. Byrne, K. Farrell, E. Mayes, E. Minchin, D. Wilson, J. and Wilson, J. Climate Change Scenarios and Impacts for Ireland. ERTDI Report Series No. 15. Environmental Protection Agency. 2003.

www.erbd.ie

www.floodmaps.ie

www.oecd.org/std/ppp

www.privateseller.ie/estivalue

Appendix A. – Data Register

Appendix B. Stage 1 Summary Results

B1 Ballyboghill and Lusk

B2 Broadmeadow and Ward

B3 Coastal

B4 Mayne and Sluice

B5 Nanny and Delvin

Appendix C. Stage 2 Summary Results

Appendix D. Stage 3 Guidance

D1 Local Weightings Guidance

D2 Stage 3 Scoring Guidance

Appendix E. Stage 3 Summary Results

E1 Broadmeadow and Ward

E2 Coastal

E3 Mayne and Sluice

E4 Nanny and Delvin

Appendix F. BCR Summary

Appendix G. IRR Assessment Results

Appendix H. Information for non APSRs

Appendix I. FEM Objectives, sub-objectives and targets

Appendix J. Cost database

Appendix K. List of Stakeholders

Appendix L. List of culverts for proactive maintenance by the Local Authority

Appendix M. Executive Summary of the Hydrology Report