ARUP

Cork County Council

Midleton Flood Relief Scheme

Options Report

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Issue 1 | 31 May 2024



This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 252803-00

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Executive Summary

Arup has been commissioned by Cork County Council (CCC) to develop a Flood Relief Scheme (FRS) for Midleton. The overall scheme will consist of flood alleviation measures that defend against fluvial, tidal, pluvial and groundwater flooding sources of flooding. The required Standard of Protection (SoP) of the Scheme is the 1% AEP fluvial flood event and the 0.5% AEP tidal / coastal flood event.

The first stage of the project, the *Development of a number of flood defence options and the identification of a preferred Scheme* (Stage I) is now complete. This stage included hydrological analysis, hydraulic modelling and analysis, and preparation of flood risk mapping. The existing flood risk and flood mechanisms are described in detail in the accompanying Hydrology Report and Hydraulics Report.

Based on the hydraulic analysis carried out as part of this study, the areas listed in the following table were identified as being the critical locations at risk.

Table 1 Areas at Risk

Area No	Area Name	Categories of Properties at Risk in this Area	Potential Flood Mechanisms
1	Tir Cluain to Willowbank	Domestic properties	Fluvial
2	Northern Relief Road to Riverside Way	Domestic and Commercial properties	Fluvial
3	Town Centre and Bailick Road	Domestic and Commercial properties	Fluvial/Tidal
4	Lauriston Estate/ Rugby Club/ East of IDL	Domestic and Commercial properties	Fluvial/ Groundwater
5	Ballinacurra	Domestic and Commercial properties,	Fluvial
6	Water Rock including Dwyer's Road	Domestic and Industrial properties, wastewater treatment infrastructure	Fluvial/ Tidal/ Groundwater

Significant consultation with all interested parties including the public was undertaken throughout Stage I in order to give interested parties an opportunity to communicate local knowledge, how they may be impacted by existing flood risk and also to obtain feedback on the proposals from all relevant affected stakeholders and landowners who might be impacted by the Scheme. Feedback throughout the project to date has been very carefully considered by the project team and, where appropriate, has influenced decisions on the final emerging preferred scheme.

The options development commenced with an initial screening assessment of flood risk management measures. Some measures were not deemed as viable and as a result were screened out. Other measures were considered as potentially viable and these were carried forward for further assessment. This is discussed in Section 3.

Following the initial screening of the potentially viable measures, seven measures were assessed in greater depth to ensure suitability within the scheme areas. The potentially viable measures considered are discussed in Section 4.

The potentially viable measures, which were progressed through the screening stages and met the project objectives, were then combined to develop reasonable alternatives/ flood relief options. The reasonable alternatives developed for each area are described in Section 5.

An environmental assessment of the reasonable alternatives was undertaken and considered the key environmental constraints that were identified for each area and the potential environmental effects of the proposed interventions. This is described in Section 6.

Section 8 describes the detailed multi-criteria analysis (MCA) of the reasonable alternatives which was carried out to evaluate the performance of each option in terms of predefined technical, environmental, social and economic objectives. Multi-criteria analysis is a decision-making support tool, developed for complex multi-criteria problems that include quantitative and/or qualitative aspects of the problem in the decision-making process.

An economic assessment for the reasonable alternatives was undertaken and is outlined in Section 7. This included the estimation of the project costs of the flood relief options/reasonable alternatives. An economic damages assessment was also completed to estimate the reduction in risk of flooding to property derived from the flood protection works. This risk is quantified as the expected damage to property that would occur over the lifetime of the scheme which has been assumed as 50 years. A cost benefit ratio for each flood relief option combination was then prepared.

Following the multi-criteria assessment (MCA) and the cost-benefit assessment (CBA), the emerging preferred option was selected. The merits of the alternative options are summarised in Section 9 on the basis of cost, MCA score, environmental and ecological impact, climate change adaptability and consideration of the feedback which arose during the public and stakeholder consultation process.

It was concluded during the selection process for the emerging preferred option that flood relief measures upstream of the Cave system in Water Rock are not viable. This is due to the high costs/low benefit associated with the options as well the technical complexity of delivering any of these options. It is not therefore proposed to progress with the flood relief culvert/channel options to mitigate flood risk in the area upstream of the cave system. It is instead proposed to carry out further investigations into potential flood risk management measures that may provide flood mitigation, albeit not to the target standard of protection of the scheme.

The emerging preferred option in each area is as per table below.

Area	Option
Area 1&2: Tír Cluain to Riverside Way	Option 1&2B – Direct Defences Only
Area 3 (North): Town Centre and Bailick Road to Choctaw Park	Option 3A – Direct Defences Only
Area 3 (South): Bailick Road	Option 3A – Direct Defences Only
Area 4: Lauriston Estate/Rugby Club/East of IDL	Option 4E: Groundwater cut-offs and direct defences east of the current IDL site and along Greenway
Area 5: Ballinacurra	Option 5B-1: Upstream storage – Refined storage area (smaller footprint than Option 5B) and over pumping

Midleton was severely flooded by Storm Babet on the 18th of October 2023. Following on from the event Arup was asked by Cork County Council (CCC) to reconsider the hydrological estimation undertaken to inform the emerging preferred option given that the flow rate experienced at the Ballyedmond hydrometric gauge during Babet was the highest flow event ever recorded at the gauge and therefore impacts on its rating curve.

A revised hydrological assessment of the study area was undertaken which resulted in increased design flows and therefore increased water levels. These higher design water levels in turn required changes to be made to a number of the flood defences in the fluvially dominated area with the changes varying between the individual defences. On average however the increase in defence height required to accommodate the post Storm Babet design flows and water levels is circa 100mm and the average increase in length of the defences is circa 10m. These changes to the direct defences are deemed to be modest and can be accommodated as part of the current scheme without any significant impact on the environmental and/or landscape heritage constraints.

Due to the changes in the defence's heights and lengths arising from the Post Babet revisions to the hydrology, the Emerging Preferred Option as originally outlined in this Options Report needed to be refined.

An Options Report Addendum[a] (August 2026) has therefore been drafted to detail the updates to the scheme which are required to ensure the Standard of Protection of the scheme (1% AEP Fluvial / 0.5% AEP tidal plus an allowance for freeboard) is maintained across the whole of the scheme area when the updated hydrology and design water level assessment is considered. **Section 11 to 14 of this report has been superseded by the Options Report Addendum.**

The scope of the Options Report Addendum report is provided as:

- The Detailed Freeboard Analysis presented in Section 11 of the original options report has been updated using the revised post-Babet design water levels. The updated freeboard analysis is presented in Section 1 of the Options Report Addendum;
- The proposed climate change allowance presented in Section 12 of the original options report has been reassessed in light of the revised design water levels and is presented in Section 2 of the Options Report Addendum;
- The modifications to the Midleton Flood Relief Scheme emerging preferred option arising from the change to the hydrology and design water levels are detailed in Section 3 of the Options Report Addendum. It is noted that these changes incorporate the both the updated design water levels and the updated freeboard as well as the revised climate change allowance. It is noted that the final defence heights and alignments will be developed and finalised through the planning design development and will be informed by the final topographic survey. the ground investigation surveys and stakeholder/landowner engagement. The revised defences presented in Section 4 of the Options Report Addendum are therefore subject to modest changes;
- A detailed description of the proposed scheme is presented in Section 5 of the Options Report Addendum

[a] https://www.floodinfo.ie/frs/media/filer_public/3d/ce/3dce8a29-b58b-4e10-830d-e59996d1585a/252803-arup-zz-xx-rp-z-000051_options_report_addendum_issue1.pdf

1. Introduction

1.1 Context

Arup has been commissioned by Cork County Council (CCC) to develop a Flood Relief Scheme (FRS) for Midleton. The overall scheme will consist of flood alleviation measures that defend against fluvial, tidal, pluvial and groundwater flooding sources of flooding.

There are five stages to the project:

- Stage I – Development of a number of flood defence options and the identification of a preferred Scheme
- Stage II – Statutory Planning Process incl. EIAR
- Stage III – Detailed Design and Tender Process
- Stage IV – Construction
- Stage V – Handover of works

This Options Report is produced as part of Stage I of the project and details the development and assessment of potential options and the selection of a preferred scheme for Midleton. It follows on from work carried out to date and should be read in conjunction with the following reports:

- The Constraints Study [1]
- The Hydrology Report [2]
- The Hydraulics Report [3]

1.2 Scheme Objectives

As defined in the Project Brief, the overarching objective of the scheme is to:

"Design a viable, cost-effective and sustainable Scheme to the Target Standard of Protection to reduce or prevent damages and risks associated with flooding from watercourses (rivers and streams), from groundwater, from pluvial / storm water and from the sea (Owenacurra Estuary / Midleton Harbour) in the Study Area." [4]

The scheme is to be developed primarily to protect the affected areas against fluvial and tidal flooding. In addition, consideration will be given to the potential impact of the flood relief scheme on groundwater and pluvial flood risk.

1.3 Standard of Protection

The required Standard of Protection (SoP) of the Scheme as stated in the Project Brief is to "*prevent flooding during flood events with a 1% (for fluvial floods) and 0.5% (for tidal / coastal floods) annual exceedance probability (AEP)*". While the brief does not explicitly refer to freeboard requirements, Arup have confirmed with CCC/OPW that the target SoP is to include an allowance for freeboard which will be determined as part of the optioneering.

[1] River Owenacurra & River Dungourney (Midleton) Flood Relief Scheme Constraints Report (Issue 2), October 2017

[2] Midleton Flood Relief Scheme Hydrology Report (Issue 2), October 2022

[3] Midleton Flood Relief Scheme Hydraulics Report (Issue 2), October 2022

[4] River Owenacurra & River Dungourney (Midleton) Flood Relief Scheme Project Brief (Rev. 3), June 2016

The SoP against both pluvial flooding and groundwater flooding is not specified in the brief. For pluvial flooding, Arup have therefore adopted the same SoP as for fluvial flooding, i.e. the 1% AEP plus freeboard SoP.

It is difficult to specify a SoP for groundwater flooding due to a lack of historic data on groundwater events in the town, as well as the inherent uncertainty over the behaviour of groundwater during flood events. Given that the groundwater component of the December 2015 flood event was very extreme, it has been adopted as a proxy for the groundwater design event, i.e. the groundwater SoP of the scheme includes all events up to and equivalent in magnitude to the December 2015 groundwater flood event.

The project brief states that alternative Standards of Protection should be considered as part of the project where they would "*provide greater benefits relative to cost, a more socially acceptable scheme or for other pertinent reasons*". Alternative standards of protection, to allow for the onset of climate change, are considered and are detailed in Section 12.

1.4 Study Area

Figure 1 presents an overview of the overall study area of the project. The scheme area is presented in Figure 2. As can be seen from Figure 2, the study area includes Midleton, Ballinacurra and the area in the vicinity of the Water Rock Stream.

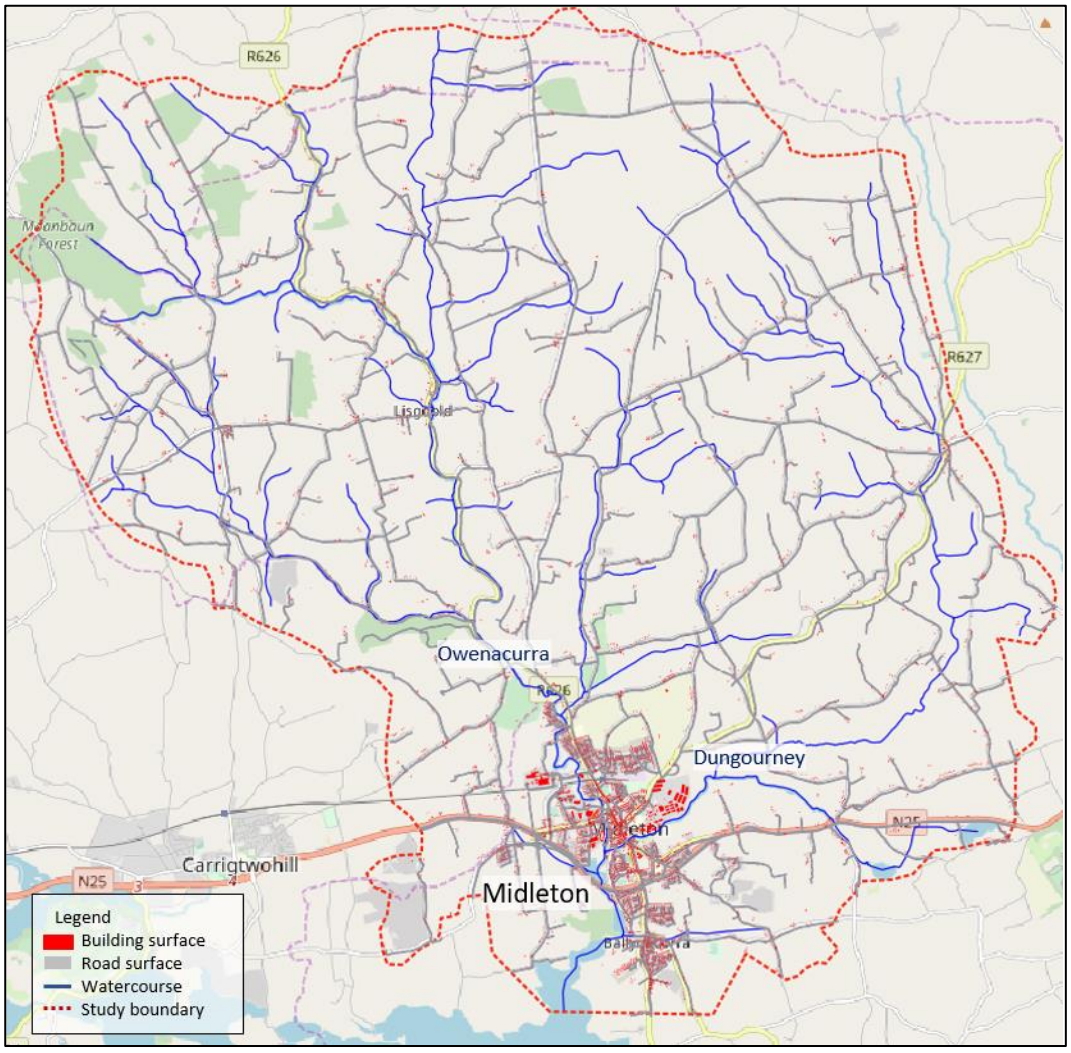


Figure 1 Study Area (© Open Street Map)

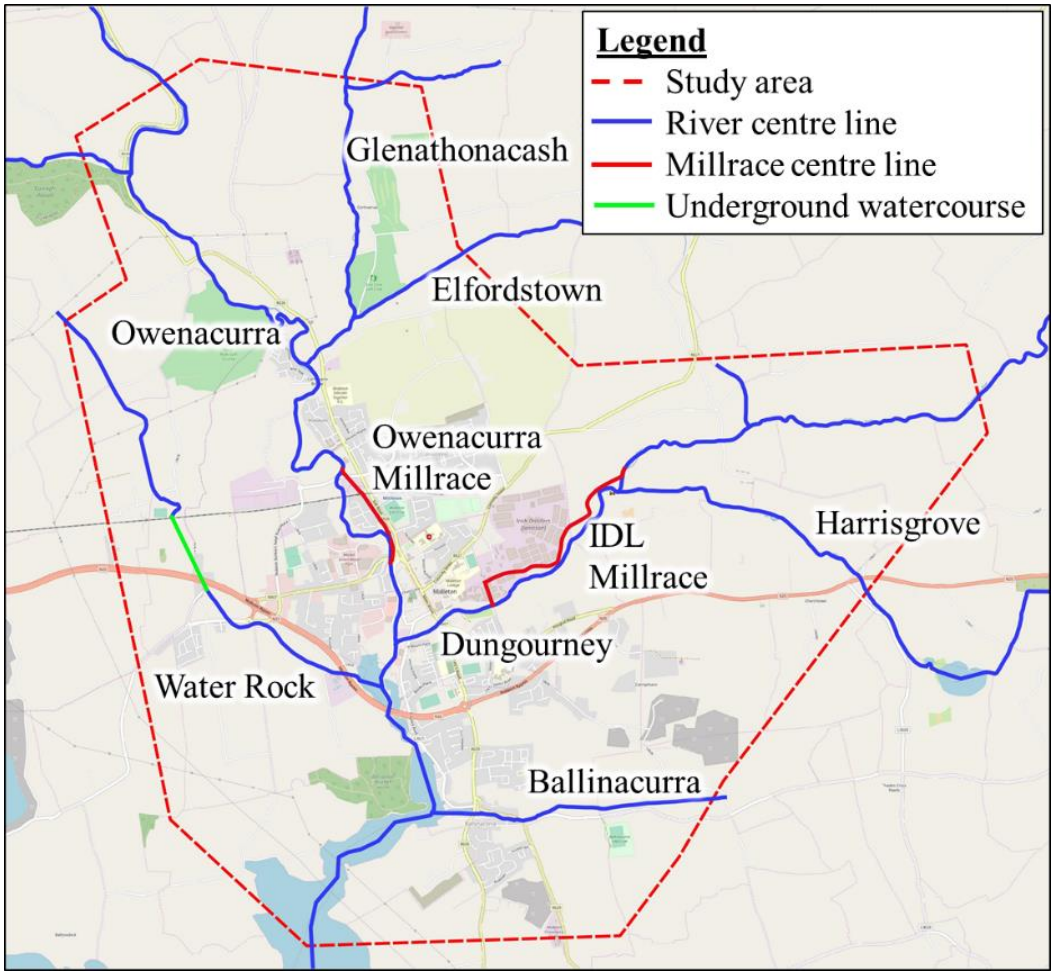


Figure 2 Scheme Area (© Open Street Map)

The watercourses considered as part of the study are listed in Table 2. The coordinates of the upstream and downstream extent of each watercourse within the study area is also provided in the table. Figure 2 highlights the centre lines of the watercourses.

Table 2 Primary Watercourses

Watercourse	Upstream extent (ING)	Downstream extent (ING)	EPA River ID
Owenacurra	186435, 76118	187974, 71749	19O03
Dungourney	192474, 74986	187967, 73112	19D07
Glenathonacash	187611, 77260	187278, 75287	19G66
Elfordstown	188204, 75975	187640, 75652	19E02
Harrisgrove	191699, 73472	189699, 74291	19H02
Ballinacurra	190523, 71922	188540, 71794	19W17
Water Rock	185584, 75434	187602, 72879	19O08

1.5 Overview of the Problem

A hydrology study and hydraulic modelling of the existing situation in the study area has been carried out as part of this project. The existing flood risk and flood mechanisms are described in detail in the accompanying Hydrology Report and Hydraulics Report.

As the locations at risk are spread over a large area, it was considered appropriate to divide the assessment of the potential flood risk management measures into discrete areas as detailed in Table 3 and presented in Figure 3 below. The flood risk management option for the overall area at risk will consist of the combination of measures for each of these areas.

Based on the hydraulic analysis carried out as part of this study, the following areas were identified as being the critical locations at risk.

Table 3 Areas at Risk

Area No	Area Name	Categories of Properties at Risk in this Area	Potential Flood Mechanisms
1	Tir Cluain to Willowbank	Domestic properties	Fluvial
2	Northern Relief Road to Riverside Way	Domestic and Commercial properties	Fluvial
3	Town Centre and Bailick Road	Domestic and Commercial properties	Fluvial/Tidal
4	Lauriston Estate/ Rugby Club/ East of IDL	Domestic and Commercial properties	Fluvial/ Groundwater
5	Ballinacurra	Domestic and Commercial properties,	Fluvial
6	Water Rock including Dwyer's Road	Domestic and Industrial properties, wastewater treatment infrastructure	Fluvial/ Tidal/ Groundwater

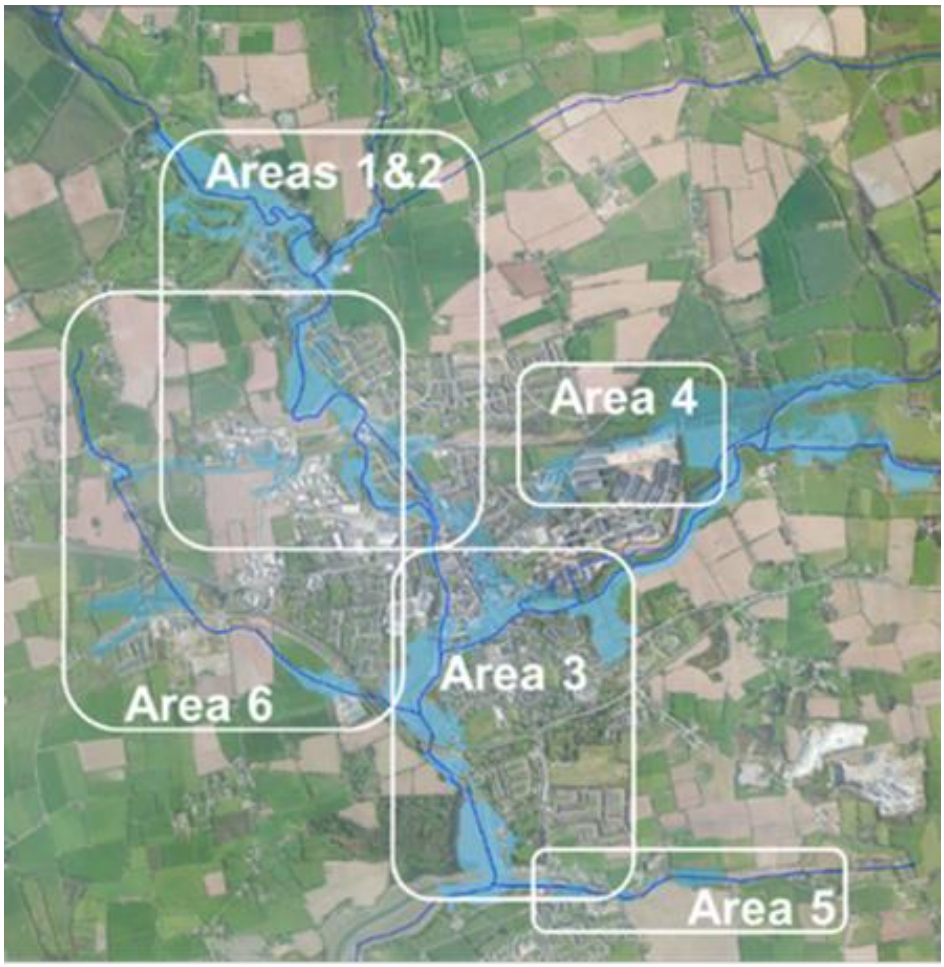


Figure 3 Key Plan of Scheme Areas

1.6 Scope of the Options Report

The purpose of this Options report is to assess all possible flood relief options that could be implemented in the Midleton area and to outline the procedure for the development and selection of the preferred options.

The process for the selection of the preferred flood relief options is outlined below:

- An initial screening of all possible flood risk management measures against a predetermined set of criteria, was carried out to determine their potential viability.
- A technical assessment of potentially viable flood risk management measures was undertaken.
- Potential flood relief options were developed using combinations of flood risk management measures which were determined to be technically viable. These flood relief options were then subjected to economic, environmental, and multi-criteria assessments, allowing a preferred flood relief option to be selected.
- The public were consulted on the potential options at Public Participation Day 2 and the emerging preferred option at Public Participation Day 3, as discussed in Section 2.1.
- The final solution was selected taking account of the following;
  - Multi Criteria Analysis;
  - Feedback from the Public and other stakeholders;
  - Cost benefit assessment;
  - Consideration of wider CCC objectives and other CCC infrastructure projects in the area;
  - Professional judgement of the project steering group.
- Cork County Council engaged the services of a landscape architect, Cunnane Stratton Reynolds (CSR), to refine and develop the emerging preferred option with particular emphasis on the Baby Walk and People's Park area, taking account of the public feedback.
- An emerging preferred option was identified, and a freeboard analysis and climate change allowance assessment was carried out.

1.7 Design Tidal Water Levels

The design tidal water levels as presented in Section 3.3.5 of the Hydraulics Report were used as the downstream boundary of the existing hydraulic model. The tidal levels were also used to inform on the modelling for the options selection process as detailed in Section 5 of this report.

The design tidal levels were however updated during the course of the study as a consequence of a very detailed assessment of tidal levels in Cork Harbour that was undertaken by Arup as part of the Lower Lee (Cork City) Flood Relief Scheme.[5] The updated design tidal levels supersede the levels used to inform on the existing scenario flood and optioneering selection as noted above. Neither of these two elements of work were updated in light of the updated water levels as part of this options report given that it would involve a very substantial volume of work to do so. The updated levels have however been used to inform the refinement of the emerging preferred option as well as the freeboard assessment which is detailed in Section 13 of this report. The updated water levels are therefore fully considered as part of the design of the preferring option for the scheme.

There are no adverse consequences associated with retaining the older set of design tidal water levels to inform on the existing scenario flood risk and the options selection as none of the conclusions from this work are altered.

[5] Lower Lee Flood Relief Scheme - Tidal Water Level Analysis, Draft Report, July 2022. It is noted that this report will be published on the Lower Lee website when it is finalised (https://www.floodinfo.ie/frs/en/lower-lee/home/).

The reader is referred to Section 10 for a detailed discussion of the revisions to the water levels.

2. Stakeholder Input and Consultation

2.1 Public Consultation

An important element of the Midleton Flood Relief Scheme (FRS) is consultation with all interested parties including the public.

The purpose of the consultation is to give interested parties an opportunity to communicate local knowledge, how they are currently affected, existing constraints, and also to obtain feedback on the proposals from all relevant affected stakeholders and landowners who might be impacted by the Scheme. Feedback throughout the project to date has been taken seriously, carefully considered, and where appropriate has influenced decisions on the final emerging preferred scheme.

The goal is that this ensures public and stakeholder opinion is taken into consideration when developing the options, and that they are informed of the influence they have had. The methods of consultation include but are not limited to Public Participation Days (PPD), technical workshops, face-to-face meetings, emails, newsletters, and social media.

This includes consultation with a wide range of interested parties with general or specific interests such as impact on society, the environment, cultural heritage, the economy, interacting infrastructure projects. All comments are considered and, where relevant, further updates to the options have been carried out. Ongoing feedback will be considered and incorporated where possible as the design moves into detailed design stage.

2.1.1 Ongoing consultation

Comprehensive communication and engagement plans have been developed and adopted by the project team, including the development, and maintenance of a project website, direct emails, newsletters, local media, and public consultation among other approaches, as outlined below.

Table 4 Communications and Consultation Approaches

Communication Activity	Purpose
Project website	• To promote and provide information to stakeholders about the project. • To provide formal updates. • To provide a source of information that stakeholders and members of the public can download and review. • To provide a means of consultation and allow stakeholders to ask questions or submit information
Direct email	• Where stakeholders have supplied their contact details, the project team will notify project updates, invitations to consultation events via email. • Names and addresses must be held securely in compliance with the with the requirements of the General Data Protection Regulations (Regulation (EU) 2016/679) and the Data Protection Act 2018.
Letter drops	• Where landowners who may not have been aware that they could be impacted by the scheme, the project team contact by letter prior to the PPD, inviting them to the PPD and directing to them to the website for further information.
CCC website	• Links to project website, publicise consultation events.
Local media, TV, radio, newspapers or publications	• Press releases are prepared in advance of Public Participation Days and distributed to the media. • Photo calls and media interviews can also be arranged.

Communication Activity	Purpose
Paid for Advertising – in a media publication	• Various methods of advertising have been employed, such as online, radio, outdoor, transport, press and more.
Public Participation Days	• Consultation exhibitions / events offer a more extensive and open form of engagement on a personal basis. They provide opportunities for members of the public to express views on the consultation subject area, ask questions, take on board the information at their leisure, discuss any concerns, provide a view and receive feedback on the issues they raise. • The events will be geared to a specific issue, based on consultation stage of the project programme. • The consultation events can be held in community facilities – providing an environment conducive to actively seeking views in the relevant communities. • These events can combine the presentation of information, visual displays, verbal presentations, computer presentations and other details whilst giving people the opportunity to provide views and opinions. Members of the design team and environmental team will be available on the day to answer any specific queries that may arise. • Events must be held in venues that are accessible for disabled users or users with special needs to maximize possible attendance. • Events must be held at suitable times and for appropriate durations to maximize possible attendance. • One factor which can determine the success of a public event is how well it has been publicised.
Council meetings	• Councillor updates are provided monthly. Opportunities to promote the project and website via meetings and newsletters. • Key councillors and TDs are invited to the Public Participation Days so may provide feedback to the wide council body.
Social Media	• Social media sites, such as CCC Facebook and Twitter, will be used to link to the project website, publicise Public Participation Days and promote messages and information about the Study.

2.1.2 Public Participation Day (PPD) 1 – Constraints Day

The first Public Participation Day (PPD) was held on Thursday 23rd March 2017 in the Midleton Park Hotel from 3pm to 8pm. The purpose of this PPD was to engage with the public, outline the process involved in the preparation for the Midleton FRS, and gather local knowledge on flooding and environmental constraints and opportunities for addressing flood risk in the area. A total of 88 attendees signed the attendance list at the event.

2.1.3 Public Participation Day (PPD) 2 – Options Day

A second PPD was held on Saturday 7th March 2020 in the Midleton Park Hotel. The purpose of PPD2 was to present a suite of potential options to the general public and to seek feedback in order to identify a preferred scheme. PPD2 was held between 11am and 6pm for members of the general public. The total PPD2 attendance was estimated to be approximately 210 people. The objectives of the Public Participation Day were to:

- Provide an update on progress to date
- Outline the Present-Day Flood Extent based on hydraulic model analysis
- Provide information and an opportunity to comment on the Potential Scheme Options
- Obtain other information relevant to the Scheme
- Outline the next steps of the Scheme

PPD2 was attended and staffed by members of Arup's engineering and environmental teams, representatives of the Office of Public Works and Cork County Council including an architect. Scheme representatives were available to answer questions from the members of the public who attended, to explain the potential options presented, and to accept feedback and information from the attendees.

The feedback received from the public, either on the day or subsequently via submissions, was used to inform the options assessment.

2.1.4 Public Participation Day (PPD) 3 – Emerging Preferred Option Day

A third PPD was held on Thursday 28th July 2022 in the Midleton Park Hotel from 2pm to 8pm, as it was considered that this would allow an increased number of people to attend outside of regular working hours.

The purpose of the PPD was to present the emerging preferred option for each area and to seek feedback from the public. The objectives of the Public Participation Day were to:

- Provide an update on progress to date
- Present the emerging preferred option in each area
- Present the findings of the Natural Flood Management Feasibility Study
- Present the findings of the Scheme Climate Change Adaptation Plan
- Obtain other information relevant to the Scheme
- Present the identified constraints in the areas
- Outline the next steps of the Scheme

PPD3 was attended and staffed by members of Arup's engineering and environmental teams, representatives of the Office of Public Works, Cork County Council and Cunnane Stratton Reynolds. Scheme representatives were available to answer questions from the members of the public who attended, to explain the options presented, and to accept feedback and information from the attendees. Approximately 115 attendees signed the attendance list at the event. The total attendance was estimated to be approximately 150 taking into account the people who did not sign in, the people who came in pairs or groups but only signed in as one.

The feedback received from the public, either on the day or subsequently via submissions, was used to refine the emerging preferred option.

2.2 Consultation with Key Stakeholders

A key tool in ensuring stakeholders' views can be incorporated where necessary has been arranging and facilitating multiple stakeholder workshops at appropriate times throughout the project. These balanced with timely on-the-ground meetings and site visits has allowed for key stakeholder concerns and constraints to be identified and addressed at source whilst creating the opportunity for interactive discussion with key stakeholders.

This consultation provided the opportunity to discuss the requirement for flood protection and present the possible options (where more than one exists) and elicit feedback. This feedback has directly informed the selection of measures and development of the preferred option. Groups who provided feedback in this way included:

- Inland Fisheries Ireland
- Irish Distillers Limited
- Irish Rail
- Irish Water
- Midleton Area Rivers Group
- Midleton GAA
- Cork County Council Biodiversity Section
- Cork County Council Heritage Section

- Cork County Council Architects

2.3 Proposed Infrastructure Projects within Scheme Area

There are a significant number of proposed infrastructure projects within the Midleton area at different stages in development that are interacting with the various scheme options. Extensive liaison and consultation has been undertaken with the various clients and stakeholders regarding the interactions between the Flood Relief Scheme options and these projects.

Many of the projects had to be taken into consideration in the development of the options and also had an impact in the MCA scoring where either the option had a negative impact on or facilitated other key proposed infrastructure.

The key projects are listed below. The specific interactions and impact on development and MCA scoring of options are described in the relevant sections.

Table 5 Interacting Infrastructure Projects

Project	Client
Ballinacurra to Midleton Cycleway Scheme	Cork County Council
Baneshane Local Infrastructure Housing Activation Fund (LIHAF)	Cork County Council
Kennedy Park Pedestrian Bridge Upgrade	Cork County Council
Midleton to Youghal Greenway	Cork County Council
Midleton Northern Relief Road Extension	Cork County Council
Midleton Town Park and Baby Walk project	Cork County Council
N25 Carrigtwohill/Midleton upgrade	Cork County Council
Owenacurra Linear Park	Cork County Council
Water Rock Local Infrastructure Housing Activation Fund (LIHAF) infrastructure	Cork County Council
Midleton Wastewater Network Upgrade	Irish Water
Midleton Wastewater Load Diversion Project	Irish Water
Midleton Wastewater LIHAF Project	Irish Water
Midleton Wastewater Treatment Plant Optimisation Project	Irish Water
Irish Rail Glounthaune to Midleton Twin Tracking Project	Irish Rail

2.4 Landowner Consultation

The design team appreciated the fundamental importance of early engagement with the affected landowners on the scheme and therefore placed a significant emphasis on this element.

An extensive landownership search was carried out to identify all landowners affected by the scheme, including farmers, private landowners and commercial businesses. A significant public consultation process was subsequently carried out, including letter drops.

Efforts were made to identify and contact all impacted landowners, so that they were aware of the proposed works. In a number of cases landowners were also met on site to ensure the design team were able to fully understand the landowners' unique concerns, preferences and suggestions and crucially the site specific complexities for each area.

Equally these meetings sought to ensure the affected landowners were fully informed and understood the proposed works (including the nature of and rational for the works, the defence alignments and finishes, access requirements and construction issues) and the processes by which they may raise additional queries or comments.

Arup addressed any landowner queries and endeavoured to understand the land use and constraints of the affected areas to inform the scheme design. All landowner feedback will be further considered and incorporated as the design moves into detailed design stage.

A large consultation database has been built up capturing all of the landowner interactions, requests and agreements. This will be maintained going forward into detailed design to ensure all issues are tracked and addressed.

Landowner interactions and requests were discussed regularly at the steering meetings and design team meetings to determine what suggestions and feedback could be adopted or addressed.

2.5 Engagement of Landscape Architect and Conservation Specialist

As a result of feedback received at PPD2, including the importance of the Baby Walk Park for the town of Midleton and the significant heritage value in the area, Cork County Council engaged the services of a landscape architect and a conservation specialist. Following a mini competition, Cunnane, Stratton, Reynolds (CSR) and John Cronin Associates were commissioned to undertake this role for Stage 1 of the project.

CSR has since worked closely as part of the multidisciplinary design team, inputting into the option assessment and development, and consideration of comments received from the public. The involvement of the landscape architect resulted in the refinement of the scheme in The Baby Walk including the alignment and finishes of the proposed defences, access in and out of the public park, and the softening of engineered work, soft landscaping, provision of seating etc.

2.6 Statutory Consultees

Consultation has taken place with a large number of statutory consultees in relation to this flood relief scheme. Please refer to the Constraints Report for further details.

3. Initial Screening of Potential Measures

3.1 Introduction

This section details all the flood risk management measures considered during the screening stage of the Midleton FRS.

At this initial stage, some measures were deemed to be not viable for this project and as a result were screened out. Other measures were considered as potentially viable and these were carried forward for further assessment.

The initial screening of measures was assessed in terms of:

- Applicability to the study area (including technical feasibility, constructability, and Health and Safety)
- Economic viability
- Environmental
- Social
- Cultural

The flood risk management measures which have been reviewed as part of this initial screening process are outlined in Table 6 below.

The measures are broken down into Non-Structural Measures and Structural Measures

Non-Structural Measures, such as land use management within a catchment, affect the way in which rainfall is directed to watercourses. Hard surfaces reduce the amount of rainfall that can infiltrate to ground water, and intensive drainage schemes will increase the speed of runoff, giving rise to earlier and higher flood peaks.

River restoration is about mitigating the negative impacts that past changes in catchment management practices, such as land drainage or deforestation, may have had on river systems. Modifications to land drainage systems within the catchment can reduce the rate at which rainfall is conveyed into the river channel and thus help to reduce peak flows. Measures of this nature would take a long time to implement and would not reduce the flood risk to an acceptable level. The proposed scheme would not however, prevent such methods being implemented in the future.

Structural measures require physical construction to reduce the risk of flooding and involves modification to the existing built environment.

Details of non-structural and structural measures considered are outlined in further depth below.

Table 6 Summary of Initial Screening

Possible Flood Risk Management Measure	Potentially viable?					Initial Screening Result	Comment
	Applicability	Economic	Environmental	Social	Cultural		
Do Nothing	N	Y	Y	N	Y	Not viable as a standalone measure. May be necessary in isolated areas	This measure provides the baseline for the study and assumes no further work or expenditure on measures to reduce flood risk in the study area. The Do Nothing scenario is defined as the measure involving no future flood defence expenditure. The implication is that the existing risk of flooding persists in the study area. This is not considered to be a viable standalone measure as it fails to meet the needs of the residents and business owners. Using this as the baseline scenario, however, allows the benefits of all existing measures which reduce the flood risk to be identified. It places the benefit of these measures into true perspective.
Do Minimum	N	Y	Y	N	Y	Not viable May be necessary in isolated areas	This measure would consist of minor works and maintenance measures, which could include filling in gaps in existing masonry river walls, regularly clearing the channel of vegetation, etc. The risk of flooding would remain high. Therefore, this is not considered to be a viable measure as it fails to meet the needs of the residents and business owners.
Non-Structural Measures							
Planning Control/ Land Use Management	N	Y	Y	Y	Y	Not viable	This measure would assist in ensuring flood risk is not increased by future development. The measure would take a long time to implement and would not reduce the current flood risk to an acceptable level. Therefore, it is not considered to be viable for the current scenario. However it could be considered in the Scheme Climate Change Adaptation Plan.
SuDS	N	N	Y	Y	Y	Not viable as a standalone measure.	Midleton is an urbanised and well-developed area. The land required for attenuation or other SuDS features would be limited. While existing green spaces are plentiful, a large proportion already exist as flood plains which naturally already provide the storage functionality of SuDS. Of the remaining parks and green spaces, there would be insufficient land available to implement SuDS measures at the scale required to reduce the current flood risk to an acceptable level. The ability to repurpose these green spaces for SuDS use would also likely be limited by the underground services typically present in an urban area. Therefore, this measure is not considered to be viable.

Possible Flood Risk Management Measure	Potentially viable?					Initial Screening Result	Comment
	Applicability	Economic	Environmental	Social	Cultural		
Flood Forecasting/ Flood Warning System	N	Y	Y	Y	Y	Not viable as a standalone measure. May be viable as an ancillary measure.	A flood forecasting system could be a potentially viable ancillary measure to be used in combination with other defences. The viability of the system would be dependent on catchment characteristics. For example, it may not be beneficial if river levels were to rise quickly during a storm event, which would be common in urbanised areas where water infiltration is limited.
Public Awareness Campaign	N	Y	Y	Y	Y	Not viable as a standalone measure.	This measure would help to increase public awareness and preparedness for future flood events. However, the measure would not reduce the current flood risk. Therefore, it is considered unviable as a standalone measure. It may still be appropriate to implement along with other measures. Naturally public awareness would grow throughout the planning stage of the scheme where public consultation would be necessary, and an opinion is sought.
Relocation	N	N	Y	N	N	Not viable	This measure involves the relocation of people and businesses from properties at risk of flooding to an area with lower flood risk. It is not considered feasible, due to the urbanised nature of the area at risk and the large number of properties at risk.
Structural Measures							
Natural Flood Management	Y	Y	Y	Y	Y	Not viable as a standalone measure. Not viable for tidal flooding.	Initial screening of the measure found that it would not be viable due to the large land take requirements, interaction with land owners and the general operation and maintenance of such a measure. The risk of flooding would likely remain high and the target Standard of Protection would not be achieved. Further to public feedback as part of PPD2, a more in-depth assessment was completed to consider if Natural Flood Management could form part of the proposed scheme.
Upstream Storage	Y	Y	Y	Y	Y	Potentially viable Not viable for tidal flooding.	Flooding in Midleton comes from a variety of sources, including but not limited to, fluvial flooding. It may be potentially viable to provide upstream storage in some locations where fluvial flooding is present, provided there is sufficient space to implement it.

Possible Flood Risk Management Measure	Potentially viable?					Initial Screening Result	Comment
	Applicability	Economic	Environmental	Social	Cultural		
Direct Flood Defences	Y	Y	Y	Y	Y	Potentially viable	Direct flood defences include flood walls and embankments. These would be potentially viable across the scheme area, pending an assessment on the available space in which to implement them.
Diversion Channels or Culverts	Y	Y	Y	Y	Y	Potentially viable	Diversion channels or culverts may be viable in some areas of the scheme. It is unlikely that these would be viable in the heavily urbanised areas however, due to their spatially constrained nature.
Sediment/Debris Control	N	Y	Y	Y	Y	Not viable as a standalone measure. May be viable as an ancillary measure.	Sediment or debris control would involve catchment management measures to limit material from entering waterbodies, and to conduct regular maintenance at areas where debris typically accumulates, such as bridges. While these measures may help reduce flooding by maximising river capacity in-stream, they would be insufficient to achieve the required standard of protection.
Conveyance Improvements/ Dredging	Y	Y	Y	Y	Y	Potentially viable Not viable for tidal flooding.	Conveyance improvements aim to maximise river capacity to reduce the flood risk to neighbouring lands. This is typically done through channel realignment or widening. Dredging maximises river capacity by removing sections of the riverbed, deepening the river. Both can have significant environmental impacts, depending on location.
Individual Property Protection	N	N	Y	Y	Y	Not viable as a standalone measure	This measure may be viable for some isolated properties at risk, or in areas where no other measures are viable however it is likely that the target Standard of Protection will not be achieved using this measure. In the urban areas, this measure is not considered to be viable due to the number of properties at risk.
Pumping	Y	Y	Y	Y	Y	Potentially viable Not viable for tidal flooding.	Pumping may be viable at some locations in the scheme where other measures are not viable, or where the quantities of flood waters expected are minimal. It is likely that pumping may be considered as an ancillary measure to support other interventions.
Tidal Barrier	Y	Y	Y	Y	Y	Potentially viable Not viable for fluvial flooding.	Tidal barriers are large structures which can open and close to restrict tidal waters from traveling upstream during surge events. These typically span across estuaries or rivers, and have significant environmental and economic impacts. Given the potential technical viability however, this measure has been selected for further assessment.

3.1.1 Pluvial flood risk mitigation measures

The assessment and mitigation of pluvial flood risk across the entire study area is not within the scope of the project. The scheme is to be developed primarily to protect the affected areas against fluvial and tidal flooding. However, consideration will be given to the potential impact of the flood relief scheme on pluvial flood risk (e.g. urban stormwater that may accumulate behind walls and be unable to drain), and mitigate any detrimental impacts of the scheme on the other source of flood risk.

Typical measures to address pluvial flooding include:

- Installation of surface water pumping stations;
- Increasing pipe capacity;
- Increasing number of gullies;
- Installing linear kerb drains etc;
- Retrofitting sustainable urban drainage measures such as bioretention tree pits;
- Local ground regrading of roadways and/or footpaths in order to divert excess surface water from sensitive receptors;
- Segregating combined foul and stormwater sewers and installing a dedicated surface water pipe network in order to reduces the volume of water discharging to waste water treatment works.

In addition, drainage improvement works at the Baby Walk end of the Main Steet / Distillery Walk, St Mary's Road and the Youghal Road have been included as part of the project and are discussed in Section 5.4.1.

3.2 Screening of Potential Measures

3.2.1 Initial Measures Screened Out as Not Viable

Further to the initial screening, the following flood risk management measures have been identified as being non-viable and have not been carried forward for further technical assessment:

Do Nothing – The Do Nothing scenario establishes a baseline scenario from which comparisons can be made. Given the well documented existing risk of flooding in Midleton, it is not deemed to be a suitable solution. As a result, it has been eliminated as a potential measure following the initial screening.

Do Minimum – The do minimum scenario would see minor interventions made in specific locations. For example, maintenance work in-stream or repairs to existing walls or embankments. These interventions would not be sufficient in providing the necessary flood protection to the area as a standalone solution. Due to the modest height of existing defences in some areas, flooding would persist regardless. As such, this measure has been removed from consideration following the screening.

Relocation – This would involve the relocation of people or businesses from areas of risk of flooding to other areas not at risk. Given the number of impacted homes and businesses identified as being at risk of flooding currently, it is not deemed that this is a viable solution in Midleton. As a result, this measure has been removed from consideration.

Planning Control / Land Use Management – This would involve limiting the impact that future developments may have in the area. This can be done through either restricting development in key areas, or by ensuring that developments with potential impacts on flooding are required to mitigate them completely once completed. This measure would not be sufficient on the basis that flooding already occurs in the area. For this reason, the measure has been removed from consideration.

Public Awareness Campaign – A public awareness campaign would aim to inform the public about the potential risks of flooding and measures individual households can take to limit impacts. It would not reduce the risk of flooding from occurring.

3.2.2 Initial Measures Screened Out as Not Viable as Standalone Measures

The following flood risk management measures have been identified as being non-viable as standalone measures as they would not be adequate in providing the level of protection required for Midleton and have therefore not been carried forward for further technical assessment:. However they could potentially be used alongside other measures and may form part of the options.

SuDS – This would involve the use of Sustainable Drainage Systems (SuDS) or landscape features to attenuate and store flows. This would usually involve guiding excess water into grassed areas designed to act as ponds during storm events, which would later regain their functionality once the water levels naturally reduce. This measure would not be adequate in providing the level of protection required for Midleton but could potentially be used alongside other measures.

Flood Forecasting/Flood Warning System – This would involve setting up a monitoring system to automatically detect rising river or sea levels which could later result in flooding. Giving residents time to prepare, or operatives an opportunity to install temporary defences such as demountable barriers. This would not be adequate in providing the level of protection required for Midleton but could potentially be used alongside other measures.

Sediment/Debris Control – This would involve the removal of material such as branches from bridges and other structures which may otherwise restrict water flow. This is an ongoing maintenance measure, as opposed to a once off occurrence. This would not be adequate in providing the level of protection required for Midleton but could potentially be used alongside other measures.

Individual Property Protection – This would typically involve using a combination of flood resistant doors, door barriers, gate barriers or small-scale pumping. These measures would need to be implemented based on a property-by-property level of suitability assessment. This would not be suitable across the entire scheme area, but may be viable in select areas if an alternative solution cannot be found. This measure requires early warning systems and is likely to require human input resulting in an active scheme rather than a passive one.

3.2.3 Potentially Viable Measures Considered

Further to the initial screening, the following flood risk management measures were identified as potentially viable measures for Midleton and have been taken forward for further technical assessment. Some measures are included for further consideration following feedback from the public and stakeholders:

- Structural Measures
  - Conveyance Improvements/Dredging
  - Direct Flood Defences
  - Diversion Channels or Culverts
  - Natural Flood Management
  - Pumping
  - Upstream Storage
  - Tidal Barrier

Conveyance Improvements/Dredging – Conveyance improvements alter the natural path of rivers to improve flow conditions, typically through widening or realignment. Dredging has the same objective but involves removing sections of riverbed to deepen the channel.

Direct Flood Defences – These defences typically refer to flood defence walls and embankments. These defences would predominantly be constructed along the banks of rivers or estuaries to restrict water from exiting and flooding adjacent lands.

Diversion Channels or Culverts – This would see a portion of river flows diverted away from key receptors, such as homes or businesses, where they would instead be relocated to areas of reduced risk.

Natural Flood Management – Natural Flood Management (NFM), or Natural Water Retention Measures (NWRM) as it is often referred to, involves implementing features to restore or mimic the natural functions of rivers, floodplains and the wider catchment to reduce flood risk downstream. NFM aims to slow water down upstream before it reaches towns and cities by temporarily storing it elsewhere during times of flood. NFM aims to store water in the landscape, where it will not cause damage to properties or infrastructure, and slow the rate at which water runs across the landscape and into rivers. While it was initially determined that there would be significant technical and landowner issues with this measure, following feedback from the public, a more in-depth natural flood management feasibility assessment was conducted for Midleton.

Pumping – Pumping involves the installation of pumping stations in specific locations to redirect flood water back into the rivers, floodplains or estuaries and away from properties. Pumping can be an effective method of flood prevention when used in combination with other flood defence measures.

Upstream Storage – This would involve utilising certain locations to store and attenuate water during storm events. A large upstream area would be allowed to flood, with a controlled release of water taking place after the risk to downstream areas subsides. A large area of land is generally required to implement this measure.

Tidal Barrier – A tidal barrier is a large structure which spans across a river or estuary. The barrier typically closes when a surge in tidal water levels is predicted to occur, offering protection to upstream areas. Once the threat subsides, it would reopen again to facilitate tidal exchange and navigation. Despite economic and environmental concerns, it was decided to include the tidal barrier for additional assessment following feedback from the public.

3.2.4 Summary of Initial Screening

Table 7 below presents a summary of the screening of potential measures.

Table 7 Summary of the screening of potential measures

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Screening Conclusion
Do Nothing	N	Y	Y	N	Y	Does not meet project objectives
Do Minimum	N	Y	Y	N	Y	Does not meet project objectives
Planning Control/Land Use Management	N	Y	Y	Y	Y	Does not meet project objectives
SUDS	N	Y	Y	Y	Y	Does not meet project objectives as standalone measure
Public Awareness Campaign	N	Y	Y	Y	Y	Does not meet project objectives
Flood Forecasting/Flood Warning System	N	Y	Y	Y	Y	Does not meet project objectives as standalone measure
Relocation	N	N	Y	N	N	Does not meet project objectives
Natural Flood Management	Y	Y	Y	Y	Y	Requires further study
Upstream Storage	Y	Y	Y	Y	Y	Meets project objectives
Direct Flood Defences	Y	Y	Y	Y	Y	Meets project objectives

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Screening Conclusion
Diversion Channels or Culverts	Y	Y	Y	Y	Y	Meets project objectives
Sediment/Debris Control	N	Y	Y	Y	Y	Does not meet project objectives as standalone measure
Conveyance Improvements/ Dredging	Y	Y	N	Y	Y	Meets project objectives
Individual Property Protection	N	N	Y	Y	Y	Does not meet project objectives
Pumping	Y	Y	Y	Y	Y	Meets project objectives
Tidal Barrier	Y	Y	Y	Y	Y	Requires further study

4. Further Assessment of Potentially Viable Measures

4.1 Description of Potentially Viable Measures

Following the initial screening of the potentially viable measures outlined in Section 3, seven measures were selected for further assessment from the initial sixteen. These measures were assessed at greater depth to ensure suitability within the scheme areas. The potentially viable measures considered are detailed in Table 8 below.

It should be noted that not all areas of the scheme are suitable for every measure listed. For example, a tidal barrier is not suitable for Area 1&2 or Area 4, as there is no tidal flooding in these areas.

Table 8 Potentially viable measures by area

Potentially Viable Measures	Area 1&2	Area 3	Area 4	Area 5	Area 6
Natural Flood Management	Y	N	Y	N	N
Upstream Storage	Y	N	N	Y	Y
Direct Flood Defences	Y	Y	Y	Y	Y
Diversion Channels or Culverts	N	Y	N	Y	Y
Conveyance Improvements/Dredging	Y	N	N	N	Y
Pumping	N	N	Y	Y	N
Tidal Barrier	N	Y	N	N	N

Justification for why each of the measures listed in Table 8 were considered potentially viable or not is provided in the following section of the report.

4.1.1 Area 1&2 – Tír Cluain to Riverside Way

A decision was made to group Areas 1&2 together, as the main source of flooding is fluvial only and the measures deemed feasible for both areas were the same. Four of the seven measures brought forward for further assessment were considered viable for Area 1&2. Details of the assessment of potentially viable measures for the area are outlined below.

4.1.1.1 Natural Flood Management (NFM)

Natural Flood Management (NFM) was considered as a measure but determined not to be viable. Given the level of public interest in natural flood management, in particular during PPD2, it was decided to undertake an in-depth assessment of NFM as a potential solution. A Natural Flood Management Feasibility Study[6] was conducted, the results of which are included in a report which is on the project website.

In summary, the study indicated that Tree Planting was the most suitable NFM intervention across ~47.6% of the catchment, followed by Runoff Attenuation across ~38% of the catchment area. Contour ploughing was indicated to be the most suitable NFM intervention across ~13.9%. The remaining portion of the catchment area (0.5%) was considered suitable locations for buffer strips, floodplain reconnection, large woody debris or wet woodland.

The study concluded that natural flood management would reduce peak flows by 6-10% depending on intervention type, at a cost of between €7 million and €15 million. The significant cost paired with the limited impact rendered this type of intervention neither technically nor economically feasible.

4.1.1.2 Upstream Storage

This option considered a combination of upstream storage and direct defences. Embankments constructed in the Water Rock Golf Course areas would be required to impound water. The golf course would be utilised as a flood water storage area during flood events, with water being released in a controlled manner downstream through a flow control structure. An embankment would be constructed through the golf course along the right bank of the Owenacurra that would increase the threshold of flooding and reduce the risk of fluvial flooding at lower return periods. The upstream storage measure would result in reduced defences heights/ extents required downstream, however it would not completely negate the need for direct defences.

In some locations the proposed defences may obstruct existing pluvial flow paths, i.e. the route rain water takes when discharging into rivers, at these locations pumping stations would be required to over pump pluvial water during times when intense rainfall and high water levels on the river coincide. These are required anywhere proposed defences may obstruct existing pluvial flow paths.

4.1.1.3 Direct Defences

A direct defences only measure was also considered. Embankments were considered upstream of Moore's Bridge, while immediately downstream of Moore's Bridges walls were deemed to be appropriate due to the limited space available along the riverbanks. As part of the direct defences only measure, Moore's Bridge was maintained in place with new bridge parapets proposed to tie into high ground. Similarly, the existing bridge south of the Northern Relief Road would be maintained. As per the upstream storage measure in combination with direct defences measures detailed in Section 4.1.1.2, pumping stations will be required.

4.1.1.4 Diversion Channels or Culverts

There was no opportunity in Area 1&2 to provide diversion channels or culverts as a viable measure. For this reason, diversion channels or culverts were not considered as a viable measure in this area.

4.1.1.5 Conveyance Improvements/ Dredging

Conveyance improvements/dredging were considered in combination with direct defences for this area.

[6] Midleton Flood Relief Scheme Natural Flood Management Feasibility (Issue 1), February 2021

Widening and deepening of the river channel were considered downstream of Moore's Bridge, with Moore's Bridge to be removed to increase conveyance. Conveyance improvements were also considered through the removal of the existing bridge south of the Northern Relief Road.

Direct defences in the form of embankments and walls would be required on the Glenathonacash and along the Owenacurra reach where conveyance improvements could not exclusively provide the target SoP. As per the upstream storage measure in combination with direct defences measures detailed in Section 4.1.1.2, pumping stations will be required.

4.1.1.6 Pumping

Pumping of fluvial flood water back into the rivers or floodplains and away from properties was not considered technically achievable in Area 1&2 due to the scale of flooding across a large area and limited channel capacity. For this reason, pumping was not considered as a viable measure in this area.

4.1.1.7 Tidal Barrier

A tidal barrier would not be a suitable measure for Area 1&2, as the source of flooding in this area is primarily fluvial from the Owenacurra and Glenathonacash River and the Owenacurra Millrace.

4.1.2 Area 3 – Town Centre and Bailick Road

Three of the seven measures brought forward for further assessment were considered viable for Area 3. Details of the assessment of potentially viable measures for the area are outlined below.

4.1.2.1 Natural Flood Management

NFM measures would not contribute to any reduction in flood defence requirements in Area 3 as the area requiring defences is also subject to tidal flooding.

4.1.2.2 Upstream Storage

Similar to NFM measures, upstream storage measures would not contribute to any reduction in flood defence requirements in Area 3 as the area requiring defences is also subject to tidal flooding.

4.1.2.3 Direct Defences

This measure involves the use of direct defences as the primary flood prevention measure. Flood defence walls were considered throughout a large portion of the area, as given the urban nature, there is limited space to introduce embankments. Embankments were prioritised in parks or existing green areas, given the additional space available for their construction.

4.1.2.4 Diversion Channels or Culverts

A flood relief culvert was investigated for the Dungourney River. This examined the possibility of diverting a portion of the flow through a culvert starting at People's Park, passing underneath Main Street and Broderick Street, before joining the Owenacurra River at John F. Kennedy Memorial Park. During periods of high tide, a tidal gate downstream of the Dungourney would close reducing the risk of tidal flooding along the Dungourney. This would negate the requirement for direct defences between the tidal gate and diversion upstream. The potential alignment of the flood relief culvert and the location of the tidal gate is presented in Figure 4.

Direct defences along the Owenacurra and in the tidal estuary would still be required in combination with this measure. Engineering works in the People's Park would also be required in order to store fluvial water if the downstream end of the diversion culvert gets tide locked.

A pump station may also be required just upstream of the tidal gate to over pump residual fluvial flow not diverted by the flood relief culvert.

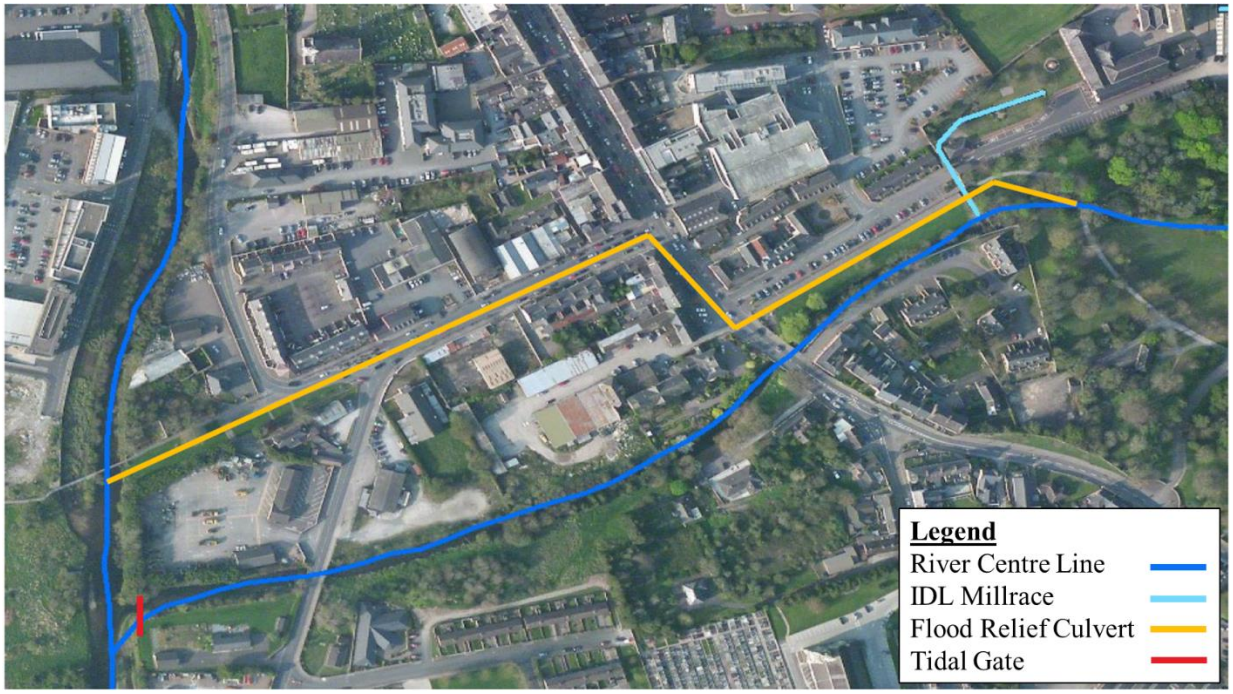


Figure 4 Flood diversion culvert for the Dungourney River

This measure was considered to be non-viable due to;

- The requirement for active management of the measure,
- The significant number of clashes with existing services/utilities in the urban area,
- The negative environmental impacts during the diversion of the river,
- The significant disruption during construction,
- The significant in channel works required upstream of the diversion.

4.1.2.5 Conveyance Improvements/Dredging

Conveyance improvements/dredging was considered for the area. However, further assessment indicated that the flooding through this section of the reach was tidally dominated. Dredging of the riverbed/ estuary is not technically viable in a tidally dominated reach as the maximum water level of the tide will still be reached regardless of how much the elevation of the bed may be reduced. As such, dredging of the estuary and downstream of the Owenacurra and Dungourney has been ruled out as a measure in Area 3.

4.1.2.6 Pumping

Due to the nature of tidal flooding, pumping is not technically achievable in Area 3. For this reason, pumping was not considered as a viable measure in this area.

4.1.2.7 Tidal Barrier for Midleton Scheme Area

A tidal (or storm surge) barrier is a fully or partly moveable barrier structure which is located across a river or estuary. It can be closed temporarily to prevent the ingress of a tidal surge upstream of the barrier in order to reduce the frequency and severity of tidal flooding. During normal conditions, the barrier is kept open to allow for tidal exchange and navigation.

A tidal barrier for Midleton would need to operate during forecasted tidal flood events in Cork Harbour. When it is closed the barrier could prevent tidal surges from propagating through the Owenacurra estuary and inundating Midleton. Water from the Owenacurra and Dungourney rivers would however be prevented from flowing out to sea while the barrier is closed and unless there is a sufficient volume upstream of the barrier for storing water, Midleton will be at risk of fluvial flooding while the barrier is closed. One of the key technical considerations of implementing a barrier is therefore to ensure that there is a sufficient volume upstream available for storing fluvial flows.

The feasibility of constructing a tidal barrier in the Owenacurra estuary to protect Midleton from tidal flooding was investigated at four separate locations as indicated in the figure below. The available storage volume upstream of each barrier location was calculated assuming that water can be stored to a level of 2.5mOD which corresponds to the assumed threshold of flooding along Bailick Road[7]. A high-level cost estimate for constructing a barrier at each location was also made.

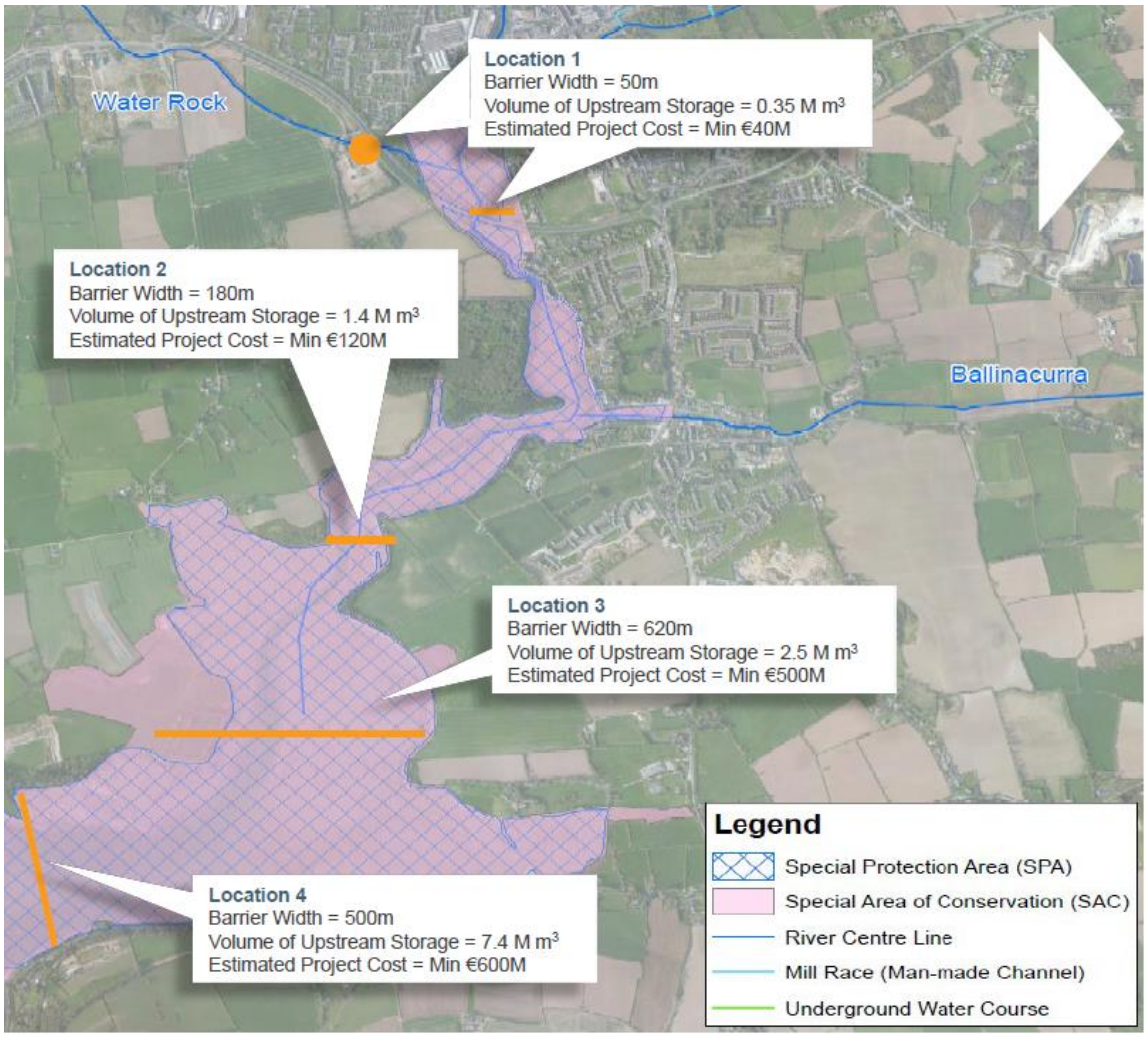


Figure 5 Potential Tidal Barrier Locations

Based on the observed hydrodynamics in Cork Harbour, a barrier would need to be closed for circa 6hrs to prevent tidal flooding of Midleton for each tidal flood event. The required volume of upstream storage is a function of the magnitude of the flow in both the Owenacurra and Dungourney rivers while the barrier is closed. Based on our hydrological analysis of the Q100 event it is estimated that circa 2.3M m^3 of upstream storage would be required in order to prevent fluvial flooding.

It can be seen from the figure below that a tidal barrier situated at Locations 1 and 2 does not have sufficient upstream storage to prevent fluvial flooding of Midleton while the barrier is closed. Both of these locations are therefore not deemed to be technically viable and have been ruled out. Location 3 and Location 4 however have sufficient upstream storage and are considered technically viable.

The width of the estuary at Location 3 is circa 620m. Assuming the tidal barrier has an average gated length percentage of 40%, the project costs of constructing a barrier at this location is estimated to be circa €500M. The project cost of constructing a barrier at Location 4, assuming the same gated length percentage, is estimated to be circa €600M.

[7] It is noted that some engineering works along Bailick Road would be needed to offer this level of protection.

While a tidal barrier situated at Location 3 or 4 may offer a technical solution to protect Midleton from tidal flooding, neither option is considered viable for a number of reasons:

1. A tidal barrier offers no direct protection against fluvial flooding. If a barrier were to be constructed, direct defences would therefore still be required to protect the areas of the town that are at risk from both fluvial flooding and tidal flooding, i.e. in the vicinity of The Baby Walk
2. The cost of constructing a barrier at Locations 3 or 4 is many times greater than the total economic benefit of the scheme. A tidal barrier in present day scenario has therefore an extremely negative benefit cost ratio.
3. The Owenacurra estuary is a designated SPA and SAC such that very significant environmental constraints would need to be addressed with the construction of a tidal barrier given the impact it would have on hydrodynamics, geomorphology and marine amenity.

For the above reasons, it was determined that a tidal barrier at these locations was not a viable measure for Midleton and has therefore not been considered as part of the detailed optioneering.

4.1.2.8 Tidal Barrier in Cork Harbour

An alternative option is the construction of a tidal barrier located in outer area of Cork Harbour that offers tidal flood protection to Cork City and other urban areas around the inner harbour i.e. a harbour wide tidal barrier solution. This is discussed in detail in the Lower Lee (Cork City) Flood Relief Scheme Supplementary Report – Option of Tidal Barrier[8] which provides detailed information in possible locations, constraints and considerations, likely impacts and costs. Of the four locations considered within the LLFRS Supplementary Report, only two would provide tidal flood protection to Midleton: either side of Great Island at Monkstown and Marlogue, and at Roches Point.

The report however found that a tidal barrier is not viable in any of the locations at the present time. It can also therefore be concluded that a harbour wide tidal barrier is not a viable measure for Midleton at the present time.

Furthermore the report also concluded that direct defences are the first step in a climate change strategy to manage flood risk in Cork City in the future and will form a key component of any future tidal barrier system if and when it may be implemented. The same principle also applies to Midleton such that any direct defences considered as part of the current scenario scheme will form part of any future strategy to manage future flood risk with a harbour wide tidal barrier.

4.1.3 Area 4 – Lauriston Estate / Rugby Club / East of IDL

Three of the seven measures brought forward for further assessment were considered viable for Area 4. Fluvial and groundwater sources are the cause of flooding in the area. Details of the assessment of potentially viable measures for the area are outlined below.

4.1.3.1 Natural Flood Management

Natural flood management was considered as a measure but determined not to be viable. Given the level of public interest in natural flood management, in particular during PPD2, it was decided to undertake an in-depth assessment of NFM as a potential solution. A Natural Flood Management Feasibility Study was conducted, the results of which are included in a report which is on the project website.

The study concluded that natural flood management would reduce peak flows by 6-10% depending on intervention type, at a cost of between €7 million and €15 million. The significant cost paired with the limited impact rendered this type of intervention neither technically nor economically feasible.

[8] Lower Lee (Cork City) Flood Relief Scheme Supplementary Report – Option of Tidal Barrier, December 2017

4.1.3.2 Upstream Storage

An assessment of the potential upstream storage available in Area 4 was carried out. However, the natural topography as well as land use, environmental and archaeological constraints upstream on the Dungourney made this measure unviable as a potential flood mitigation measure.

4.1.3.3 Direct Flood Defences

Direct defences may be a viable measure to mitigate against overland fluvial flooding from the Dungourney River. An embankment positioned across the floodplain to the north-east of the IDL site and connecting into high ground north and south could block overland flow and prevent the existing flood path which results in flooding of the Lauriston Estate and surrounding area. Under a section of this embankment, a sheet pile could be constructed to prevent groundwater from passing under the defence via the existing gravel aquifer and discharging from the springs on the Midleton Rugby Club lands.

4.1.3.4 Diversion Channels or Culverts

The use of diversion channels or culverts was not considered technically achievable due to the scale of flooding across a large area.

4.1.3.5 Conveyance Improvements/Dredging

Although conveyance improvements/dredging as an independent measure would not provide the required Standard of Protection, it may form part of an overall solution to resolve flooding in Area 4. For example, upgrading the existing sluice gate on the IDL Mill Race would restrict flow entering the IDL site which would reduce the risk of flooding.

4.1.3.6 Pumping

In order to reduce the impact of groundwater flooding in the Midleton Rugby Club which impacts Lauriston estate and the surrounding area, a pumping measure was assessed. This measure consisted of a pumping station within the grounds of Midleton Rugby Club which could alleviate groundwater flooding in the area.

4.1.3.7 Tidal Barrier

A tidal barrier would not be a suitable measure for Area 4 as the source of flooding in this area is primarily fluvial from the Dungourney River and groundwater flooding.

4.1.4 Area 5 – Ballinacurra

Four of the seven measures brought forward for further assessment were considered viable for Area 4. Details of the assessment of potentially viable measures for the area are outlined below.

4.1.4.1 Natural Flood Management

Due to a lack of available data, the Ballinacurra catchment was excluded from the additional natural flood management analysis. However, a high level assessment found that this measure on its own would not provide the target Standard of Protection for Area 5. Furthermore, if this measure was used as an ancillary measure alongside other viable measures there would be minimal impact on the design levels.

4.1.4.2 Upstream Storage

The feasibility of upstream storage for the area was examined. An area of agricultural land was identified to the east of Ballinacurra which was deemed suitable for flood water storage. Embankments would be required to maximise the storage area volume. A flow control structure would be utilised to restrict flows in the watercourse, protecting Ballinacurra downstream. The option would eliminate the need for direct defences in the urban area.

4.1.4.3 Direct Defences

The use of direct defences for the area was assessed. Flood defence walls would be required along the banks of the watercourse, including in residential gardens. An embankment would also be necessary in the field at Kearney's Cross, with channel realignment also proposed. The existing non-return valve at the watercourse outlet to the estuary would be maintained and upgraded.

4.1.4.4 *Diversion Channels or Culverts*

An assessment of a flood diversion culvert was carried out to determine the feasibility of diverting flows from the Ballinacurra Stream at Kearney's Cross, constructing a culvert beneath Lower Road and Bransfield Green, before discharging the flow into the Owenacurra Estuary. This was determined not to be technically viable due to the significant number of clashes with existing services/utilities and the environmental impacts of the in-stream construction works. The alignment of the proposed diversion culvert is presented in Figure 6. It was not found to be technically viable.

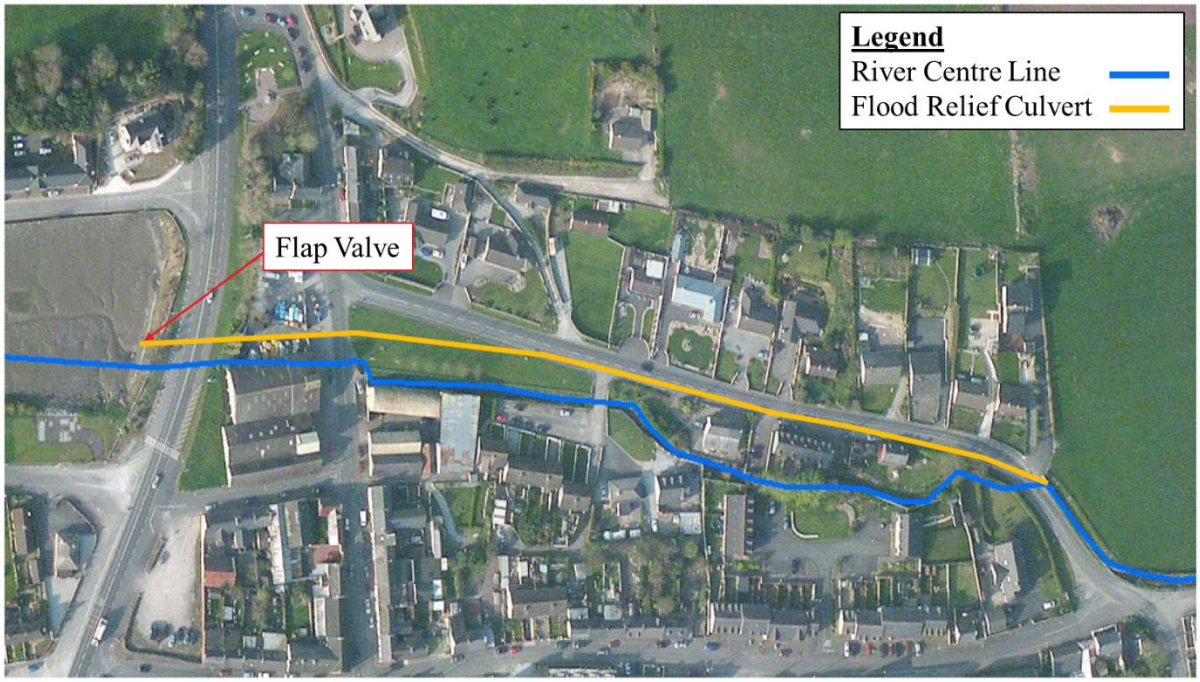


Figure 6 Flood diversion culvert Ballinacurra

4.1.4.5 *Conveyance Improvements/Dredging*

Conveyance improvements/dredging would not provide the required Standard of Protection due to the space constraints in the area.

4.1.4.6 *Pumping*

In combination with other viable measures, a pumping station at Bransfield Green could be installed to ensure fluvial flows could be over-pumped into the estuary during high tides when the existing culvert is "tide locked". However, pumping as a standalone measure would not be technically viable.

4.1.4.7 *Tidal Barrier*

A tidal barrier would not be a suitable measure for Area 5 as the source of flooding in this area is primarily fluvial from the Ballinacurra Stream.

4.1.5 Area 6 – Water Rock (including Dwyer's Road)

Four of the seven measures brought forward for further assessment were considered viable for Area 6. Details of the assessment of potentially viable measures for the area are outlined below.

4.1.5.1 *Natural Flood Management*

Due to a lack of available data, the Water Rock catchment was excluded from the additional natural flood management analysis. However, a high-level assessment found that this measure on its own would not provide the target Standard of Protection for Area 6. Furthermore, if this measure was used as an ancillary measure alongside other viable measures there would be minimal impact on the design flood levels.

4.1.5.2 Upstream Storage

A potential area upstream of the cave system was assessed to determine if an upstream storage measure could provide a solution to flooding in the area. The potential upstream area is shown in Figure 7 below.

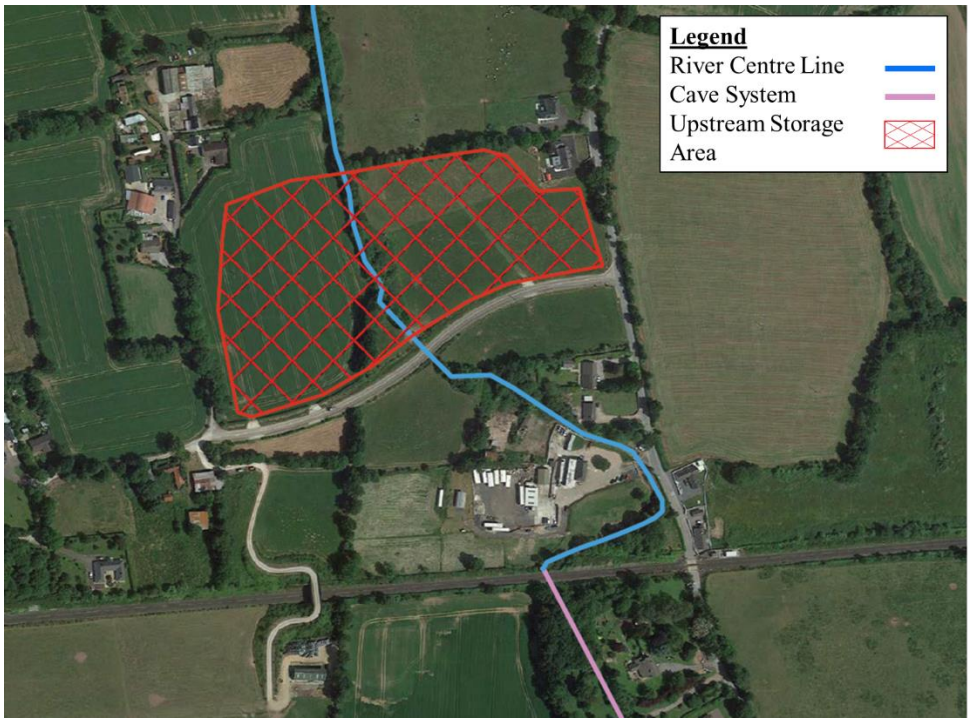


Figure 7 Water Rock potential upstream area

It was found that this measure was not viable for the following reason:

- The capacity of the cave system is likely to be severely compromised in a major flood event due to elevated groundwater levels. The watercourse may therefore be unable to discharge into the cave such that the upstream storage area would be required to store the full volume of the design hydrograph, circa 205,000m^3. As the available volume offered by the storage area (circa 120,000m^3) is less than the required volume, the Standard of protection is not provided and the option is not deemed to be viable.

4.1.5.3 Direct Flood Defences

Direct defences upstream of the cave system were determined not to be a technically viable solution. This area features a complex cave system which has an indeterminable storage capacity for flood waters. When the cave system reaches capacity, the water is restricted from entering the system, resulting in flooding to the surrounding area. Direct defences upstream would require walls greater than 3.5m high, which would be considered excessively high given the residential setting. In addition, the assessment noted that groundwater flooding in the area may not be prevented. As such, it was determined that this was not a technically feasible measure as it does not achieve the required standard of protection.

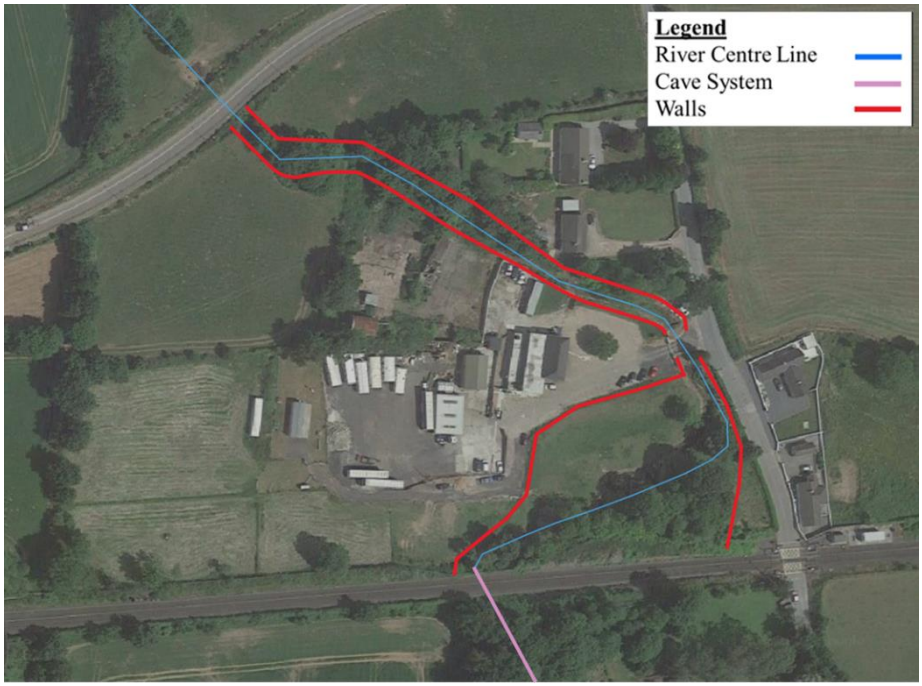


Figure 8 Direct defences (upstream of the cave system)

Direct defences downstream of the cave system (south of the N25) are considered to be a viable measure. These defences may include an embankment to protect residential properties at the cave system outlet, an embankment located north-west of the wastewater treatment plant, with flood waters naturally stored behind it when high-tide conditions are present and an embankment defending Dwyer's Road during periods of high-tide.

4.1.5.4 Diversion Channels or Culverts

The use of flood diversion channels/ culverts to mitigate against flooding in the area was investigated. A number of potential diversion channels/culverts arrangements were assessed for both the area upstream and downstream of the cave system.

Culvert under the existing railway line west of Water Rock House

A culvert under the existing railway line west of Water Rock House was assessed. During flood events residual water could enter a diversion channel which would connect to the culvert. This measure is presented in Figure 9 below.

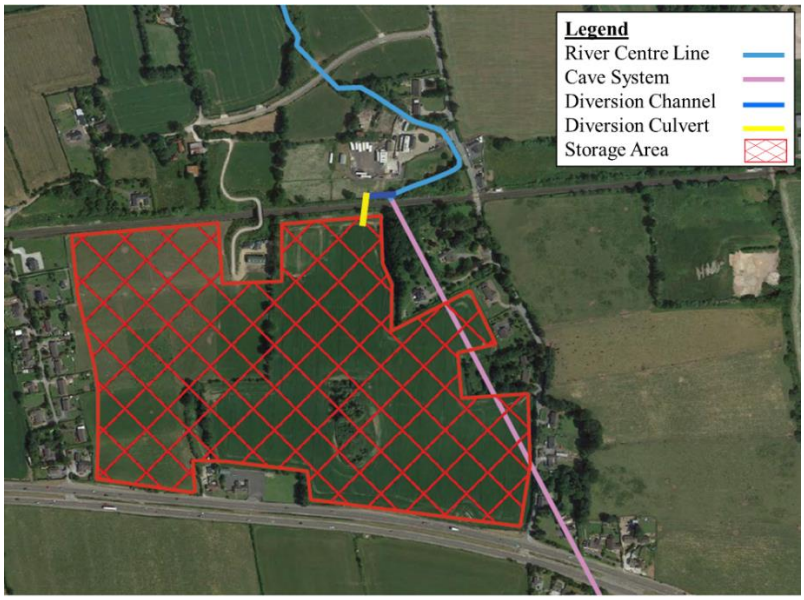


Figure 9 Culvert under railway line to west of Water Rock House

The assessment determined this measure was not viable for the following reasons:

- Standard of protection is not provided due to an insufficient volume offered by the storage area. It is noted that the available storage volume is limited by water spilling back into the site of Water rock house
- Introduction of flood risk to properties to the west, requirement for additional defences
- Difficulty draining the land following flood event
- Flood warning system not feasible
- Construction under railway line required

Culvert east of Water Rock House to the south under the N25

An alternative flood diversion channels/culverts arrangement was also considered. During periods when the cave system is at capacity, this measure would allow flow to bypass the Water Rock cave system via a series of channels and culverts and discharge south of the N25 back into the Water Rock stream. This potential measure is presented in Figure 10.

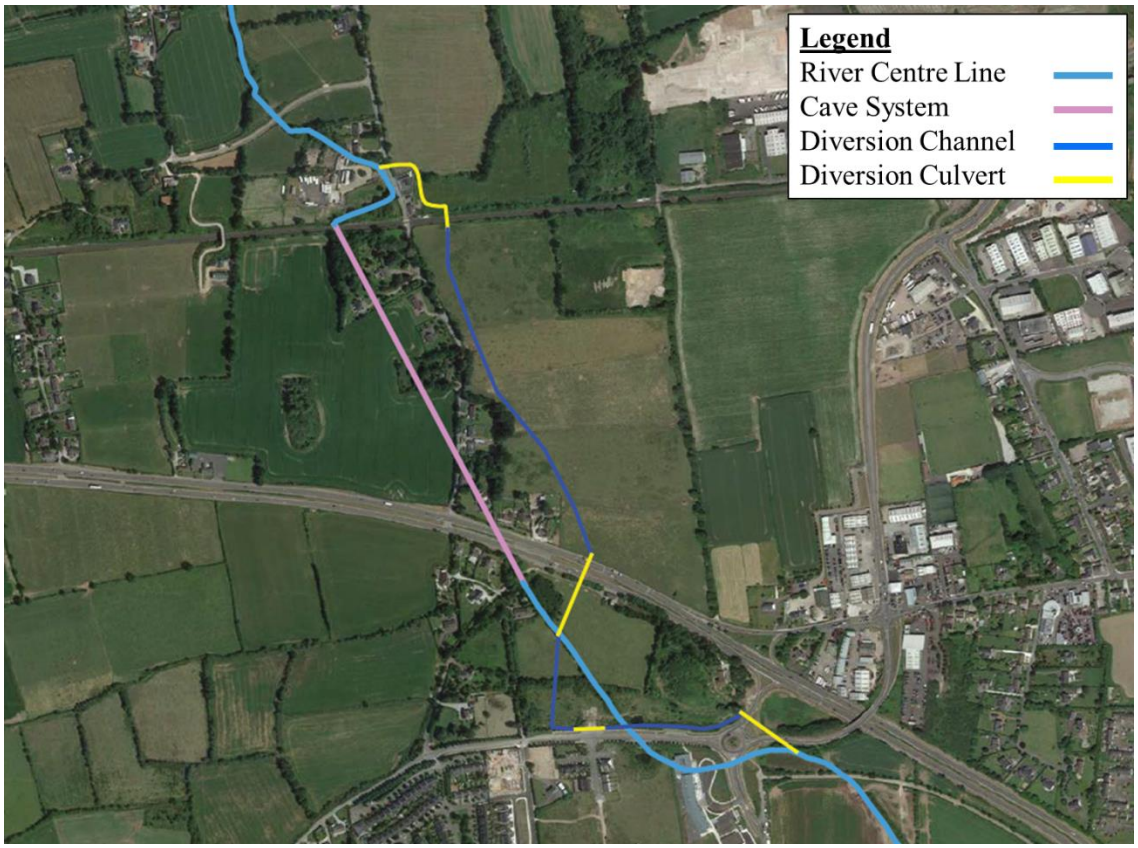


Figure 10 Flood diversion channel/culvert to the south discharging downstream of the cave system

It was considered that this measure is potentially viable.

Culvert east of Water Rock House to discharge into the Owenacurra

A third flood diversion channels/ culverts arrangement was developed and assessed. This measure consists of a flow control structure which could divert flows from the Water Rock Stream to the east via a series of culverts and open channels, and ultimately discharge into the Owenacurra River. Two alternative alignments were developed:

- Alignment north of the existing Midleton-Cork rail line through the North Point Business Park
- Alignment passing under the rail line and parallel in an easterly direction south of the rail line

These alignments are presented in Figure 11. The concept of both alignments is the same: during periods of flooding excess water would be diverted away from the Water Rock House area.

Downstream of the cave system would also benefit as the measures would involve a reduction in water entering the cave system and hence reduce the likelihood of flooding occurring downstream.

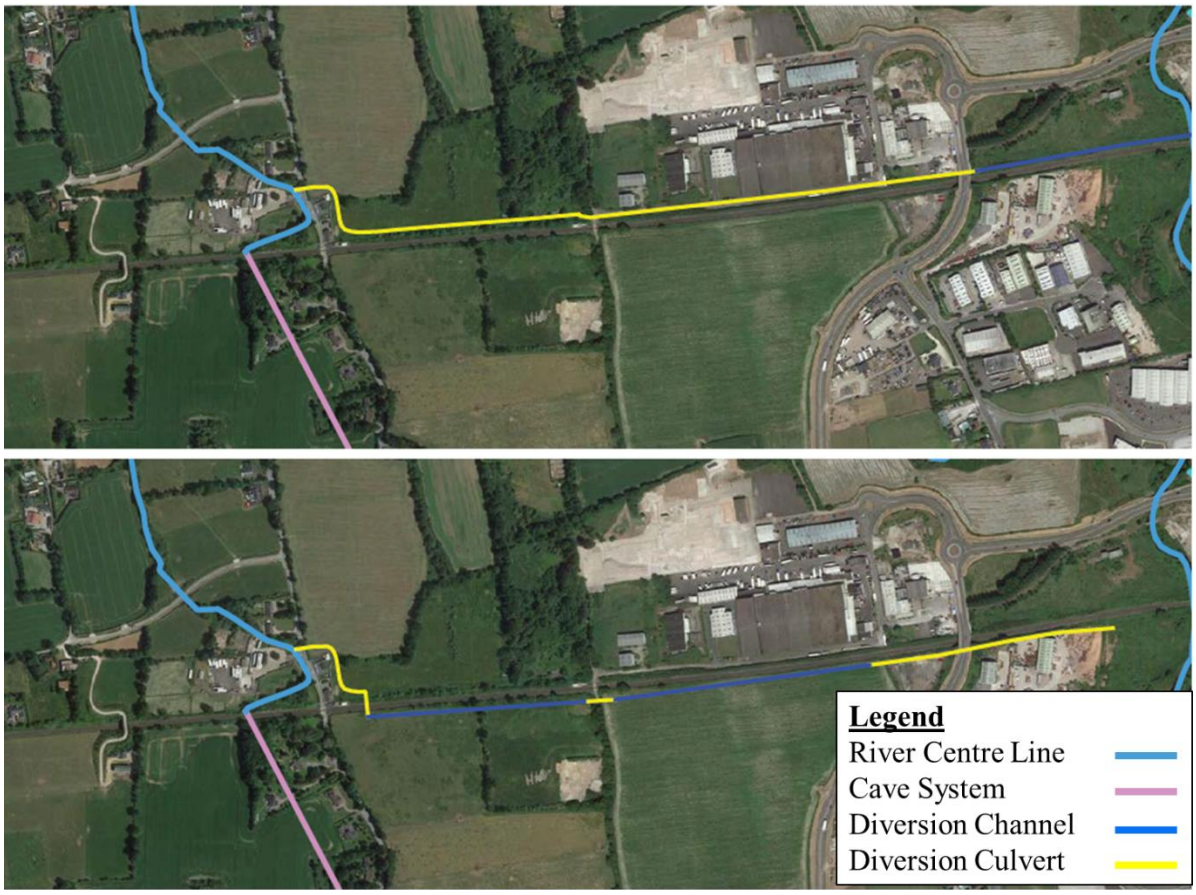


Figure 11 Flood diversion channel/ culvert to the east discharging into the Owenacurra

It was considered that this measure is potentially viable.

Culvert within Wastewater Treatment Plant

A culvert measure was also assessed for the area downstream of the cave system. This measure consists of replacing the existing open channel in the vicinity of the wastewater treatment plant with a culvert to protect the area. This measure was considered to be viable and may form part of a flood relief solution in this area.

4.1.5.5 Conveyance Improvements/Dredging

Geo engineering measures were assessed as a way to alleviate flooding upstream of the cave system. The measures considered to improve the conveyance through the cave system included:

- Horizontal Directional Drilling (HDD) to form a direct connection between the swallow hole and the spring;
- Localised directional drilling at the swallow hole and spring to improve localised conveyance at the entrance and exit to the karst system;
- Grid of vertical borehole drilling along the flow path with well stimulation and acidification to improve the karst fracture network connectivity.

These measures were not however considered viable for the following reasons:

- Significant costs, resulting in measures that are not cost beneficial;
- Significant construction complexity;
- Potential environmental impacts;

- Difficult to confirm the Standard of Protection with the works in place

4.1.5.6 Pumping

Pumping of fluvial flood water back into the rivers or floodplains and away from properties was not considered technically achievable in Area 6 due to the scale of flooding across a large area. Downstream of the Water Rock Stream is predominantly impacted by tidal flooding, due to the nature of tidal flooding, pumping is not technically achievable in this area. For these reasons, pumping was not considered as a viable measure in this area.

4.1.5.7 Tidal Barrier

A tidal barrier would not be a suitable measure for Area 6 as the source of flooding in this area is primarily fluvial from the Water Rock Stream.

4.2 Conclusion of the Further Assessment of Potentially Viable Measures

Following the further assessment, the potential measures considered to meet the project objectives are outlined below:

Table 9 Summary of potentially viable measures by area

Potentially Viable Measures	Area 1&2: Tír Cluain to Riverside Way	Area 3: Town Centre and Bailick Road	Area 4: Lauriston / Rugby Club / East of IDL	Area 5: Ballinacurra	Area 6: Water Rock (including Dwyer's Road)
Upstream Storage	Y			Y	
Direct Flood Defences	Y	Y	Y	Y	Y
Diversion Channels / Culverts					Y
Conveyance Improvements / Dredging	Y				
Pumping			Y	Y	

The measures which were progressed through the screening stage will be combined to create potential flood relief options which will manage the flood risk and achieve the scheme objectives. The following section further develops the potentially viable measures into reasonable alternatives.

5. Development and Description of Reasonable Alternatives

5.1 Introduction

Most measures, whilst providing some reductions in flood risk, will not manage the flood risk entirely by themselves and achieve the objectives set by the study. Measures which have progressed through the screening stage and meet the project objectives therefore need to be combined in order to create reasonable alternatives/ options.

Additional assessments were undertaken in Areas 4, 5 and 6 following the Public Participation Day No. 2 (PPD2), which took place in March 2020. These assessments were undertaken due to additional information becoming available to the project after this date and include:

- constraints arising out of interacting infrastructure projects;
- feedback from the stakeholders on the technical, environmental and cultural heritage constraints in the areas.

This additional information resulted in the development of additional options in these areas.

The reasonable alternatives developed for each area are listed as:

Area 1&2: Tír Cluain to Riverside Way

Option 1&2A: Direct defences with conveyance improvements along the Owenacurra River

Option 1&2B: Direct defences

Option 1&2C: Combination of direct defences and upstream storage in Water Rock Golf Course and adjacent fields

Area 3: Town Centre and Bailick Road

Option 3A: Direct defences (only option deemed reasonable for this area)

Area 4: Lauriston Estate/Rugby Club

Option 4A: Groundwater cut-off and direct defences east of the current IDL site

Option 4B: Pumping and direct defences

Option 4C: Combine flood embankment with planned Northern Relief Rd Extension (NRRE) road embankment with embankment at Greenway crossing

Option 4D: Combine flood embankment with planned Northern Relief Rd Extension (NRRE) road embankment with flood barrier at Greenway crossing

Option 4E: Groundwater cut-offs and direct defences east of the current IDL site and along Greenway to mitigate impact on NRRE

Area 5: Ballinacurra

Option 5A: Direct defences

Option 5B: Upstream storage and over pumping

Option 5B-1: Upstream storage – Refined storage area (smaller footprint than Option 5B) and over pumping

Option 5C: Optimised direct defences and over pumping

Option 5D: Optimised direct defences, upstream storage and over pumping

Area 6: Water Rock (including Dwyer's Road)

Option 6A: Flood diversion channel / culvert (north of railway line) to the Owenacurra and direct defences

Option 6B-1: Flood diversion culvert (south of railway line) to the Owenacurra and direct defences

Option 6B-2: Flood diversion channel / culvert (south of railway line) to the Owenacurra and direct defences

Option 6C: Flood diversion channel / culvert (bypassing cave system) to the Water Rock stream and direct defences

5.2 Description of Reasonable Alternatives

The potential flood relief options / reasonable alternatives for each of these areas are presented below. For the purpose of the initial development and assessment of the reasonable alternatives, a fixed freeboard level was assumed across all options. A detailed freeboard assessment was undertaken for the Emerging Preferred Scheme and is included in Section 10.

In some locations the proposed defences may obstruct existing pluvial flow paths, i.e. the route rain water takes when discharging into rivers. At these locations pumping stations would be required to over pump pluvial water during times when intense rainfall and high water levels on the river coincide. The majority of pumping stations proposed as part of these options are required to mitigate the effects of pluvial flooding and would only operate during a flood event if required. In Areas 4 and 5, pumping stations are however also proposed to mitigate against groundwater flooding and tidal locking respectively. These are described in more detail within the option in the following sections of the report.

Where flood defence works are located in proximity to existing or known proposed utilities, the design of the option will have to take account of these utilities where necessary. Diversions will be required to facilitate these works.

5.2.1 Climate Change Adaptability

For each reasonable alternative, the potential for adaptability to climate change has been assessed using the following criteria:

- Adaptability in the future and ideally to multiple adaptation pathways with flexibility to respond to multiple climate change scenarios and timelines;
- maintaining the required standard of protection at an acceptable cost if possible;
- to not impede any future interventions,

Two general approaches can be taken to manage future flood risk:

- Assumptive Approach: designing the current scheme to account for an assumed increased in flood risk associated with a future flood risk scenario i.e. increasing the height of defences to account for future seal level rise;
- Adaptive Approach: undertaking regular interim modifications of the scheme after it is constructed in order to maintain the target standard of protection as flood risk increases due to climate change.

Both approaches have been considered as part of the optioneering for the project.

5.3 Area 1&2: Tír Cluain to Riverside Way

Area 1 and 2 is situated north of Midleton Town Centre and covers the upper reach of the Owenacurra as well as the Glenathonacash and the Owenacurra Millrace. This area includes Tir Cluain, Moore's Bridge, Willowbank, Millbrook, the Northern Relief Road, Midleton Train Station, the Railway Cottages, Cork Road Bridge and extends to Riverside Way.

A decision was made to group Areas 1&2 together, as the options deemed feasible for both areas were the same and could be linked together to offer a comprehensive solution.

The extent of flooding for the current 1% AEP fluvial event and the 0.5% AEP tidal event in this area is shown in Figure 12 below.

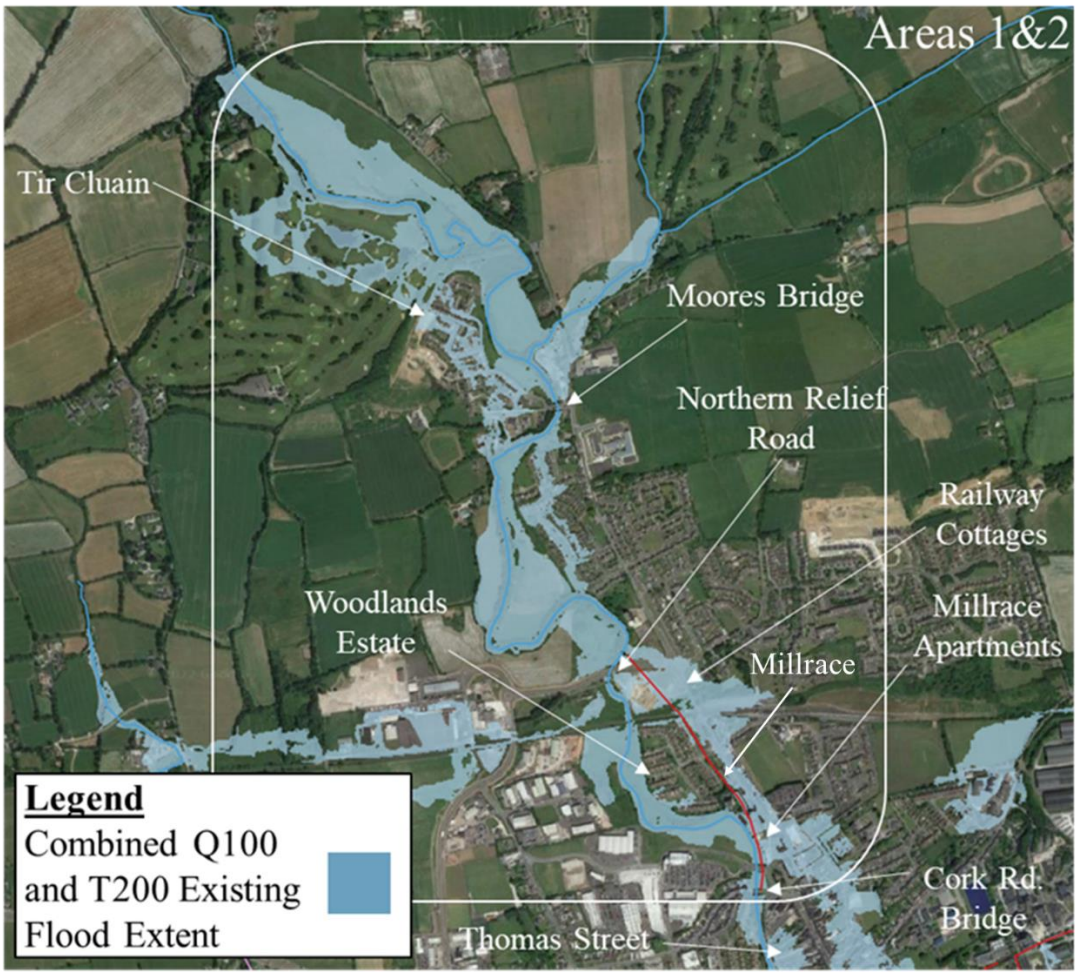


Figure 12 Areas 1 and 2- Max flood extent 1% AEP fluvial event and the 0.5% AEP tidal event

5.3.1 Option 1A and 2A – Direct Defences and Conveyance Improvements

The proposed direct defences and conveyance improvements from Tír Cluain to Riverside Way are presented in Figure 13 and Figure 14. A summary of the proposed interventions and existing constraints is provided in Table 10.

As can be seen in the figures, the works would involve the construction of a 1.1m embankment upstream of the bridge along the R626 road, on the south side of the Glenathonacash River. The bridge would be replaced, with the existing embankment downstream being upgraded to 2m high. This would offer protection to the residential properties and businesses south of Broomfield Ridge Road, as well as those situated between the river and the R626 road. Two pumping stations would also be introduced in this area.

A 1.2m high embankment is proposed on the western side of Tír Cluain, with a smaller 0.4m high embankment or local regrading being proposed along Riverwalk Road. These embankments would prevent flood water from entering the residential area by containing it to the existing green areas and Water Rock Golf Course, which is already at risk of flooding.

Moore's Bridge would be removed, with an alternative vehicle access arrangement introduced. This would involve the removal of a section of wall between Tír Cluain - The Lawn and local private road. Two new walls would be introduced either side of the river downstream from the Tír Cluain Bridge. These would be 1.1m high to the west and 0.7m high to the east.

Significant dredging works to deepen and widen the channel at river bend thereafter would also be required, with the channel being widened by 8m and deepened by 1m at maximum extents. This option would require regular maintenance that would see dredging in the area downstream of Moore's Bridge on a routine basis to maintain the conveyance improvement.

This option continues with the replacement of a 1.0m high wall along the riverbank south of the Brook Lane Vella Homes estate. A flow control structure would be added to limit the water flow entering the mill race during flood events. A minor bridge downstream of the Northern Relief Road would be removed, with the inclusion of a pumping station and additional 1.0m high wall that ties into the retained bridge parapet to the north and the railway embankment to the south. The embankment at the back of the Millbrook estate would be upgraded to 0.7m high. A 0.5m wall would be constructed from the proposed embankment to the existing Market Green bridge parapet downstream, along the eastern side of the river. A fourth pumping station would be located behind the wall.

A 0.8m high wall is required between the Market Green bridge and the Cork Road Bridge on the western side downstream. A 0.5m high wall would be constructed on the western side downstream, offering protection to the residential areas. A fifth pumping station would be located in a grassed area of The Woodlands estate, behind the wall. A 0.4m high embankment/regrading is required on the western side of the bank downstream, along Riverside Way for circa 160m.

5.3.1.1 Option 1A and 2A – Climate Change Adaptability

This option was found to be readily adaptable with limited difficulty, cost and impact. The option provides no impediment to future interventions to address future risk.

An adaptive approach can be taken by designing the direct defences to permit an acceptable extension in height in the future in order to maintain the required level of protection. The required standard of protection can also be achieved through other means such as upstream storage instead of increasing wall heights.

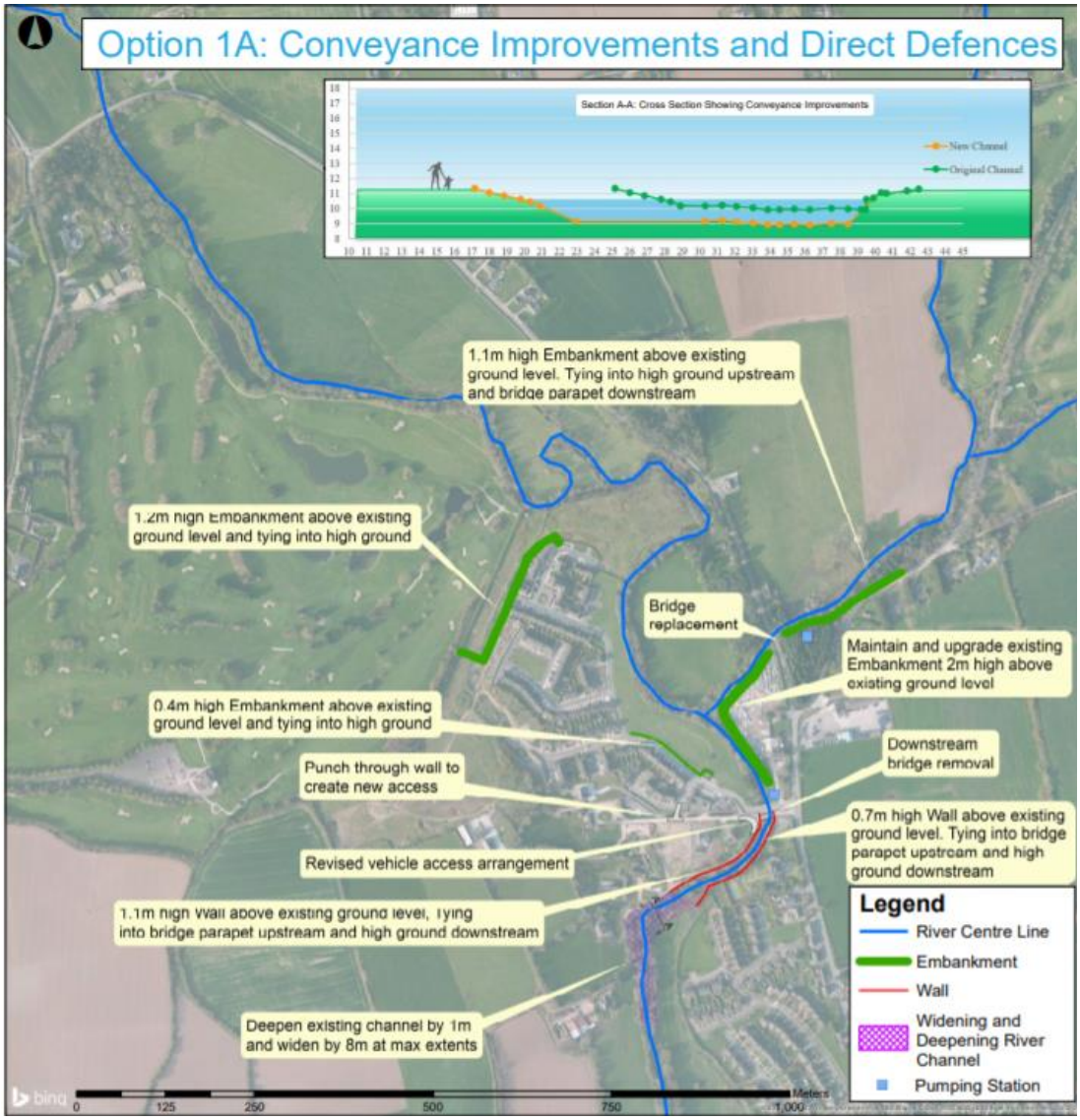


Figure 13 Option 1A – Conveyance Improvements and Direct Defences

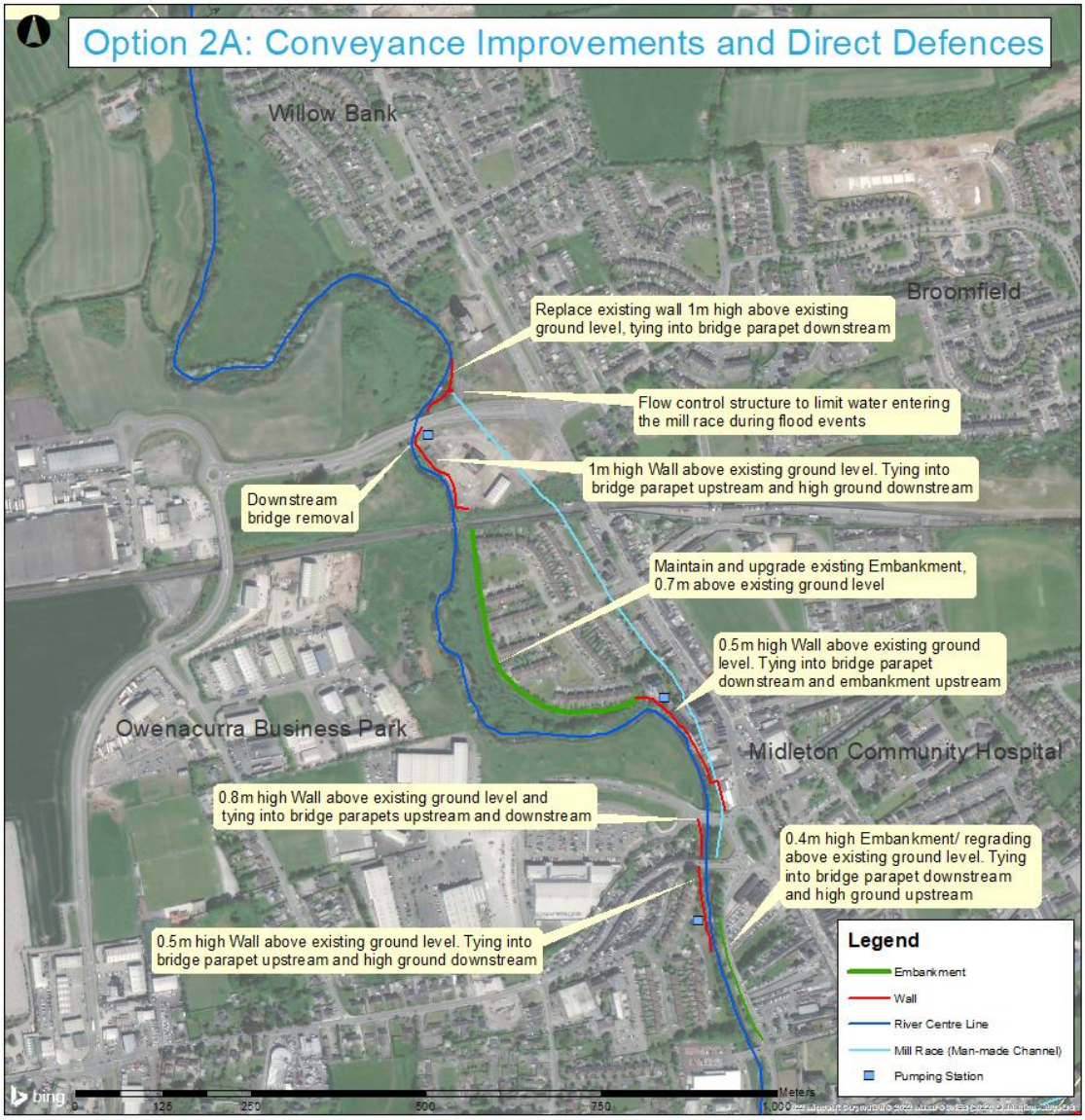


Figure 14 Option 2A – Conveyance Improvements and Direct Defences

Table 10 Description of Option 1A and 2A- Conveyance Improvements and Direct Defences

Description of proposed works	Comments
Glenathonacash	
1.1m high, 187m long embankment at Broomfield Ridge	In-stream works. Removal of vegetation / trees. Proximity to ESB assets.
2.0m high, 275m long embankment at Clohessy's Yard, upgrade of R626 bridge upstream of Clohessy's Yard	In-stream works. Removal of vegetation / trees. Proximity to ESB assets. Social impact.
Owenacurra	
1.2m high, 251m long embankment at the rear of Tír Cluain.	Removal of vegetation / trees. Proximity to ESB assets
0.4m high, 139m long embankment embankment/ local re-grading in Tír Cluain	Removal of vegetation / trees
Removal of Moore's Bridge and revised vehicle access.	In-stream works. Social impact.
0.7m high, 181m long sheet pile wall on the left bank downstream of Moore's Bridge.	In-stream works. Removal of vegetation / trees. Proximity to Cloonmullin House
1.1m high, 179m long sheet pile wall on the right bank downstream of Moore's Bridge.	In-stream works. Removal of vegetation / trees. Proximity to ESB assets.
Widening and deepening of the Owenacurra River by 8m wide and 1m deep at maximum extents.	In-stream works. Regular dredging required. Disposal of dredged material. Proximity to ESB assets.
Replacement of an existing wall with a 1.0m high, 99m long sheet pile north of the Northern Relief Road.	In-stream works. Removal of vegetation / trees.
Installation of a flow control structure at the Owenacurra mill race entrance north of the Northern Relief Road.	In-stream works. Removal of vegetation / trees.
1.0m high, 156m long sheet pile wall on the left bank downstream of the Northern Relief Road.	In-stream works. Removal of vegetation / trees
Removal of access bridge south of the Northern Relief Road.	In-stream works. Disposal of material Removal of vegetation / trees.
Upgrade of the 0.7m high, 424m long embankment at the rear of Millbrook.	In-stream works. Removal of vegetation / trees. Proximity to ESB assets. Impact to existing stone wall.
Replacement of an existing wall with a 0.5m high, 228m long sheet pile wall at the rear of River Wharf	In-stream works. Removal of vegetation / trees. Proximity to IW assets.

Description of proposed works	Comments
0.8m high, 54m long reinforced concrete wall between the Market Green bridge and Cork Road Bridge.	Removal of vegetation / trees. Proximity to IW assets.
0.5m high, 124m long reinforced concrete wall on the right bank at The Woodlands.	Removal of vegetation / trees.
0.4m high, 160m long embankment/ regrading on the left bank at Riverside Way.	Removal of vegetation / trees.
5No pumping stations at various locations as identified.	Regular maintenance required.

5.3.2 Option 1B and 2B – Direct Defences Only

The proposed direct defences only option from Tír Cluain to Riverside Way are presented in Figure 15 and Figure 16. A summary of the proposed interventions and existing constraints is provided in Table 11.

As can be seen from the figures, the works would involve the construction of a 2.0m embankment upstream of the bridge along the R626 road, on the south side of the Glenathonacash River. The embankment downstream of the bridge would be upgraded to 2.0m high. This would offer protection to the residential properties and businesses south of Broomfield Ridge Road, as well as those situated between the river and the R626 road. Two pumping stations would also be introduced in this area.

A 1.2m high embankment is proposed on the western side of Tír Cluain, with a smaller 0.4m high embankment or local regrading being proposed along Riverwalk Road. These embankments would prevent flood water entering the residential area by containing it to the existing green areas and Water Rock Golf Course, which is already at risk of flooding.

At Moore's Bridge, the upstream and downstream parapets would be raised. A new 1.2m high wall on the upstream side of the bridge would tie into the new parapet, while on the downstream side, two new walls of 0.7m and 1.1m height would connect to the new parapet and extend approximately 180m downstream.

Option 1B and 2B continues with the replacement of a 1.0m high wall along the riverbank south of the Brook Lane Vella Homes estate. A flow control structure would be added to limit the water flow entering the mill race during flood events. A pumping station and 1.0m high wall would be constructed south of Northern Relief Road. The embankment at the back of Millbrook estate would be upgraded to 0.7m high, separating it from the Owenacurra River.

A 0.5m wall would be constructed from the proposed embankment to the existing Market Green bridge parapet downstream, along the eastern side of the river. A fourth pumping station would be constructed behind the wall.

A 0.8m and 0.5m high wall would be constructed on the western side downstream, offering protection to the residential areas. A fifth pumping station would be located in a grassed area of The Woodlands estate, behind the wall. A 0.4m high embankment/regrading is required on the eastern side of the bank downstream, along Riverside Way for circa 160m.

5.3.2.1 Option 1B and 2B – Climate Change Adaptability

This option was found to be readily adaptable with limited difficulty, cost and impact. The option provides no impediment to future interventions to address future risk.

An adaptive approach can be taken by designing the direct defences to permit an acceptable extension in height in the future in order to maintain the required level of protection. The required standard of protection can also be achieved through other means such as upstream storage instead of increasing wall heights.

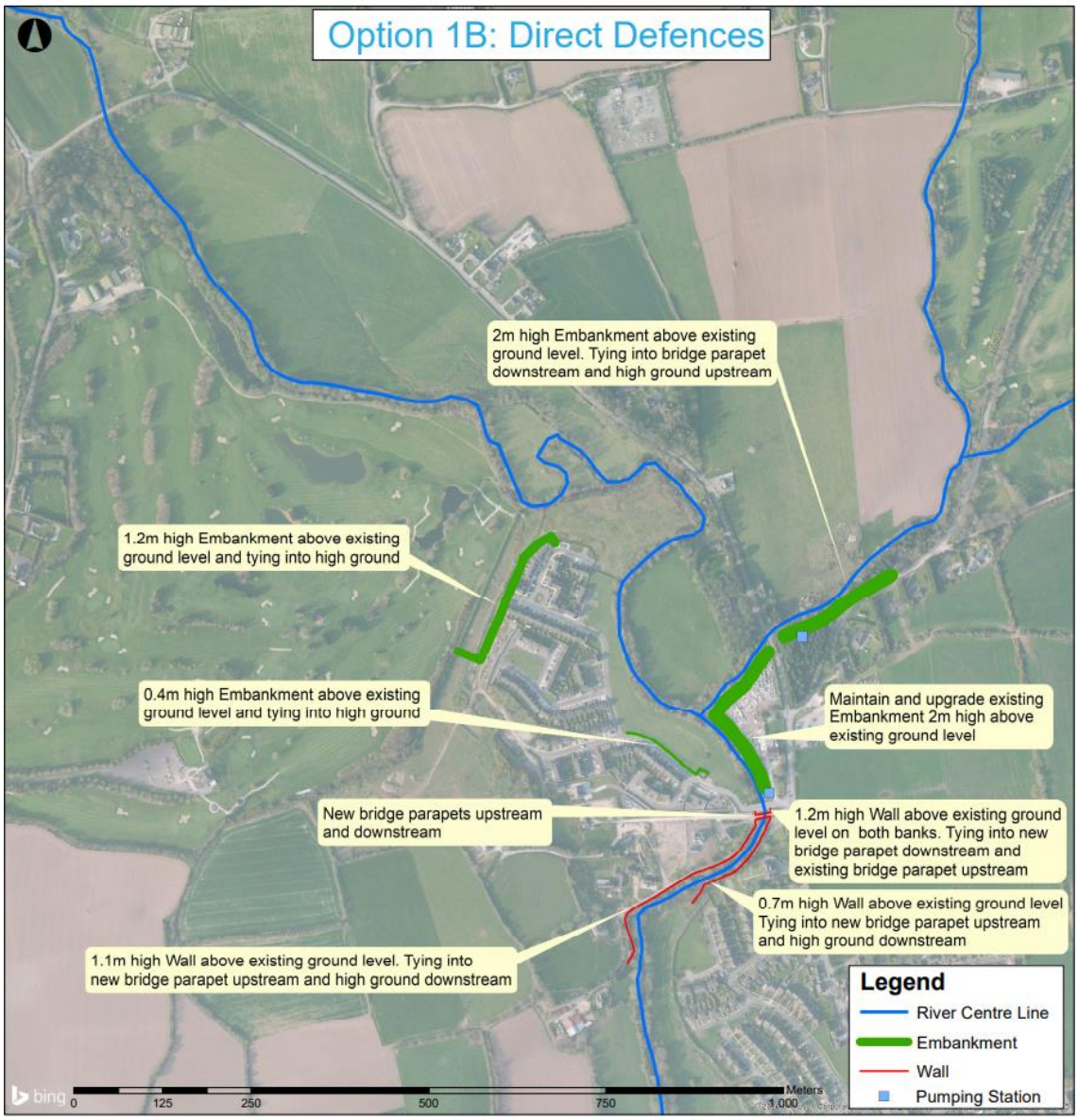


Figure 15 Option 1B – Direct Defences

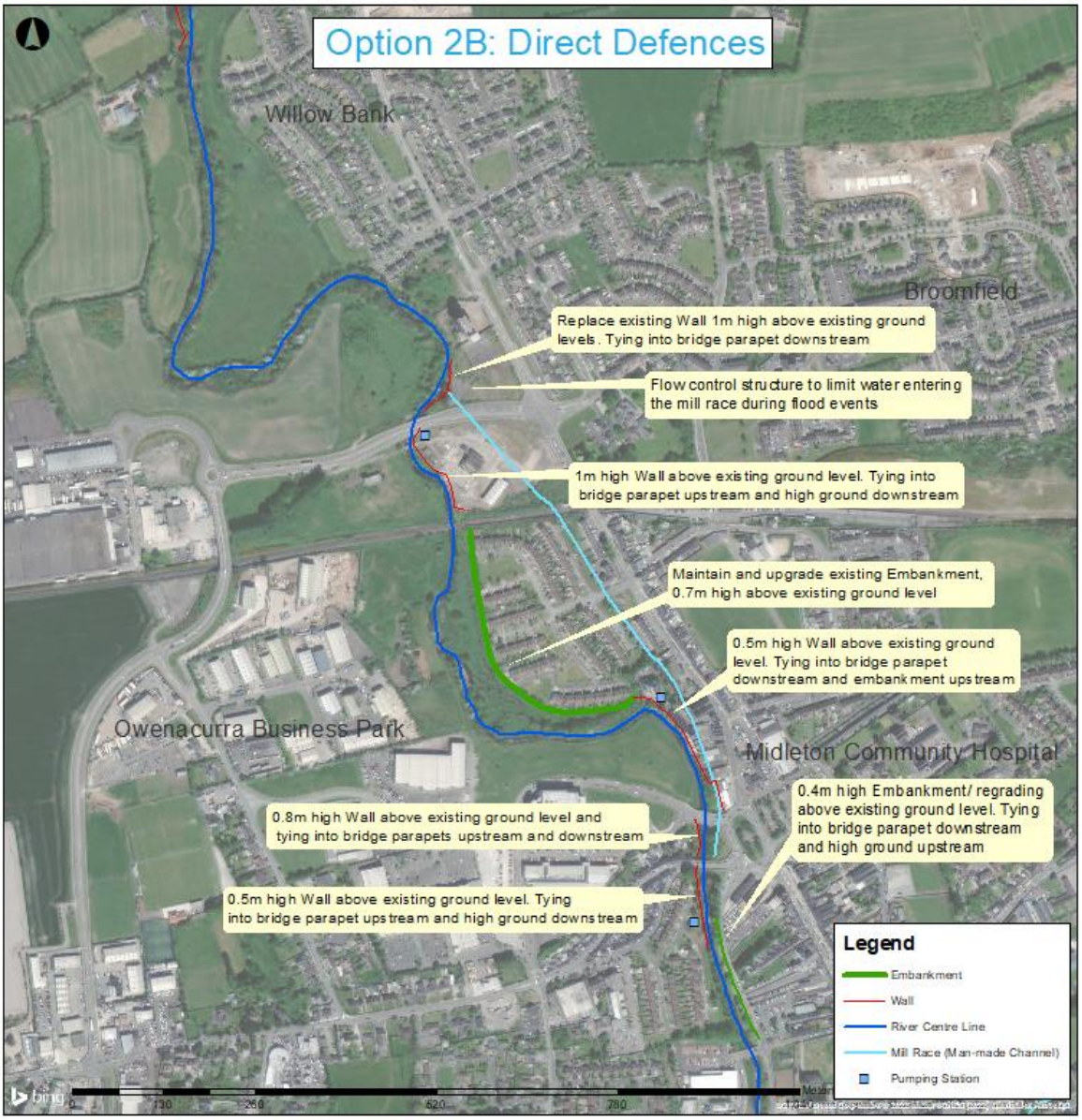


Figure 16 Option 2B – Direct Defences

Table 11 Description of Option 1B and 2B – Direct Defences

Description	Comments
Glenathonacash	
2.0m high, 187m long embankment at Broomfield Ridge.	In-stream works. Removal of vegetation / trees. Proximity to ESB assets.
2.0m high, 275m long embankment at Clohessy's Yard.	In-stream works. Removal of vegetation / trees. Proximity to ESB assets.
Owenacurra	
1.2m high, 251m long embankment at the rear of Tír Cluain.	Removal of vegetation / trees. Proximity to ESB assets
0.4m high, 139m long embankment embankment/ local re-grading in Tír Cluain	Removal of vegetation / trees
Parapet upgrades on Moore's Bridge	In-stream works
0.7m high, 173m long sheet pile wall on the left bank downstream of Moore's Bridge.	In-stream works. Removal of vegetation / trees. Proximity to Cloonmullin House
1.1m high, 311m long sheet pile wall on the right bank downstream of Moore's Bridge.	In-stream works. Removal of vegetation / trees. Proximity to ESB assets.
Replacement of an existing wall with a 1.0m high, 99m long sheet pile north of the Northern Relief Road.	In-stream works. Removal of vegetation / trees.
Installation of a flow control structure at the Owenacurra mill race entrance north of the Northern Relief Road.	In-stream works. Removal of vegetation / trees.
1.0m high, 156m long sheet pile wall on the left bank downstream of the Northern Relief Road	In-stream works. Removal of vegetation / trees. Disposal of material
Upgrade of the 0.7m high, 424m long embankment at the rear of Millbrook.	In-stream works. Removal of vegetation / trees.
Replacement of an existing wall with a 0.5m high, 228m long sheet pile wall at the rear of River Wharf	In-stream works. Removal of vegetation / trees. Proximity to ESB assets. Impact to existing stone wall.
0.8m high, 54m long reinforced concrete wall between the Market Green bridge and Cork Road Bridge.	In-stream works. Removal of vegetation / trees. Proximity to IW assets.
0.5m high, 124m long reinforced concrete wall on the right bank at The Woodlands.	Removal of vegetation / trees. Proximity to IW assets.
0.4m high, 160m long embankment/ regrading on the left bank at Riverside Way.	Removal of vegetation / trees.
5No pumping stations at various locations as identified.	Regular maintenance required.

5.3.3 Option 1C and 2C – Upstream Storage and Direct Defences

The proposed upstream storage and direct defences option from Tír Cluain to Riverside Way is presented in Figure 17 and Figure 18. A summary of the proposed interventions and existing constraints is provided in Table 12.

As can be seen in the figures, works would involve the construction of a 2.0m embankment upstream of the bridge along the R626 road, on the south side of the Glenathonacash River. This would offer protection to the residential properties and businesses south of Broomfield Ridge Road. A single pumping station would also be introduced in this area.

The storage area would be located on the Owenacurra River and would consist of a 3.0m high embankment along the southern side of the R626 Road, beginning from west of the junction with the L3601 Road before cutting across the existing agricultural land and running between the western side of Tír Cluain and the Water Rock Golf Course. A flow control structure to limit water flowing downstream during a flood event would be constructed within the embankment. Some local realignment of the river channel where it meanders would occur just beyond the downstream section of the embankment.

Two 3m high embankments would be constructed on Water Rock Golf Course, adjacent to the neighbouring properties to the west, with a 0.7m high embankment running adjacent to the Owenacurra River on its southern side, which would tie into the main embankment in the east. This smaller embankment would limit the occurrence of flooding to the golf course during lesser flood events but would overtop by design for the design flood event.

The storage area would see up to approximately 105,000m^2 of agricultural land and 170,000m^2 of Water Rock Golf Course land being inundated during Q100 design flood event. While the extent of downstream works is reduced by this option, some defences adjacent to the channel remain necessary.

From an operational perspective, the option could be designed to be either an “active” or “passive” system. Active systems require manual intervention, while passive systems can operate based on fixed design parameters without any additional intervention. Should an active system be considered, a flood forecasting and water level monitoring system would be required to indicate when the storage is required, and the flow control structure is to be put into operation. Upstream gauges would need to be installed to inform this flood forecasting system. Maintenance requirements would likely be significant to ensure that functionality was maintained. Active controls, such as actuated gates or valves, would need to be routinely serviced alongside the ancillary components which inform its operation. This would include visual inspections, monitoring of motor and gauge data and the repair/replacement of parts where deemed necessary.

A passive system would be designed to allow a fixed maximum flow of water from the storage area. This would eliminate the need for manual intervention during a flood event. Upstream gauges would not be required. Passive controls, such as throttled culverts or Hydrobrakes, would require inspection to ensure sediment build up does not occur that could restrict flows.

Regardless of what manner of control system is implemented, some general maintenance works would be common to both. Embankments would require visual inspections for signs of erosion or vegetation growth, with the crest inspected for signs of sunken areas possibly indicative of settlement or culvert failure. A trash screen at the flow control/culvert entrance would require maintenance to remove debris which may accumulate over time and restrict flow.

The option continues with the replacement of a 0.8m high wall along the riverbank south of the Brook Lane Vella Homes estate. A flow control structure would be added to limit the water flow entering the mill race during flood events. The embankment at the back of the Millbrook estate would be upgraded to 0.5m high, separating it from the Owenacurra River. A 0.3m wall would be constructed from the proposed embankment to the existing bridge parapet downstream, along the eastern side of the river. A second pumping station would be constructed behind the wall.

A 0.8m and 0.5m high wall would be constructed on the western side downstream, offering protection to the residential areas. A third pumping station would be located in a grassed area of the Woodlands estate, behind the wall.

A 0.4m high embankment/regrading is required on the eastern side of the bank downstream, along Riverside Way for circa 160m.

5.3.3.1 Option 1C and 2C – Climate Change Adaptability

This option was found to be readily adaptable with limited difficulty, cost and impact. The option provides no impediment to future interventions to address future risk.

An adaptive approach can be taken by designing the direct defences to permit an acceptable extension in height in the future in order to maintain the required level of protection. The required standard of protection can also be achieved through other means such as additional direct defences, conveyance improvements or increased upstream storage.

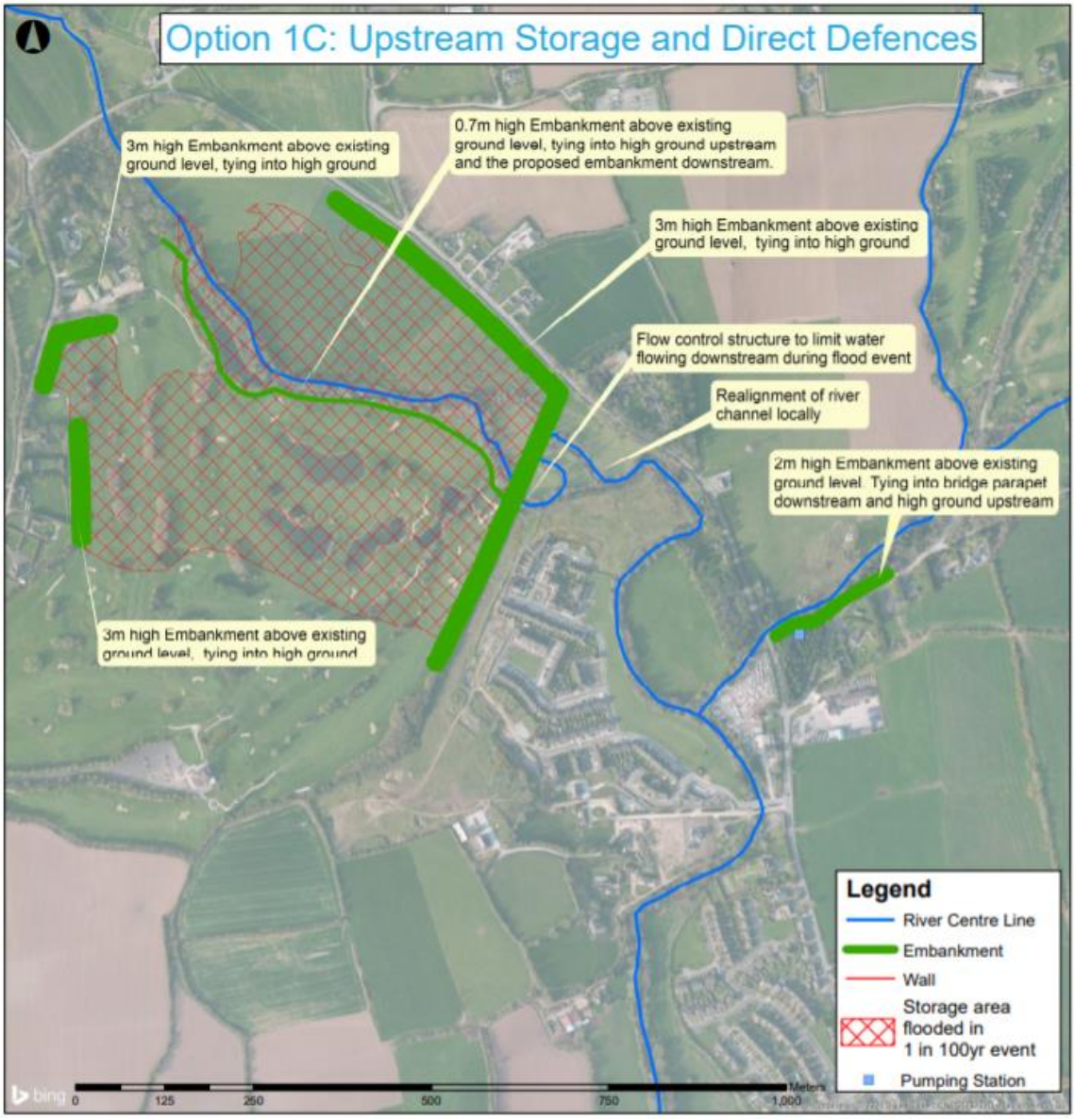


Figure 17 Option 1C – Upstream Storage and Direct Defences

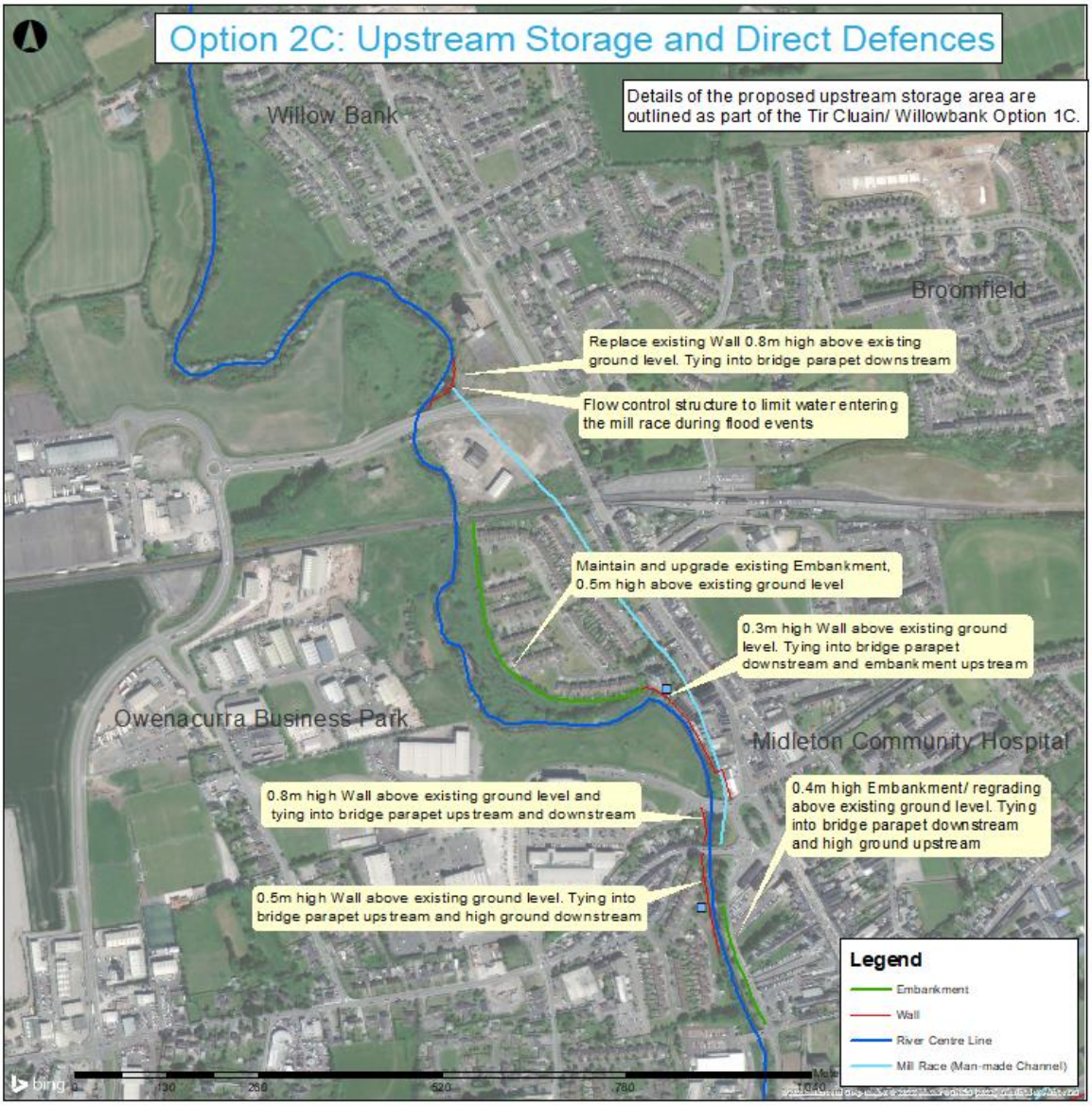


Figure 18 Option 1C and 2C- Upstream Storage and Direct Defences

Table 12 Description of Option 1C and 2C – Upstream Storage and Direct Defences

Description	Comments
Glenathonacash 2.0m high, 187m long embankment at Broomfield Ridge.	In-stream works. Removal of vegetation / trees. Proximity to ESB assets.
Owenacurra 3.0m high, 836m long embankment Northeast of Water Rock Golf Club with seepage cut off.	Removal of vegetation / trees. Proximity to ESB assets.
3.0m high, 147m long embankment West of Water Rock Golf Club along road with seepage cut off.	Removal of vegetation / trees. Proximity to ESB assets.
3.0m high, 157m long embankment West of Water Rock Golf Club behind properties at with seepage cut off.	Removal of vegetation / trees. Proximity to ESB assets.
0.7m high, 700m long embankment adjacent to riverbank.	In-stream works. Removal of vegetation / trees.
Installation of an active flow control system at Water Rock Golf Club that would require a flood forecasting system (river and rainfall gauges installed in the catchment) and human intervention (monitoring, maintenance, etc.).	In-stream works. Flood forecasting system required. Regular maintenance required.
Realignment of channel downstream of flow control structure.	In-stream works.
Drainage upgrades to Water Rock Golf Course	Removal of vegetation / trees.
Replacement of an existing wall with a 0.8m high, 99m long sheet pile north of the Northern Relief Road.	
Flow control structure at the Owenacurra mill race entrance north of the Northern Relief Road.	In-stream works. Removal of vegetation / trees.
Upgrade of the 0.5m high, 424m long embankment at the rear of Millbrook.	In-stream works. Removal of vegetation / trees. Disposal of material.
Replacement of an existing wall with a 0.3m high, 228m long sheet pile wall at the rear of River Wharf	In-stream works. Removal of vegetation / trees.
0.8m high, 54m long reinforced concrete wall between the Market Green bridge and Cork Road Bridge.	In-stream works. Removal of vegetation / trees. Proximity to ESB assets. Impact to existing stone wall.
0.5m high, 124m long reinforced concrete wall on the right bank at The Woodlands.	In-stream works. Removal of vegetation / trees. Proximity to IW assets.

Description	Comments
0.4m high, 160 long embankment/ regrading on the left bank at Riverside Way.	Removal of vegetation / trees. Proximity to IW assets. Proximity to GNI assets. Proximity to ESB assets.
3No pumping stations at various locations as identified.	Removal of vegetation / trees. Regular maintenance required.

5.4 Area 3: Midleton Town Centre and Bailick Road

Area 3 includes Midleton Town Centre, southern side of IDL site, the Baby Walk, People's Park, areas adjacent to Dungourney River and Bailick Road. The area is at risk of fluvial flooding from the Owenacurra and the Dungourney as well as tidal flooding.

The extent of flooding from the Q100 and T200 Events in this area are shown in Figure 19 below.

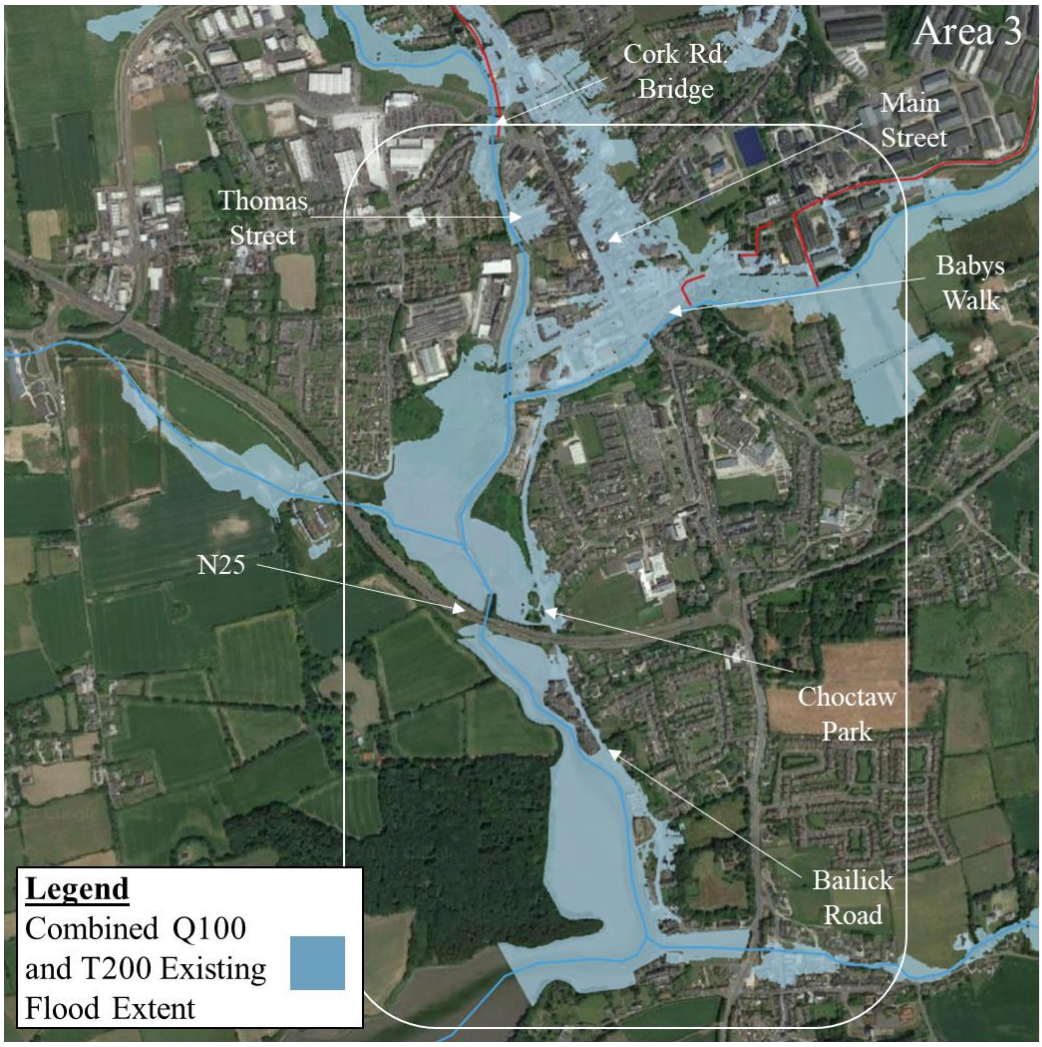


Figure 19 Area 3: Midleton Town Centre and Bailick Road

5.4.1 Option 3A – Direct Defences Only

This was the only option deemed technically viable for this area, due to the constraints identified by the Preliminary Technical Assessment. The option is presented in Figure 20. A summary of the proposed interventions and existing constraints is provided in Table 13.

This option includes a 1m high wall south of the IDL site. At the existing mill race, a non-return flap valve would be constructed at the mill race outlet, preventing water from passing back upstream through it and causing flooding in the IDL site. The 1m high wall would connect to a proposed 1m high embankment to be constructed through the People's Park. The existing wall at the Baby Walk would be replaced with a 1.2m high wall, with the existing mill race outlet also being fitted with a non-return flap valve. The wall would tie into Lewis Bridge, where the parapets would be raised to 1.2m above ground level.

Drainage network upgrades would be required along St. Mary's Road and Youghal Road. These include:

- The construction of a new stormwater drainage network with separate outfall and non-return valve to supplement the existing network along Youghal Road

- The construction of a new stormwater system along St. Mary's Road to alleviate pressure on the combined foul system and help mitigate surface water flooding of Main Street.

A pumping station would also be required in this area. Between Lewis Bridge and Bailick Road Bridge, a 1m high wall on the northern side of the Dungourney River would be constructed. The parapets on Bailick Road Bridge would be raised to 1.0m above ground level. A pumping station would be required in this area.

Downstream of the bridge, a 1.2m high wall would be constructed on the northern side of the river, which would then connect to a 0.7m high wall proposed along the eastern bank of the Owenacurra River. A 0.7m high wall and pumping station would be required between the GAA pitches and Beechwood Drive.

The option continues with the upgrade of an existing embankment on Dwyer's Rd, west of the estuary, to 0.8m to protect against tidal flooding in this area. Two new embankments and upgrades to existing embankments are proposed at Choctaw Park. An embankment is proposed adjacent to Bailick Road car park. These would be 0.6m, 0.8m and 0.6m high respectively. A pumping station would be required in the car park. A 0.6m high wall is proposed at the back of the residential properties at The Moorings, tying into high ground or existing walls on either side. A pumping station would be required at a low point adjacent to Cherrywood Ridge.

A 1.3m high wall would replace the existing wall along Bailick Road, south of The Granary, which would extend to beyond the disused industrial site overlooking the river. A 1.2m wall would run from here to the rear of Charlestown Wharf, Charlestown Maltings and north of Ballinacurra Estuary along Bailick Road, some extents will replace existing walls and others will be new walls set back from the existing quay walls. A pumping station would be located in vicinity of Charlestown Maltings.

On the opposite side of the estuary, a 0.8m high wall would run along The Maltings and South Quay, before connecting to a proposed 0.8m high embankment which would connect to the R630 Road. A pumping station would be situated south of the embankment, in the green area.

In this area, construction adjacent to the Cork Harbour SPA and to the Great Channel SAC will be required. Construction methodology will have to take into consideration these environmentally protected sites.

Construction will also be required adjacent to existing historic quay walls, the flood defence walls will be set back as far as possible. However some remediation works will be required to the existing quay walls where the new flood defence walls require support.

5.4.1.1 Option 3A – Climate Change Adaptability

This option was found to be adaptable for the Mid Range Future Scenario (MRFS) at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

An adaptive approach can be taken by designing the direct defences to permit an acceptable extension in height in the future in order to maintain the required level of protection for the MRFS. However, these adaptation measures would have negative implications, e.g. very high (greater than 1.7m) direct defences or demountables.

This option would not be adaptable for the High End Future Scenario (HEFS) as the required defence height would have significant negative implications with defence heights greater than 2.2m in public areas.

It is noted that there are no reasonable alternative options for this area and that direct defences are the only viable current option. Alternative options, such as a tidal barrier, may become viable in the future when adapting the scheme for the MRFS and HEFS.

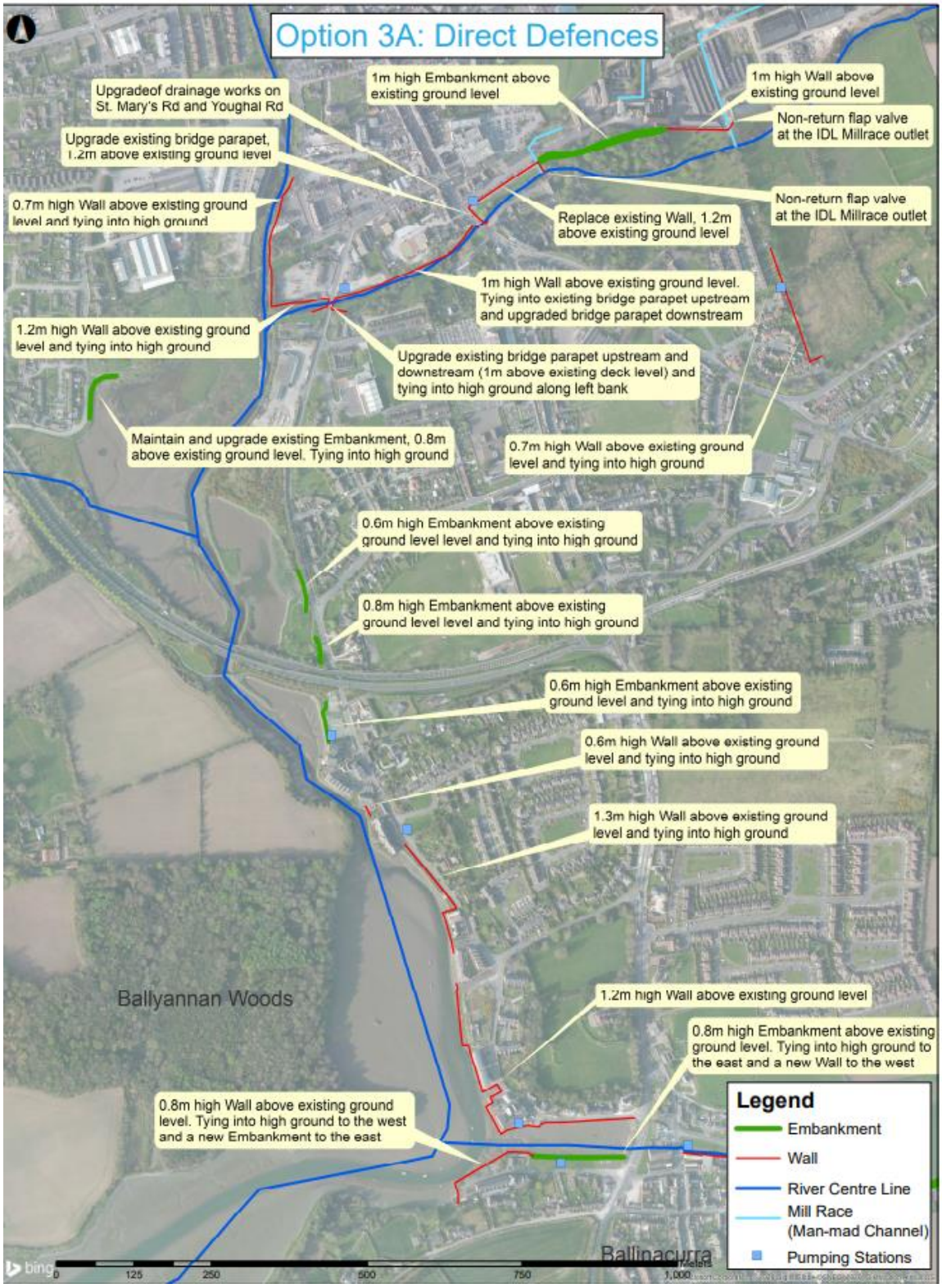


Figure 20 Option 3A – Direct Defences

Table 13 Description of Option 3A – Direct Defences

Description	Comments
Owenacurra and North of the N25	
0.7m high, 217m long sheet pile wall at rear of Funeral Home along left bank of Owenacurra	In-stream works. Removal of vegetation / trees. Proximity to ESB assets.
Upgrade existing embankment on Dwyer Rd (west of estuary) with a 0.8m high, 94m long embankment	Removal of vegetation / trees. Proximity to IW assets.
0.6m high, 70m long embankment North of Choctaw Park	Removal of vegetation / trees. Within Cork Harbour SPA. Proximity to Great Channel SAC.
0.8m high, 42m long embankment North of Choctaw Park	Removal of vegetation / trees. Within Cork Harbour SPA. Proximity to Great Channel SAC.
Dungourney	
0.7m high, 209m long wall at GAA Pitches	Removal of vegetation / trees.
1.0m high, 117m long wall tying into embankment at People's Park	Removal of vegetation / trees. Proximity to GNI assets.
2 non-return valves at outlets of IDL Mill Race – upstream of Baby Walk and upstream of People's Park	Proximity to IW assets.
1.0m high, 203m long embankment through People's Park	Removal of vegetation / trees. Proximity to GNI assets.
Upgrade of the existing wall along Baby Walk with a 1.2m high, 150m long wall	In-stream works. Removal of vegetation / trees. Proximity to IW assets.
Upgrade of bridge parapet at Lewis Bridge	Proximity to protected structure – Lewis Bridge
1.0m high, 313m long wall with seepage cut-off west of Lewis Bridge	In-stream works. Removal of vegetation / trees. Proximity to IW assets. Proximity to ESB assets.
Upgrade of bridge parapet at Bailick Road Bridge	
1.2m high, 132m long sheet pile wall at ESB site along the right bank of the Dungourney	Proximity to IW assets. Proximity to ESB assets.
Local upgrades to the drainage system along St. Mary's Road	Proximity to IW assets. Proximity to ESB assets.
Local upgrades to the drainage system along Youghal Road	Proximity to ESB assets.
3No pumping stations at various locations as identified.	

Description	Comments
Estuary (South of the N25)	
0.6m high, 66m long embankment at Bailick Rd Carpark south of N25	Removal of vegetation / trees. Proximity to Great Channel SAC and Cork Harbour SPA. Proximity to ESB assets.
0.6m high, 16m long wall at The Moorings Development	Proximity to SAC and SPA.
1.3m high, 223m long tidal defence wall from the Granary to rear of derelict site/warehouse	Proximity to SAC and SPA. Proximity to GNI, ESB and IW assets. Proximity to existing quay walls.
1.2m high, 547m long tidal defence wall rear of Charleston Wharf, Charleston Maltings and north of Ballinacurra Estuary along Bailick Road	Proximity to SAC and SPA. Proximity to GNI, ESB and IW assets. Proximity to existing quay walls.
0.8m high, 146m long tidal defence embankment at South Quay (south of Ballinacurra Estuary)	Removal of vegetation / trees. Proximity to SAC and SPA. Proximity to IW assets.
0.8m high, 175m long tidal defence wall at The Maltings, South Quay (south of Ballinacurra Estuary)	Proximity to SAC and SPA. Proximity to ESB assets. Proximity to existing quay walls.
4No pumping stations at various locations as identified.	

5.5 Area 4: Lauriston Estate/Rugby Club/East of IDL

Area 4 includes the IDL site, Midleton Rugby Club, Lauriston Estate, Townspark Industrial Estate and the land to the east of the Irish Distillers Limited (IDL) site adjacent to the Dungourney.

The Midleton to Youghal Greenway is currently under construction and passes through this area. The proposed Northern Relief Road extension will also pass through this area, although the alignment is not yet confirmed.

The area is at risk of fluvial flooding from the Dungourney as well as groundwater flooding. The extent of flooding from the Q100 and T200 Events in this area are shown in Figure 21 below.

Note on the sluice gate which is relevant to all options: The existing sluice gate located adjacent to Cahermone Castle would be maintained and upgraded to prevent flooding within the IDL site. It is intended to maintain no flow or a low flow through the IDL millrace This decision will be undertaken in consultation with the IDL. If a low flow is to be maintained, it is envisaged that the sluice gate will be designed such that the max flow entering the millrace does not exceed the required low flow rate. It is envisaged to be passive in design and will not require human intervention.

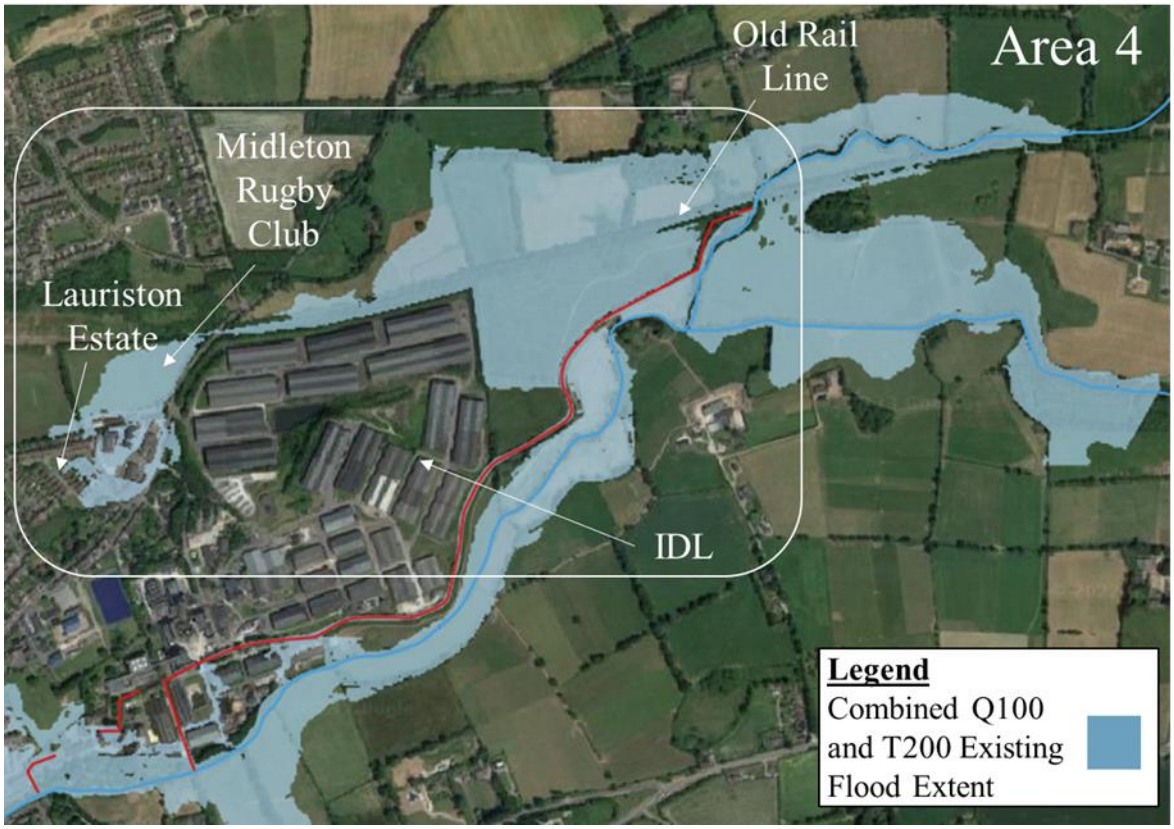


Figure 21 Area 4: Lauriston Estate/Rugby Club/East of IDL

5.5.1 Option 4A – Groundwater Cut-Off and Direct Defences

Option 4A is presented in Figure 22. A summary of the proposed interventions and existing constraints is provided in Table 14.

It can be seen from the figure that the proposal includes a 2.4m high embankment to the east of the IDL site, circa 90m to the east of the proposed NRRE (alignment to be confirmed). It is proposed that the Greenway would be regraded to pass over the proposed flood embankment resulting in a passive scheme, i.e. demountables would not be required. This alignment would impact the vertical alignment of the NRRE as the NRRE would have to pass over the Greenway. The embankment would tie into the existing high ground north and south.

An alluvium/gravel layer in the area provides an underground route for groundwater. A sheet pile cut off is required for circa 210m of the flood embankment to prevent groundwater passing through the shallow gravels.

In order to mitigate the risk of ground water flooding behind the flood embankment, it is proposed that a pumping station be installed on the dry side. This pumping station would pump water back to the wet side of the embankment or discharge south to Dungourney. This would only be required in the unlikely event that a groundwater route was still present after the sheet pile cut off is installed.

The embankment would require routine inspections to be carried out to ensure it retains its functionality. Visual inspections for vegetation, which could create flow paths and weaknesses in the embankment, would need to be conducted. Additional inspections would be required to ensure seepage is not occurring on the west face.

It is proposed that the existing sluice gate located adjacent to Cahermone Castle is maintained and/or upgraded to prevent flooding within the IDL site.

5.5.1.1 Option 4A – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the assumptive approach be adopted in the present day and that the embankment be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal future cost or intervention, however there will be a minimum increase in present day capital costs.

The assumptive approach for the groundwater cut-off is also applicable to accommodate the MRFS and HEFS required standard of protection.

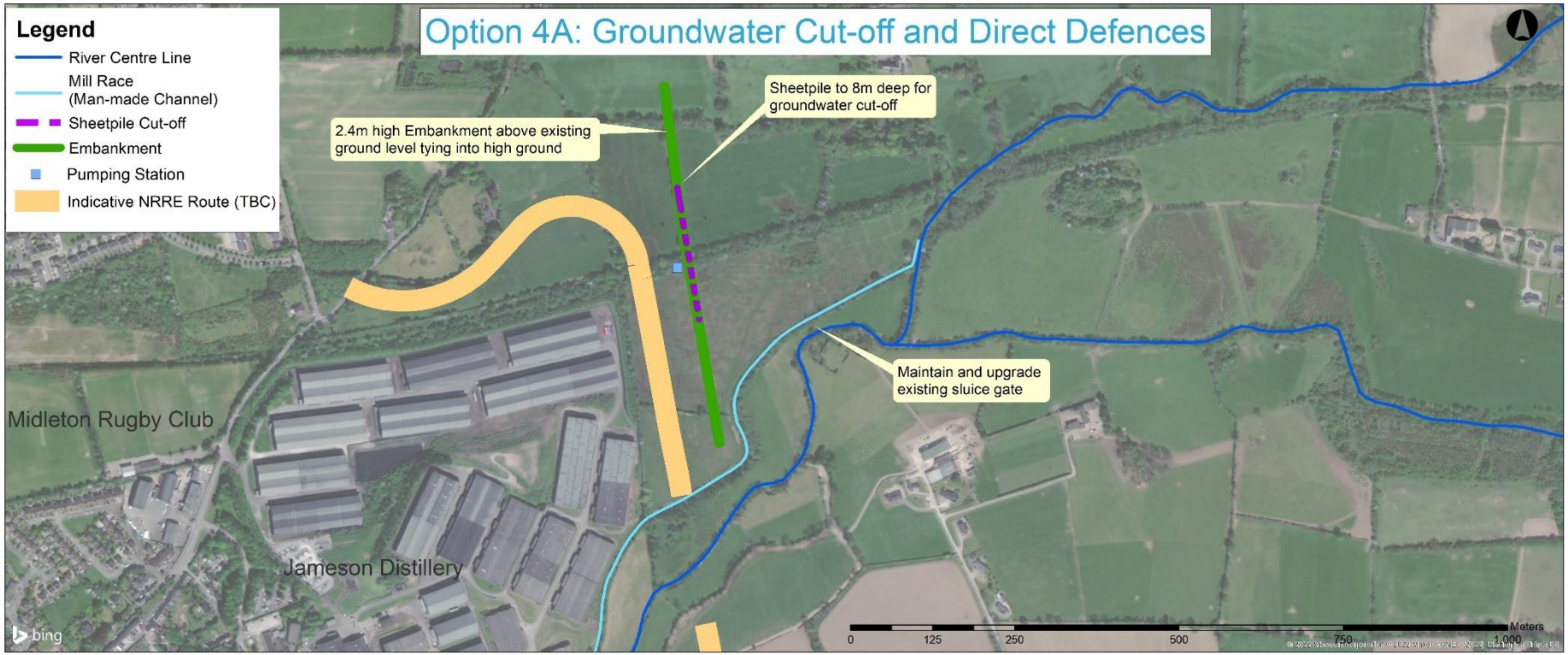


Figure 22 Option 4A – Groundwater Cut-Off and Direct Defences

Table 14 Description of Option 4A – Groundwater Cut-Off and Direct Defences

Description	Comments
Dungourney	
2.4m high, 550m long embankment across Greenway (former railway line) to cut-off surface water.	Proximity to GNI and ESB assets. Proximity to proposed NRRE. Removal of vegetation / trees.
8m deep, 220m long sheet piles across Greenway (former railway line) to cut-off ground water.	Proximity to GNI assets. Proximity to proposed NRRE. Removal of vegetation / trees.
Upgrade of the flow control structure at IDL mill race sluice gate.	Instream works. Proximity to Cahermone Castle.
1No pumping station west of the embankment.	Regular maintenance required.
Cycleway regrading on approach to Greenway crossing.	

5.5.2 Option 4B – Pumping and Direct Defences

Option 4B is presented in Figure 23. A summary of the proposed interventions and existing constraints is provided in Table 15.

It can be seen from the figure that the proposal includes a 1.6m high embankment to the east of the bridge over the railway line. It is proposed that the Greenway would be regraded to pass over the proposed flood embankment resulting in a passive scheme, i.e. demountables would not be required. This alignment would not impact the vertical alignment of the NRRE (subject to review once alignment is confirmed).

The IDL embankments would also have to be upgraded to flood defence standard and any drainage through the IDL embankments would be blocked up. Routine inspections would be required along the embankments to ensure there is no vegetation growth or seepage which would damage the embankments.

In order to mitigate the risk of ground water flooding behind the flood defence embankment, it is proposed that a pumping station be installed on the dry side, in the vicinity of the rugby club. This pumping station would pump water back to the wet side of the embankment.

It is proposed that the existing sluice gate located adjacent to Cahermone Castle is maintained and/or upgraded to prevent flooding within the IDL site.

5.5.2.1 Option 4B – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the assumptive approach be adopted in the present day and that the embankment be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal future cost or intervention, however there will be a minimum increase in present day capital costs.

The assumptive approach for elements of the pumping systems is also applicable to accommodate the MRFS and HEFS required standard of protection, e.g. pump chambers could be designed to accommodate larger/ more pumps in the future but the capacity of the pump would not be upgraded until required.

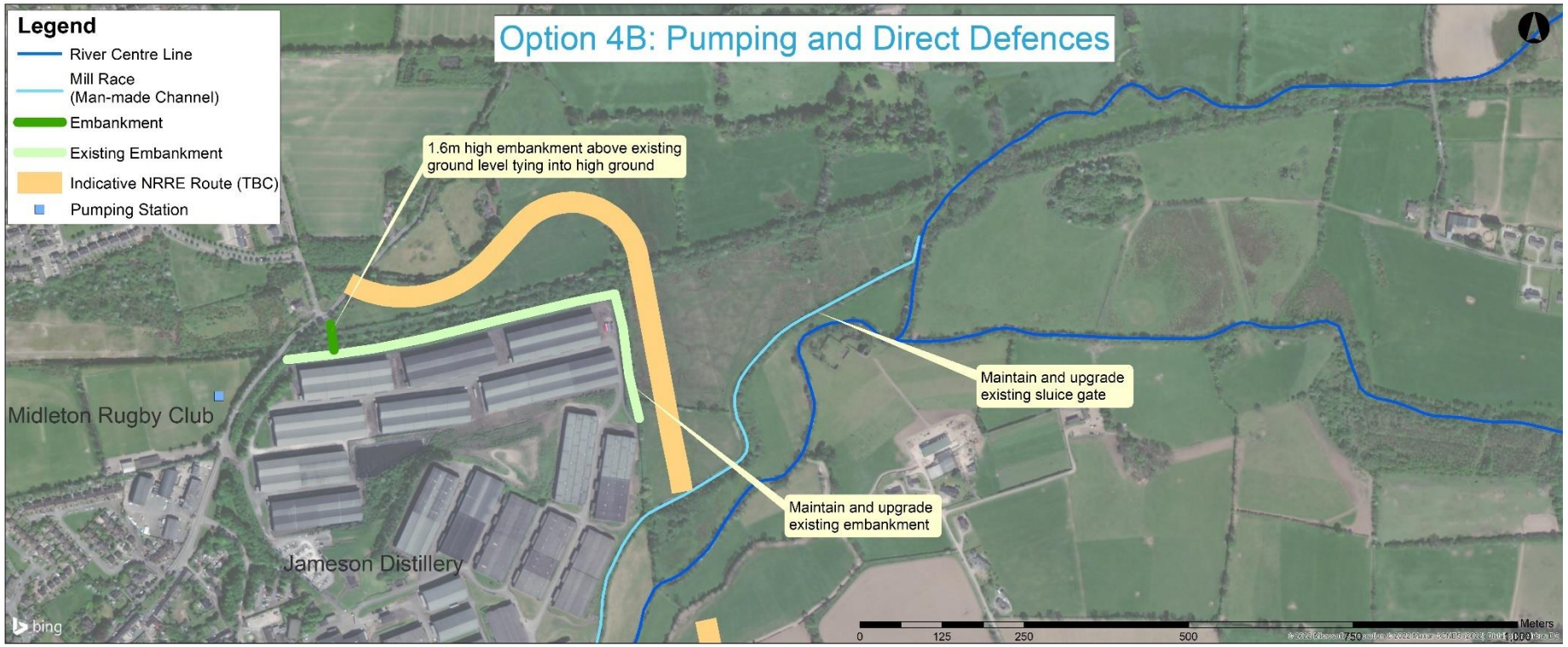


Figure 23 Option 4B – Pumping and Direct Defences

Table 15 Description of Option 4B – Pumping and Direct Defences

Description	Comments
Dungourney	
1.6 high, 60m long embankment across Greenway (former railway line) to cut-off surface water.	Proximity to proposed NRRE. Removal of vegetation / trees.
Upgrade of the existing IDL embankments to flood defence standard, 730m in length	Removal of vegetation / trees.
1No pumping station west of the embankment.	Regular maintenance required.
Upgrade of the flow control structure at IDL mill race sluice gate.	Instream works. Proximity to Cahermone Castle.
Cycleway regrading on approach to Greenway crossing.	

5.5.3 Option 4C – Combine Flood Embankment with Planned Northern Relief Road Extension (NRRE) Road Embankment with Embankment at Greenway Crossing

Option 4C is presented in Figure 24. A summary of the proposed interventions and existing constraints is provided in Table 16.

It can be seen that the FRS embankment and NRRE are combined into one embankment element. This option proposes the Greenway passes under the NRRE and over the flood embankment at the same location, allowing for a passive scheme. The NRRE would remain functional during a flood event. No manual intervention would be required to prevent flooding to the west of the embankment, as the embankment would be designed to an appropriate flood defence level height.

The core of the road embankment for the extent of use as a flood embankment, circa 370m, would have to be designed appropriately as a flood defence (impermeable material to the required defence level). The proposed flood embankment extends circa 215m to the north beyond the NRRE to tie into high ground. The embankment would also tie into the existing high ground to the south.

An alluvium/gravel layer in the area provides an underground route for groundwater. A sheet pile cut off is required for circa 220m of the flood embankment. This would restrict flows from travelling underneath the embankment and flooding areas to the west.

In order to mitigate the risk of ground water flooding behind the flood embankment, it is proposed that a pumping station be installed on the dry side. This pump would pump water to the wet side of the embankment or discharge south to Dungourney. This would only be required in the unlikely event that a groundwater route was still present after the sheet pile cut off is installed.

It is proposed that the existing sluice gate located adjacent to Cahermone Castle is maintained and/or upgraded to prevent flooding within the IDL site.

This option would require integration with both the Northern Relief Road Extension and the Midleton to Youghal Greenway, increasing project delivery risk. However, the land required would be reduced in comparison to Option 4A.

5.5.3.1 Option 4C – Climate Change Adaptability

This option is limited in its ability to adapt to future climate change requirements due to its combination with the NRRE, which will be designed to a fixed height.

However, it is proposed that the assumptive approach be adopted in the present day and that the embankment be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal future cost or intervention, however this would result in an increase in present day capital costs.

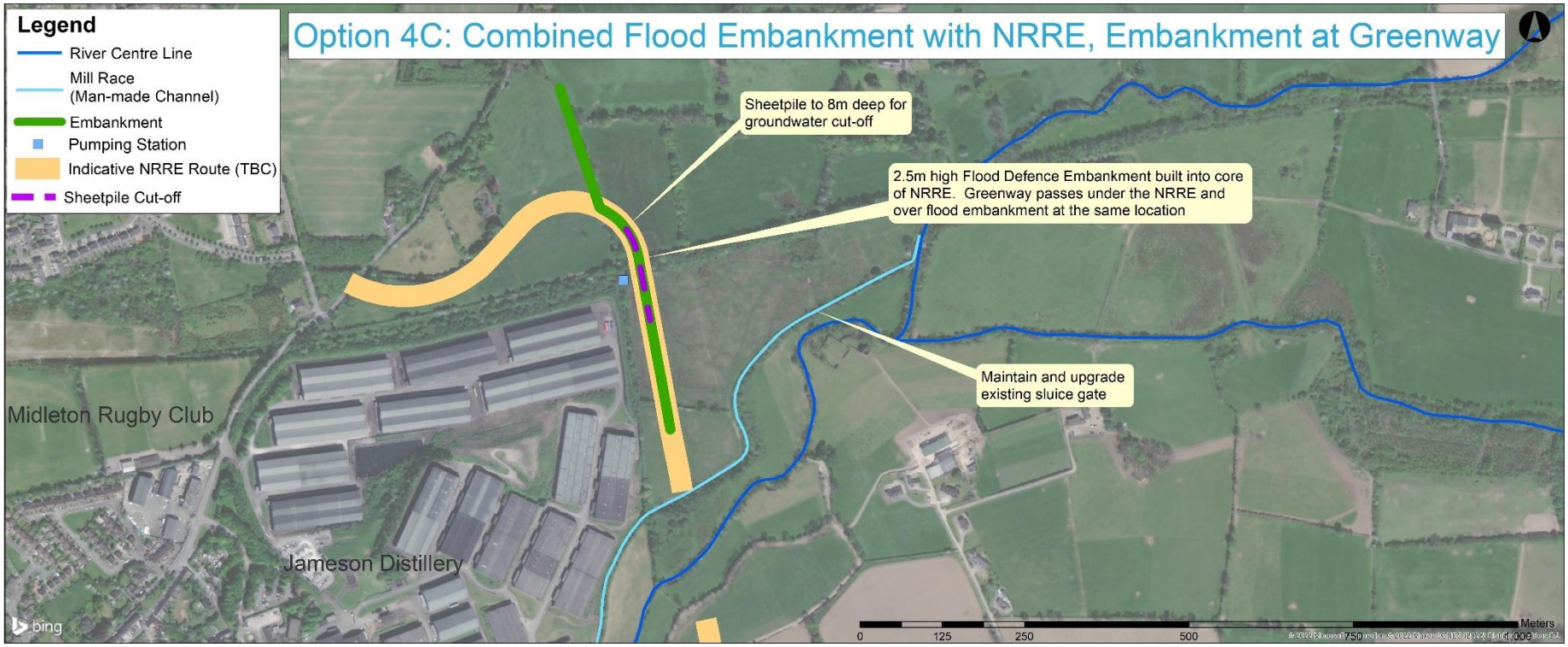


Figure 24 Option 4C – Combined Design with Embankment at Greenway Crossing

Table 16 Option 4C – Combined Design with Embankment at Greenway Crossing

Description	Comments
Dungourney	
2.5m high, 600m long embankment across Greenway (former railway line) to cut-off surface water	Proximity to GNI and ESB assets. Coordination with NRRE required. Removal of vegetation / trees.
8m deep, 220m long sheet piles across Greenway (former railway line) to cut-off ground water.	Proximity to GNI assets. Coordination with NRRE required. Removal of vegetation / trees.
Upgrade of the flow control structure at IDL mill race Sluice gate.	Instream works. Proximity to Cahermone Castle.
1No pumping station west of the embankment.	Regular maintenance required.
Cycleway regrading on approach to Greenway crossing.	

5.5.4 Option 4D – Combine Flood Embankment with Planned Northern Relief Road Extension (NRRE) Road Embankment with Flood Barrier at Greenway Crossing

Option 4D is presented in Figure 25. It can be seen that the FRS embankment and NRRE are combined into one embankment element. A summary of the proposed interventions and existing constraints is provided in Table 17.

The core of the road embankment for the extent of use as a flood embankment, circa 370m, would have to be designed appropriately as a flood defence (impermeable material to the required defence level). The proposed flood embankment extends circa 215m to the north beyond the NRRE to tie into high ground. The embankment would also tie into the existing high ground to the south.

This option proposes the Greenway passes under the NRRE, however instead of the Greenway passing over the flood embankment, a flood barrier (i.e. gate or demountable) would be deployed during a flood event. This would eliminate the requirement to revise the Greenway and NRRE vertical alignments.

The inclusion of a flood barrier would require a flood forecasting system to determine when the barrier should be deployed. This would be considered an active system, requiring intervention prior to a flood event. Given this area is fluvially dominated, upstream gauges would need to be installed to inform this flood forecasting system. Failure to deploy the barrier in advance of a flood event would likely result in flooding to the west.

Maintenance work would be required for the barrier to ensure it remains functional when required. Upstream monitors would also require maintenance to ensure data is being captured correctly in advance of any potential flood event.

An alluvium/gravel layer in the area provides an underground route for groundwater. A sheet pile cut off is required for circa 220m of the flood embankment.

In order to mitigate the risk of ground water flooding behind the flood embankment, it is proposed that a pumping station be installed on the dry side. This pump would pump water back to the wet side of the embankment or discharge south to Dungourney. This would only be required in the unlikely event that a groundwater route was still present after the sheet pile cut off is installed.

It is proposed that the existing sluice gate located adjacent to Cahermone Castle is maintained and/or upgraded to prevent flooding within the IDL site.

This option would require integration with both the Northern Relief Road Extension and the Midleton to Youghal Greenway, increasing project delivery risk. However, the land required would be reduced in comparison to Option 4A.

5.5.4.1 Option 4D – Climate Change Adaptability

This option is limited in its ability to adapt to future climate change requirements due to its combination with the NRRE, which will be designed to a fixed height.

However, it is proposed that the assumptive approach be adopted in the present day and that the embankment be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal future cost or intervention, however this would result in an increase in present day capital costs.

However this would not be applicable for the design of the flood barrier, which would have to be adapted in the future.

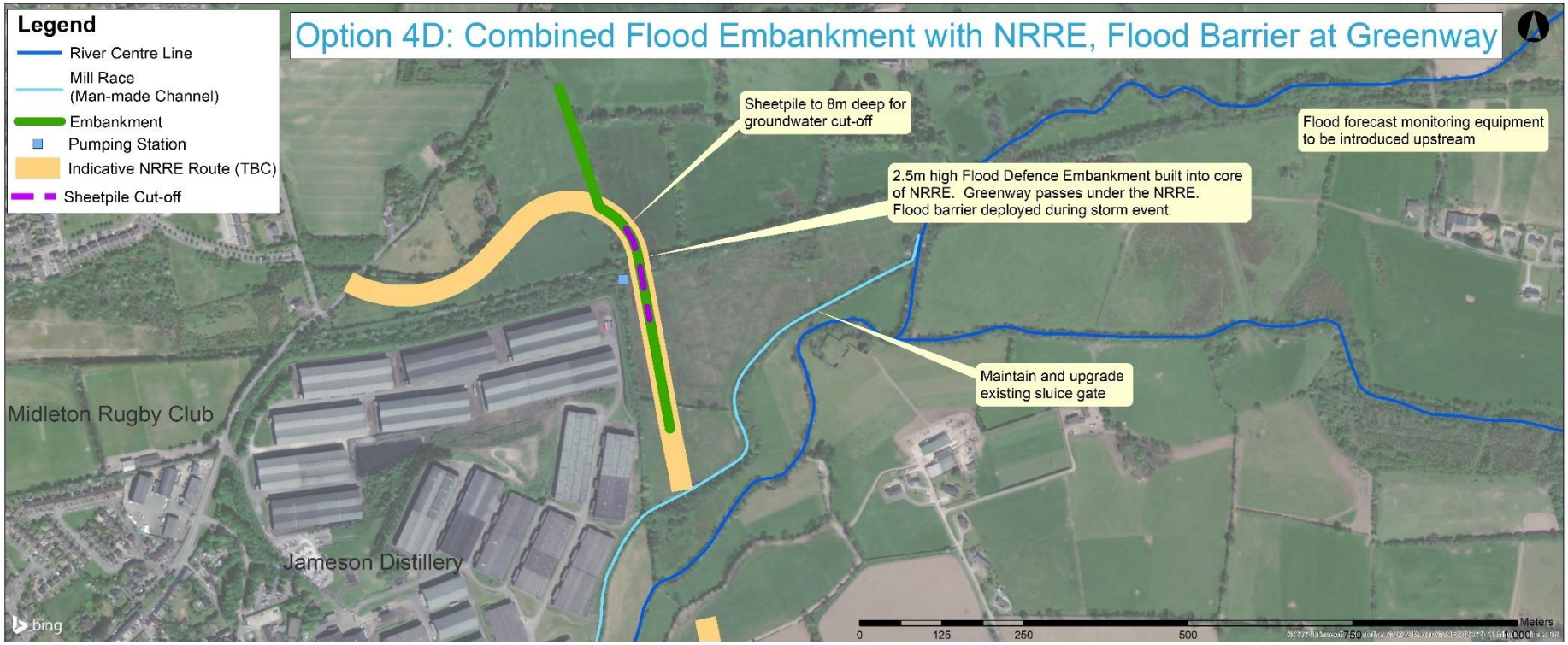


Figure 25 Option 4D – Combined Design with Flood Barrier at Greenway Crossing

Table 17 Option 4D – Combined Design with Flood Barrier at Greenway Crossing

Description	Comments
Dungourney	
2.5m high, 600m long embankment across Greenway (former railway line) to cut-off surface water.	Proximity to GNI and ESB assets. Coordination with NRRE required. Removal of vegetation / trees.
8m deep, 220 long sheet piles across Greenway (former railway line) to cut-off ground water.	Proximity to GNI assets. Coordination with NRRE required. Removal of vegetation / trees.
Upgrade of the flow control structure at IDL mill race Sluice gate.	Instream works. Proximity to Cahermone Castle.
1No pumping station west of the embankment.	Regular maintenance required.
Upstream flood forecasting and monitoring equipment.	Regular maintenance required. Instream works.
Demountable flood barrier to be installed in advance of flood event occurring.	Manual intervention required during flood event. Regular maintenance required.

5.5.5 Option 4E – Groundwater Cut-Offs and Direct Defences along Greenway

Option 4E is presented in Figure 26. A summary of the proposed interventions and existing constraints is provided in Table 18.

It can be seen from the figure that the proposal includes a 3.1m high embankment to the east of the IDL site, circa 90m to the east of the proposed NRRE.

It is proposed that the Greenway would be regraded to pass over the proposed flood embankment resulting in a passive scheme, i.e. demountable defences would not be required to prevent flooding to the west. Maintenance works would be reduced as a result.

As can be seen in the figure, sections of the embankment would extend parallel to the Greenway on the north and south of the Greenway. The offset positioning of the embankment crossing the Greenway would facilitate the NRRE without impacting on its vertical alignment. It is noted that the NRRE could be combined with the proposed flood embankment however the underside of the NRRE would need to be increased to provide sufficient clearance for the Greenway to pass underneath, this would not impact how Option 4E functions or the standard of protection offered by the option. It is proposed that impermeable material be filled in the area between proposed u-shaped embankment to mitigate the groundwater flow/seep underneath u-shaped embankment and then along current railway line and over sheet pile cut off. The embankment would tie into the existing high ground north and south.

An alluvium/gravel layer in the area provides an underground route for groundwater. A sheet pile cut off is required for circa 220m of the flood embankment.

In order to mitigate the risk of ground water flooding behind the flood embankment, it is proposed that a pumping station be installed on the dry side. This pump would pump water back to the wet side of the embankment or discharge south to Dungourney. This would only be required in the unlikely event that a groundwater route was still present after the sheet pile cut off is installed.

It is proposed that the existing sluice gate located adjacent to Cahermone Castle is maintained and/or upgraded to prevent flooding within the IDL site.

5.5.5.1 Option 4E – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the assumptive approach be adopted in the present day and that the embankment be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal further cost or intervention, however there will be a minimum increase in present day capital costs.

The assumptive approach for the groundwater cut-off is also applicable to accommodate the MRFS and HEFS required standard of protection.

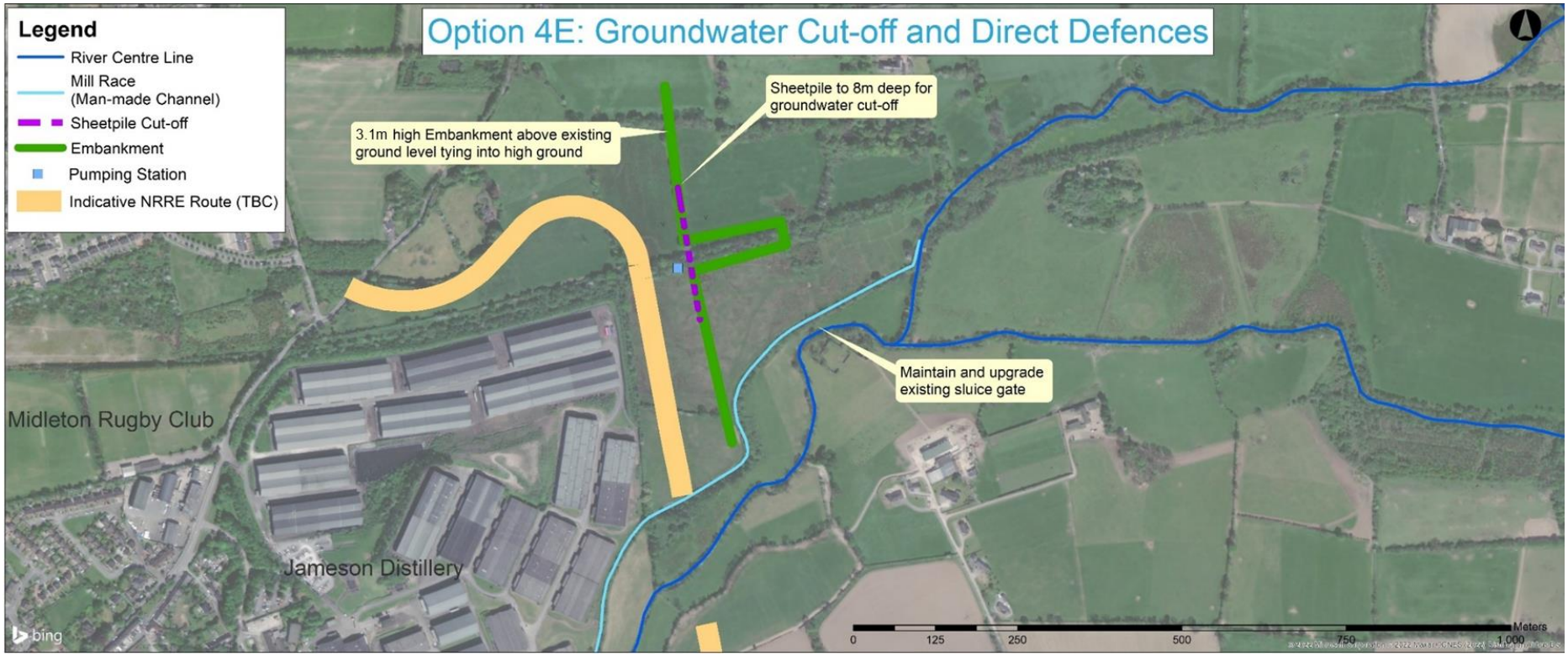


Figure 26 Option 4E – Groundwater Cut-Off and Direct Defences along Greenway

Table 18 Option 4E – Groundwater Cut-Off and Direct Defences along Greenway

Description	Comments
Dungourney	
3.1m high, 968m long embankment across Greenway (former railway line) to cut-off surface water.	Proximity to GNI and ESB assets. Proximity to proposed NRRE. Removal of vegetation / trees.
8m deep, 220m long sheet piles across Greenway (former railway line) to cut-off ground water.	Proximity to GNI assets. Proximity to proposed NRRE. Removal of vegetation / trees.
Upgrade of the flow control structure at IDL mill race sluice gate.	Instream works. Proximity to Cahermone Castle.
1No pumping station west of the embankment.	Regular maintenance required.
Cycleway regrading on approach to Greenway crossing.	

5.6 Area 5: Ballinacurra

Area 5 covers Ballinacurra village and upstream along the Ballinacurra watercourse. The extent of flooding from the Q100 Event in this area are shown in Figure 27 below.



Figure 27 Area 5: Ballinacurra

5.6.1 Option 5A – Direct Defences

The direct defences option for the Ballinacurra Watercourse is presented in Figure 28 below. A summary of the proposed interventions and existing constraints is provided in Table 19.

The works would consist of the construction of a 0.5m and 0.7m high wall on the north and south side of the Ballinacurra Watercourse respectively, between the residential properties east of Kearney's Cross. Pumping stations would be required on the dry side of the walls. If during design it was found that the walls were not feasible due to the proximity of the existing properties, a culvert could instead be constructed.

Downstream, these walls would connect to a proposed 0.9m high embankment running along the southern edge of the agricultural land at Kearney's Cross. Some local river channel realignment would also take place along the embankment.

As the stream passes through the residential area, west of Kearney's Cross, it is proposed to replace the existing walls on the north and south side, and to rebuild them to 1.3m and 0.7m high respectively. Two additional pumping stations would be required outside the walls, one on the north side and another on the south. The upstream and downstream bridge parapets at Father Murphy Terrace Bridge would require raising to 1.1m above the existing deck level. Downstream of the bridge, the existing wall on the south side of the channel would be replaced by a 1.1m high wall. This would connect the new raised parapet to the existing culvert headwall at the Dairygold culvert inlet.

A pumping station located near the inlet on Bransfield Green would be required to mitigate risk of tide locking. This would be connected by a rising main under the Dairygold Co-op site and the R630 (Whitegate to Midleton Road) to outfall into the estuary.

The existing non-return flap valve would be maintained and upgraded at the estuary, preventing tidal water from flowing back up the culvert and flooding upstream. Routine inspections would be required to ensure that the valve retains its functionality.

Given the large number of direct defences situated in a predominantly urban setting, maintenance works would include visual inspections of walls to ensure no structural deterioration occurs i.e, due to car collisions. Where the channel is proposed to be realigned at Kearney's Cross, inspections would be required to ensure that debris and silt do not accumulate. Maintenance work may be required to clear any accumulation if necessary.

5.6.1.1 Option 5A – Climate Change Adaptability

This option was found to be adaptable for the Mid Range Future Scenario (MRFS) at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

An adaptive approach can be taken by designing the direct defences to permit an acceptable extension in height in the future in order to maintain the required level of protection for the MRFS. For the High End Future Scenario (HEFS), the required defence height would have significant negative implications with defence heights greater than 1.5m in public areas. The required standard of protection can also be achieved through other means such as upstream storage or demountables instead of increasing wall heights.

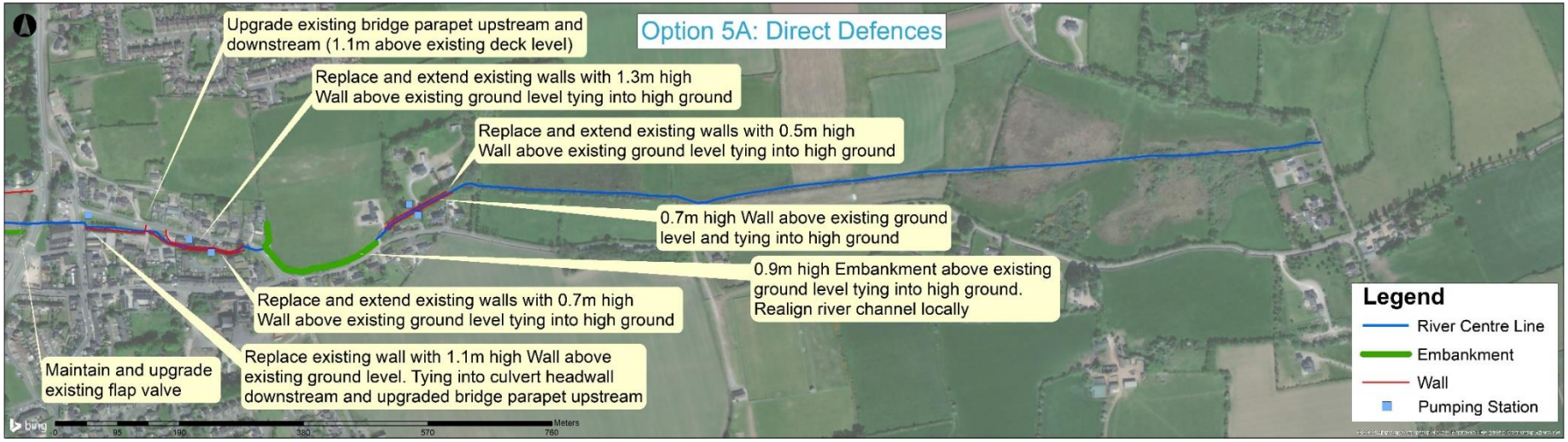


Figure 28 Option 5A – Direct Defences

Table 19 Option 5A – Direct Defences

Description	Comments
Ballinacurra	
0.5m high, 111m long wall along the right bank adjacent to the local road upstream, between the residential properties east of Kearney's Cross.	Removal of vegetation / trees. Instream works.
0.7m high, 113m long wall along the left bank adjacent to the local road upstream, between the residential properties east of Kearney's Cross.	Removal of vegetation / trees. Instream works.
2No pumping stations either side of new walls.	Regular maintenance required.
0.9m high, 235m long embankment in field north of Kearney's Cross. Realignment of channel.	Impact on existing stone wall. Instream works.
Flood defence walls of various heights from Gearagh Road (Kearney's Cross) to the bridge into Father Murphy Terrace. 295m total length.	Removal of vegetation / trees. Instream works. Proximity to ESB assets.
2No pumping stations on either side of new flood defence walls.	Regular maintenance required.
Existing bridge parapet to be upgraded.	Regular maintenance required.
Upgrade of existing wall from Father Murphy Terrace Bridge to the Dairygold culvert inlet to flood defence standard, 1.1m high, 105m long.	Instream works. Proximity to GNI assets. Impact on existing stone wall.
1No pumping station adjacent to Dairygold culvert inlet and associated infrastructure to discharge into Owenacurra Estuary.	Regular maintenance required. Proximity to GNI assets. Proximity to IW assets.
Upgrade of existing flap valve.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA.

5.6.2 Option 5B – Upstream Storage and Over Pumping

The upstream storage and over pumping option for the Ballinacurra Stream is presented in Figure 29 below. A summary of the proposed interventions and existing constraints is provided in Table 20.

Using a flow control structure and embankments, a sufficient volume of water could be held upstream during a flood event. The flow control structure would be designed to limit the volume of water passing downstream such that the capacity of the channel is not exceeded which may result in flooding. In order to maintain flow, a minimum volume of water will be allowed to pass downstream at all times and at no stage will the channel run dry during a flood event.

The works would consist of a 2m high embankment that would cross the watercourse, positioned in an area of agricultural land to the west of Ballinacurra.

This embankment would have a flow control device constructed within it, allowing a limited flow of water to pass downstream. A 0.6m high embankment would be constructed north of Geragh Road, with a 1.3m high embankment constructed south of Rocky Road. These additional embankments would protect nearby properties and shape the storage area. Additional land would be required immediately downstream of the 2m high embankment to allow for ground regrading, so that any water overtopping the embankment could be safely directed back into the watercourse channel via an overflow spillway. This spillway would be designed such that in an exceedance event the overtopping of the embankments could be managed and would ensure that the properties to the east and south are not at risk. Land access would also be a requirement for operation and maintenance works.

Downstream, localised river channel realignment would be required around Kearney's Cross.

As there is a potential that flow may backup when a fluvial event coincides with high tide, (i.e. the culvert is "tide locked" due to the high head at the culvert outlet restricting the fluvial flow from discharging in to the estuary), it is proposed that a pumping station located adjacent to the Dairygold culvert inlet will over pump any residual flow directly into the Owenacurra Estuary. This would be connected by a rising main under the Dairygold Co-op site and the R630 (Whitegate to Midleton Road) to outfall into the estuary. This pumping station may also be utilised during tidal events when the Dairygold culvert is "tide locked". Fluvial flow would be over pumped allowing the upstream storage system to remain passive and allow flow in the channel at all times.

The existing non-return flap valve would be maintained and upgraded at the estuary, preventing tidal water from flowing back up the culvert and flooding upstream.

This option could be designed to be either an "active" or "passive" system. Should an active system be considered, a flood forecasting and water level monitoring system would be required to indicate when the storage is required, and the flow control structure is to be put into operation. Upstream gauges would need to be installed to inform this flood forecasting system. Maintenance requirements would likely be significant to ensure that functionality was maintained. Active controls would need to be routinely serviced alongside the ancillary components which inform its operation. This would include visual inspections, monitoring of motor and gauge data and the repair/replacement of parts, where deemed necessary.

A passive system would eliminate the need for manual intervention during a flood event. Upstream gauges would not be required. Passive controls would require inspection to ensure sediment build up does not occur that could restrict flows.

Regardless of what manner of control system is implemented, some general maintenance works would be common to both. Embankments would require visual inspections for signs of erosion or vegetation growth, with the crest inspected for signs of sunken areas possibly indicative of settlement or culvert failure. The trash screen at the culvert entrance would require maintenance to remove debris which may accumulate over time and restrict flow.

5.6.2.1 Option 5B – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the assumptive approach be adopted in the present day and that the upstream storage be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal future cost or intervention, however there will be a minimum increase in present day capital costs.

However the assumptive approach would not be applicable for the channel maintenance, pumping station and flow control structures. The replacement of pumping station and flow control structures will still be required in the future.

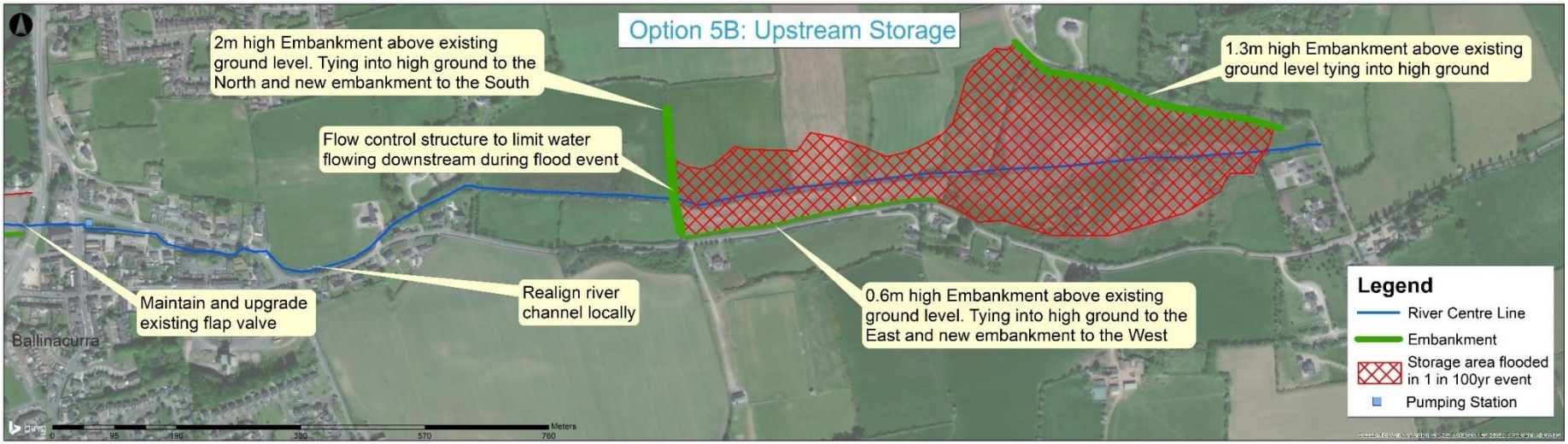


Figure 29 Option 5B – Upstream Storage and Over Pumping

Table 20 Option 5B – Upstream Storage and Over Pumping

Description	Comments
Ballinacurra	
1.3m high, 437m long East Embankment (east/west orientation) to the south of Rocky Road.	Instream works. Proximity to ESB assets. Removal of vegetation / trees.
2m high, 181m long West Embankment (north/south orientation) to the north of Geragh Road.	Instream works. Proximity to GNI assets. Removal of vegetation / trees.
0.6m high, 387m long South Embankment (east/west orientation) to the north of Geragh Road.	Removal of vegetation / trees.
Installation of a flow control structure within the West Embankment, to limit water flow downstream during a flood event.	Regular maintenance required.
Channel realignment at Geragh Road (Kearney's Cross).	Impact on existing stone wall. Instream works.
1No pumping station adjacent to the Dairygold culvert inlet to overpump flow into the Owenacurra Estuary and associated infrastructure to discharge into Estuary.	Regular maintenance required. Proximity to GNI assets. Proximity to IW assets.
Upgrade of existing flap valve at the entrance to the Owenacurra Estuary.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA.

5.6.3 Option 5B-1 Refined Storage Area and Over Pumping

This option is a derivative of Option 5B – Storage Area and Over Pumping and considers the use of a different area for water storage during flood events. It is presented in Figure 30 below. A summary of the proposed interventions and existing constraints is provided in Table 21.

The works involve the construction of a 1.9m high embankment in an agricultural area of land approximately 500m further upstream than the embankment proposed in Option 5B. The embankment would similarly be fitted with a flow control structure, which would limit the flow of water travelling downstream, while retaining the excess flow to the storage area. Additional land would be required immediately downstream of the 1.9m high embankment to allow for ground regrading, so that any water overtopping the embankment could be safely directed back into the watercourse channel via an overflow spillway. This spillway would be designed such that in an exceedance event the overtopping of the embankments could be managed and would ensure that the properties to the east and south are not at risk.. Land access would also be a requirement for operation and maintenance works.

A 0.4m high embankment would be constructed north of Geragh Road, which would connect to the 1.9m high embankment. To the north and east, two further embankments would be constructed. These would be south of Rocky Road and west of the residential properties, at 0.5m and 1.4m high respectively. These embankments would be separated by an area of naturally high land.

Downstream, localised river channel realignment would be required around Kearney's Cross.

As there is a potential that flow may backup when a fluvial event coincides with high tide, (i.e. the culvert is "tide locked" due to the high head at the culvert outlet restricting the fluvial flow from discharging in to the estuary), it is proposed that a pumping station located adjacent to the Dairygold culvert inlet will over pump any residual flow directly into the Owenacurra Estuary. This would be connected by a rising main under the Dairygold Co-op site and the R630 (Whitegate to Midleton Road) to outfall into the estuary. This pumping station may also be utilised during tidal events when the Dairygold culvert is "tide locked". Fluvial flow would be over pumped allowing the upstream storage system to remain passive and allow flow in the channel at all times.

The existing non-return flap valve would be maintained and upgraded at the estuary, preventing tidal water from flowing back up the culvert and flooding upstream.

As with Option 5B, maintenance work would be required on the flow control structure. The extent of maintenance would depend on whether the scheme was designed to be active or passive in nature. The embankment would require maintenance regardless of the flow control mechanism adopted, primarily through visual inspections to ensure no seepage or vegetation growth was occurring.

5.6.3.1 Option 5B-1 – Climate Change Adaptability

This option was found to be adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the assumptive approach be adopted in the present day and that the upstream storage be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal further cost or intervention, however there will be a minimum increase in present day capital costs.

However the assumptive approach would not be applicable for the channel maintenance, pumping station and flow control structures. The replacement of pumping station and flow control structures will still be required in the future.

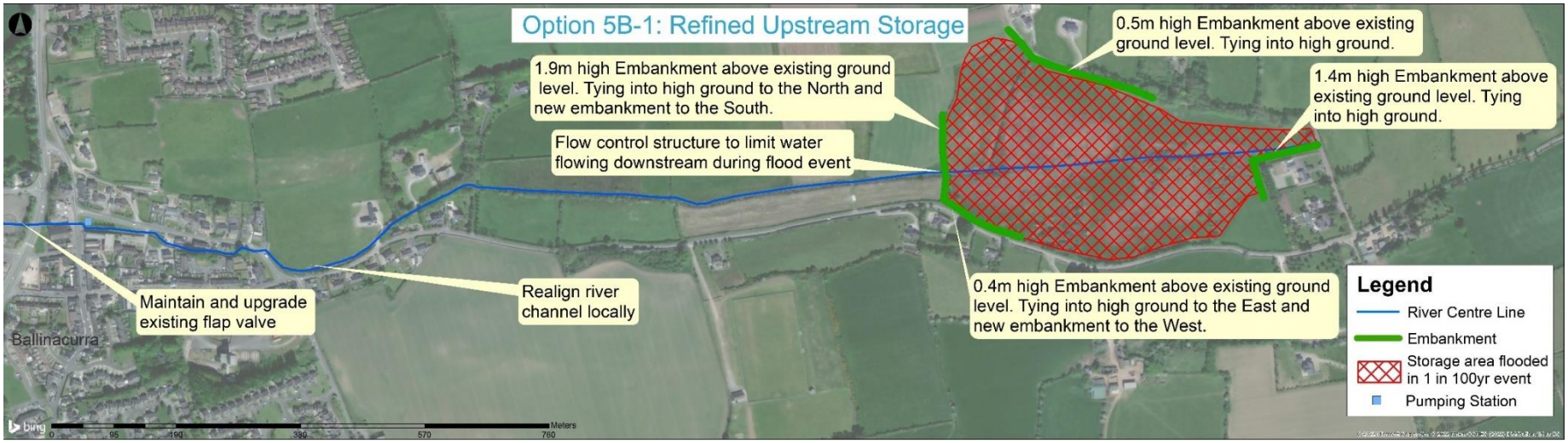


Figure 30 Option 5B-1 – Refined Upstream Storage and Over Pumping

Table 21 Option 5B-1 – Refined Upstream Storage and Over Pumping

Description	Comments
Ballinacurra	
0.5m high, 238m long North Embankment (east/west orientation) to the south of Rocky Road.	Proximity to ESB assets. Removal of vegetation / trees.
1.4m high, 133m long East Embankment (L-shape) adjacent to the residential properties along Rocky Road.	Proximity to ESB assets. Removal of vegetation / trees.
0.4m high, 164m long South-East Embankment (east/west orientation) to the north of Geragh Road.	Removal of vegetation / trees.
1.9m high, 138m long West Embankment (north/south orientation) to the north of Geragh Road.	Instream works. Removal of vegetation / trees.
Flow control structure within the West Embankment, to limit water flow downstream during a flood event.	Regular maintenance required.
Channel realignment at Gearagh Road (Kearney's Cross).	Instream works. Impact on existing stone wall.
1No pumping station adjacent to the Dairygold culvert inlet to overpump residual flow into the Owenacurra Estuary and associated infrastructure to discharge into Estuary.	Regular maintenance required. Proximity to GNI assets. Proximity to IW assets.
Upgrade of existing flap valve at the entrance to the Owenacurra Estuary.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA.

5.6.4 Option 5C – Optimised Direct Defences and Over Pumping

This option is a derivative of Option 5A – Direct Defences and is presented in Figure 31 below. A summary of the proposed interventions and existing constraints is provided in Table 22.

The principle of Option 5C is to include a $1m^3/s$ pumpstation at the Dairygold culvert inlet and therefore reduce the extent of localised direct defences required. However, due to the slope of the channel, there is no reduction in extent or height of defences upstream of Kearney's Cross in comparison to Option 5A: Direct Defences.

The works would see the replacement of the open channel between residential properties, east of Kearney's Cross, with a culvert. Two pumping stations at either side of the culvert would be required. A 0.9m high embankment would be required in the agricultural land at Kearney's Cross, in combination with local river channel realignment.

After passing under Lower Road, a 0.8m high wall would be constructed on the north side of the channel, protecting the residential properties. A 0.7m high wall would be built on the northern side of the channel further downstream, immediately prior to the green area proceeding Father Murphy Terrace Bridge. Downstream of the bridge, an existing wall on the southern side would be replaced by a 0.7m high wall, terminating at the Dairygold culvert inlet.

A pumping station designed to pump $1m^3/s$ would be installed in Bransfield Green. This pumping station would be used to pump fluvial flow into the Owenacurra Estuary during a flood event, at a rate which limits the extents of the upstream defences. This would be connected by a rising main under the Dairygold Co-op site and the R630 (Whitegate to Midleton Road) to outfall into the estuary. This pumping station may also be utilised during tidal events when the Dairygold culvert is "tide locked".

The existing non-return flap valve would be maintained and upgraded at the estuary, preventing tidal water from flowing back up the culvert and flooding upstream.

Maintenance requirements would be similar to those of Option 5A, with the addition of maintenance where necessary to the pumping station at Bransfield Green.

5.6.4.1 Option 5C – Climate Change Adaptability

This option was found to be adaptable for the Mid Range Future Scenario (MRFS) at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

An adaptive approach can be taken by designing the direct defences to permit an acceptable extension in height in the future in order to maintain the required level of protection for the MRFS.

For the High End Future Scenario (HEFS), the required defence height would have significant negative implications with defence heights greater than 1.5m in public areas. The required standard of protection can also be achieved through other means such as upstream storage or demountables instead of increasing wall heights.

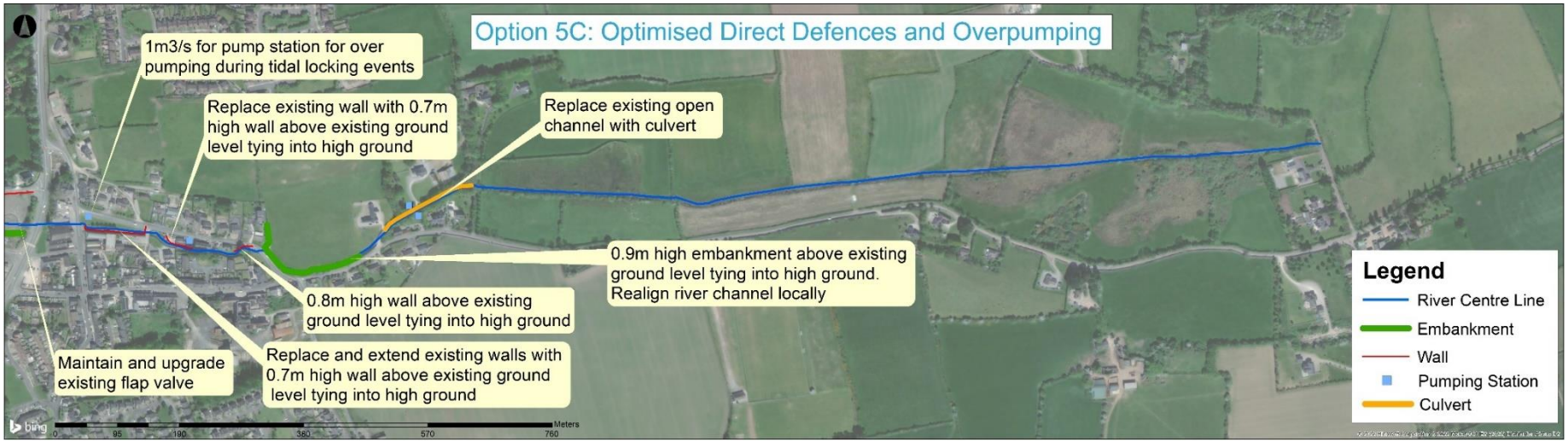


Figure 31 Option 5C – Optimised Direct Defences and Over Pumping

Table 22 Option 5C – Optimised Direct Defences and Over Pumping

Description	Comments
Ballinacurra	
Culvert between the residential properties east of Kearney's Cross, replacing existing open channel.	Removal of vegetation / trees. Instream works.
2No pumping stations either side of the culvert between the residential properties east of Kearney's Cross.	Regular maintenance required.
0.9m high, 235m long embankment in field north of Kearney's Cross. Realignment of channel.	Impact on existing stone wall. Instream works.
Flood defence walls, 0.7m and 0.8m high, from Geragh Road (Kearney's Cross) to the bridge into Father Murphy Terrace.	Removal of vegetation / trees. Instream works. Proximity to ESB assets.
Upgrade of existing wall from Father Murphy Terrace Bridge to the Dairygold culvert inlet to 0.7m high, 105m long.	Instream works. Proximity to GNI assets. Impact on existing stone wall.
1No pumping station adjacent to the Dairygold culvert inlet to overpump residual flow into the Owenacurra Estuary and associated infrastructure to discharge into Estuary	Regular maintenance required. Proximity to GNI assets. Proximity to IW assets.
Upgrade of existing flap valve at entrance to the Owenacurra Estuary.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA.

5.6.5 Option 5D – Optimised Direct Defences, Upstream Storage and Over Pumping

This option is presented in Figure 32 below and combines elements of Options 5B-1 and 5C, including a refined upstream storage area in combination with direct defences and over pumping. A summary of the proposed interventions and existing constraints is provided in Table 23.

Works in this area would involve the construction of a 1.1m high embankment over the Ballinacurra Stream, in the agricultural lands east of Ballinacurra. The embankment would be fitted with a flow control structure which would limit the flow of water travelling downstream, while retaining the excess flow to the storage area upstream. A spillway would be designed along this embankment such that in an exceedance event the overtopping of the embankments could be managed and would ensure that the properties to the east and south are not at risk. To the east, a second embankment 1m high would be constructed to protect the properties of Rocky Road.

Downstream, the works would see the replacement of the open channel between residential properties with a culvert east of Kearney's Cross. Two pumping stations at either side of the culvert would be required. A 0.5m high embankment would be required in the agricultural land at Kearney's Cross, in combination with local river channel realignment. On approach to Father Murphy Terrace Bridge, an existing wall on the north side of the channel would be replaced by 0.5m high wall to flood defence standard.

As there is a potential that flow may backup when a fluvial event coincides with high tide, (i.e. the culvert is "tide locked" due to the high head at the culvert outlet restricting the fluvial flow from discharging in to the estuary), it is proposed that a pumping station located adjacent to the Dairygold culvert inlet will over pump any residual flow directly into the Owenacurra Estuary. This would be connected by a rising main under the Dairygold Co-op site and the R630 (Whitegate to Midleton Road) to outfall into the estuary. This pumping station may also be utilised during tidal events when the Dairygold culvert is "tide locked". Fluvial flow would be over pumped allowing the upstream storage system to remain passive and allow flow in the channel at all times.

The existing non-return flap valve would be maintained and upgraded at the estuary, preventing tidal water from flowing back up the culvert and flooding upstream.

With regard to maintenance, this option would require a significant amount of additional intervention. This is due to the option's reliance on direct defences, a flow control structure, trashscreen, embankments and a pumping station.

5.6.5.1 Option 5D – Climate Change Adaptability

This option was found to be adaptable for the Mid Range Future Scenario (MRFS) at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

An adaptive approach can be taken by designing the direct defences to permit an acceptable extension in height in the future in order to maintain the required level of protection for the MRFS.

For the High End Future Scenario (HEFS), the required defence height would have significant negative implications with defence heights greater than 1.5m in public areas. Therefore required standard of protection can be achieved through other means such as upstream storage or demountables instead of increasing wall heights. Upstream storage adaptation can be integrated based on an assumptive approach to be adopted in the present day.

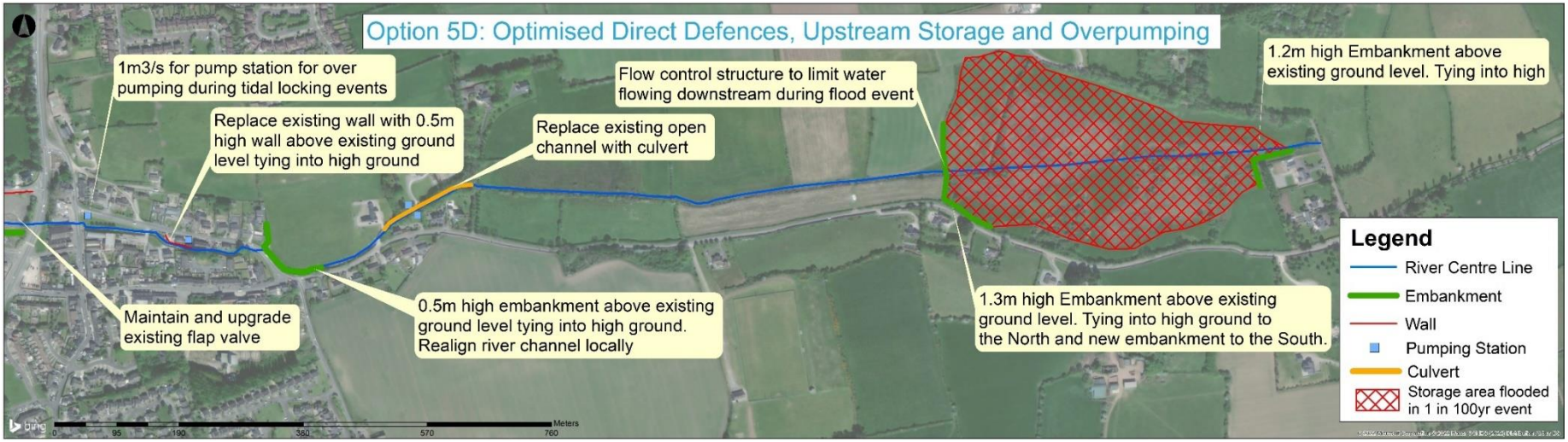


Figure 32 Option 5D - Optimised Direct Defences, Upstream Storage and Over Pumping

Table 23 Option 5D – Optimised Direct Defences, Upstream Storage and Over Pumping

Description	Comments
Ballinacurra	
1.2m high, 120m long East Embankment (L-shape), adjacent to the residential properties along Rocky Road.	Proximity to ESB assets. Removal of vegetation / trees.
1.3m high, 130m long West Embankment (north/south orientation) to the north of Geragh Road.	Instream works. Removal of vegetation / trees.
Culvert between the residential properties east of Kearney's Cross, replacing existing open channel.	Instream works. Removal of vegetation / trees.
2No pumping stations either side of culvert between the residential properties east of Kearney's Cross.	Regular maintenance required.
0.5m high, 235m long embankment in field north of Kearney's Cross. Realignment of channel.	Instream works. Impact on existing stone wall.
0.5m high, 35m long flood defence wall circa 40m upstream of the access bridge to Father Murphy Terrace.	Instream works. Proximity to ESB and GNI assets. Removal of vegetation / trees.
1No pumping station adjacent to the Dairygold culvert inlet to overpump residual flow into the Owenacurra Estuary and associated infrastructure to discharge into Estuary.	Regular maintenance required. Proximity to GNI assets. Proximity to IW assets.
Upgrade of existing flap valve at entrance to the Owenacurra Estuary.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA.

5.7 Area 6: Water Rock

Area 6 covers the Water Rock watercourse area to the estuary. This area includes Water Rock House, North Point Business Park, Castle Rock Estate, the proposed LIHAF Development site, Baneshane and the Wastewater Treatment Plant (WWTP) to the south.

There is a live rail-line passing east west through this area. There are a number of proposed infrastructure projects interacting with the scheme in this area including the Water Rock LIHAF Development, the Irish Water Wastewater Load Diversion project, the Irish Rail dual tracking project and the Ballinacurra to Midleton Cycleway scheme.

This area also includes a cave system, where the Water Rock watercourse goes underground and re-emerges south of the N25 road. The predominant risk of flooding in this area is fluvial, which can be exacerbated by the groundwater levels, and there is also a risk of tidal flooding downstream. The extent of flooding from the Q100 and T200 Events in this area are shown in Figure 33 below.

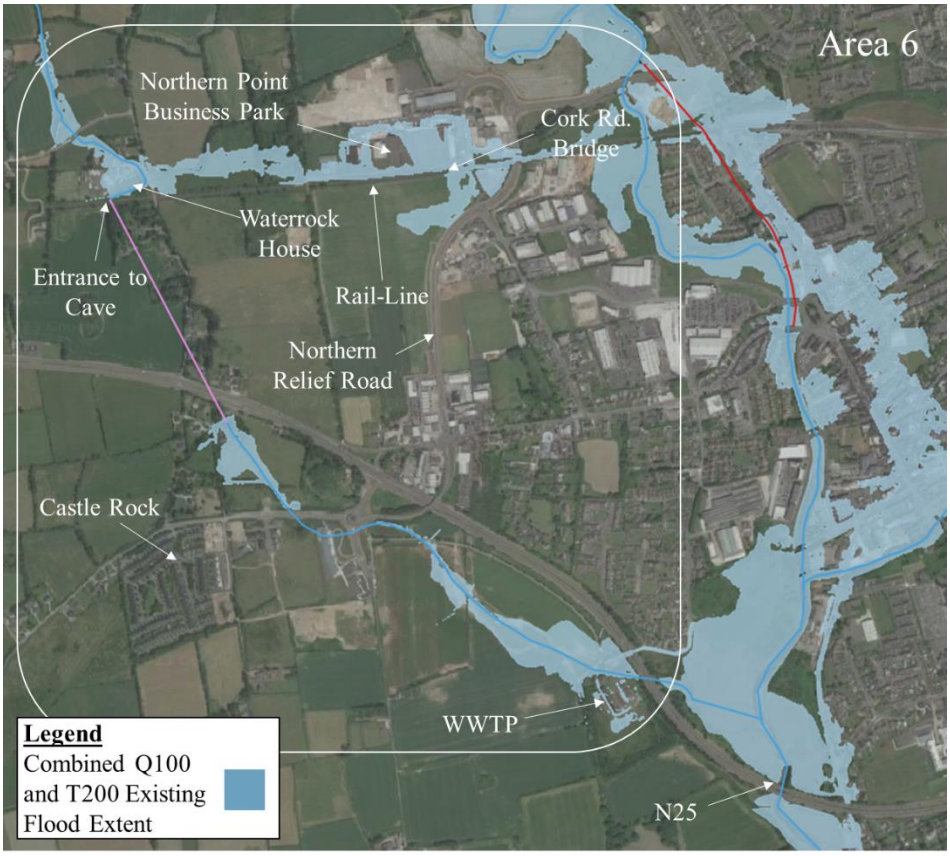


Figure 33 Area 6: Water Rock

5.7.1 Option 6A – Flood Diversion Channel/Culvert (north of the railway line) and Direct Defences

The flood diversion channel/culvert north of the railway line and direct defences option for the Water Rock area is presented in Figure 34. A summary of the proposed interventions and existing constraints is provided in Table 24.

This option includes the construction of a flow control structure on Water Rock watercourse upstream of the cave system. Should a blockage in the cave system occur, all flows north of Water Rock House would be diverted by the control structure into a proposed 1.8x2.4m box culvert. This would cross under the road north of the railway crossing, and then would run parallel to and on the north side of the existing railway line. It would pass along the North Point Business Park service road and under the existing Northern Relief Rd bridge before emerging into an open channel in the floodplain of the Owenacurra River. It would then discharge to the river.

This would significantly reduce the fluvial flood risk downstream of the cave system. Where the underground watercourse south of the N25 re-emerges to the surface, local drainage improvement works are proposed. This would serve to mitigate any remaining flood risk to the residential properties north and west of the known spring(s). However it is noted that the location of all the springs may not have been identified.

Downstream, an embankment is proposed to the north of the Midleton Wastewater Treatment Plant (WWTP). This 2.3m high embankment would protect the WWTP during the design event by utilising the existing flood plain within the agricultural land. It is proposed a culvert be constructed to replace the existing open channel through the WWTP site and connect with the existing culvert under the N25.

Maintenance would involve the visual inspection of the flow control and culvert structures. Rehabilitation measures, such as joint sealing or mortar repair works, would be conducted if necessary. Routine maintenance, such as debris or sediment removal, would also be conducted regularly. Where local drainage works are proposed, additional associated maintenance works such as gully clearing would also be required. The downstream embankment would require inspection to ensure no seepage or crest lowering is occurring, and that vegetation is not growing on it.

5.7.1.1 Option 6A – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the flow diversion culvert/channel and downstream embankments and culverts would be designed using the assumptive approach in the present day that can maintain the required standard of protection / risk reduction in a future scenario. There will be minimal future cost or intervention, however there will be an increase in present day capital costs.

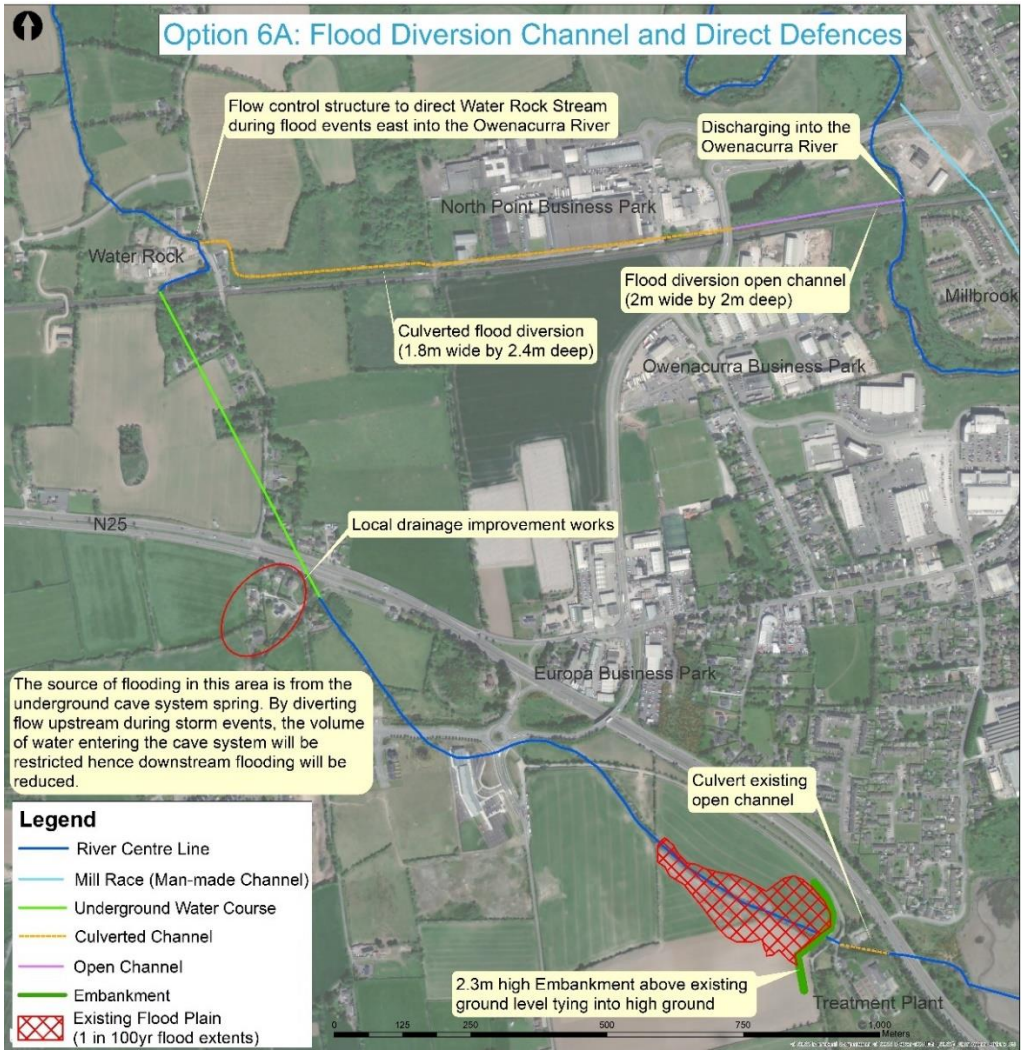


Figure 34 Option 6A – Flood Diversion Channel and Direct Defences

Table 24 Option 6A – Flood Diversion Channel and Direct Defences

Description	Comments
Water Rock	
1km long 1.8m x 2.4m box culvert from Water Rock stream to open channel	Instream works. Proximity to ESB and proposed IW assets. Removal of vegetation / trees.
300m long 2m x 2m open channel from connecting culvert to Owenacurra	Instream works. Proximity to ESB assets. Removal of vegetation / trees.
Local drainage improvement works downstream of cave system	Instream works. Removal of vegetation / trees.
2.3m high, 236m long embankment upstream of WWTP and retention of the existing floodplain	Instream works. Proximity to IW and ESB assets. Removal of vegetation / trees.
Construction of culvert at existing open channel through WWTP site.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA. Proximity to IW and ESB assets.

5.7.2 Option 6B-1 – Flood Diversion Culvert South of Railway and Direct Defences

The flood diversion culvert south of the railway line and direct defences option for the Water Rock area is presented in Figure 35 below. A summary of the proposed interventions and existing constraints is provided in Table 25.

This option includes the construction of a flow control structure on Water Rock watercourse upstream of the cave system. Should a blockage in the cave system occur, all flows north of Water Rock House would be diverted by the control structure into a proposed 1.8x2.4m culvert. This culvert would cross under the road north of the railway crossing, and then would perpendicularly cross the existing railway line, prior to running parallel to it on the south side of the railway line.

It would pass through existing agricultural land, under the existing Northern Relief Rd bridge and through an industrial site, before discharging into the floodplain of the Owenacurra River. It is not proposed to extend the culvert all the way to the riverbank.

This culvert would significantly reduce the fluvial flood risk downstream of the cave system. Where the underground watercourse south of the N25 re-emerges to the surface, local drainage improvement works are proposed. This would serve to mitigate any remaining flood risk to the residential properties north and west of the known spring(s). However it is noted that the location of all the springs may not have been identified.

Downstream, an embankment is proposed to the north of the Midleton Wastewater Treatment Plant (WWTP). This 2.3m high embankment would protect the WWTP during the design event by utilising the existing flood plain within the agricultural land. It is proposed a culvert is to be constructed to replace the existing open channel through the WWTP site and connect with the existing culvert under the N25.

The maintenance requirements for this option are identical to those set out in Option 6A, as the defences proposed are the same, but in different locations.

5.7.2.1 Option 6B-1 – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the flow diversion culvert and downstream embankments and culverts would be designed using the assumptive approach in the present day that can maintain the required standard of protection / risk reduction in a future scenario. There will be minimal future cost or intervention, however there will be an increase in present day capital costs.

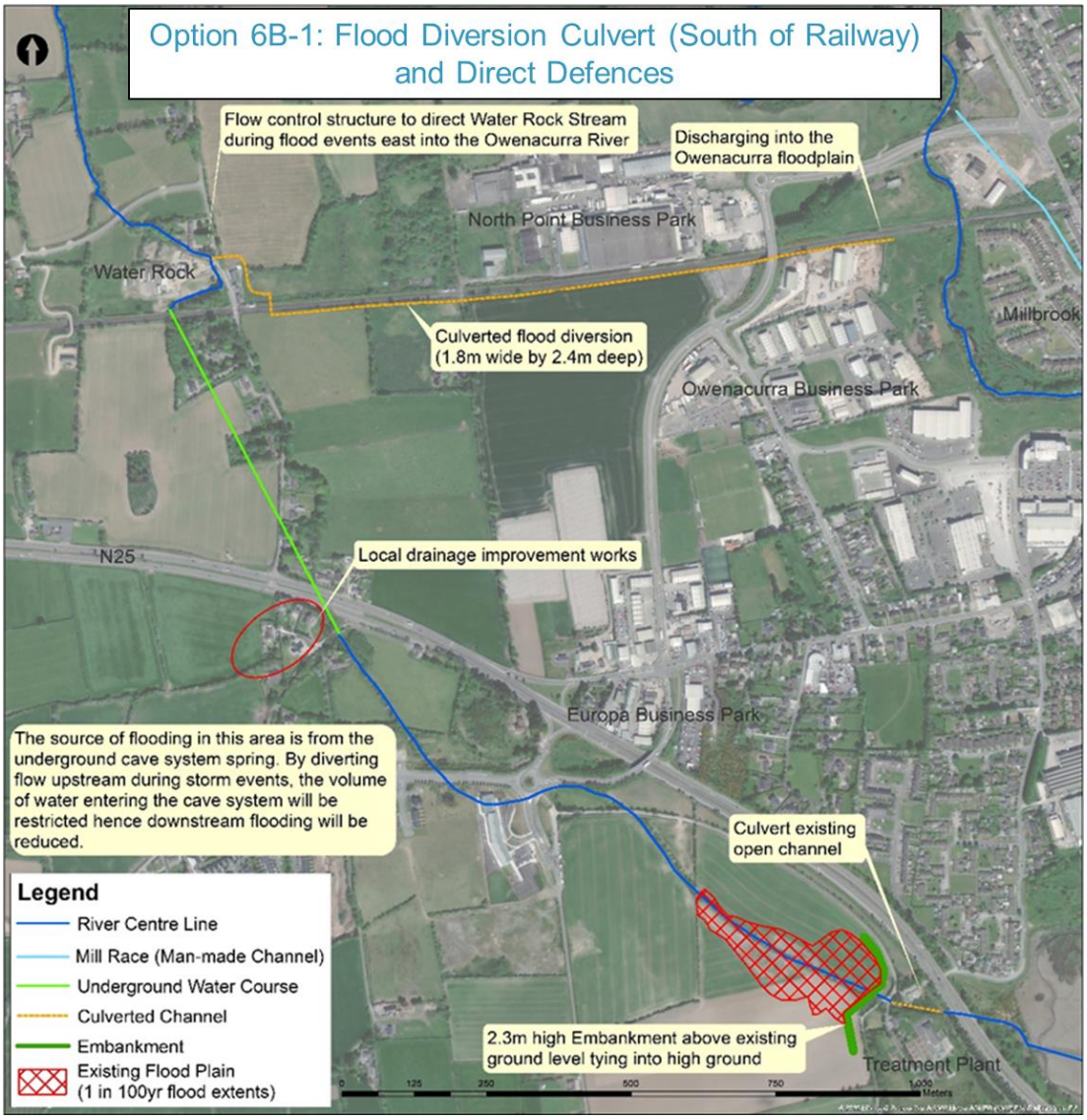


Figure 35 Option 6B-1 – Flood Diversion Culvert South of Railway and Direct Defences

Table 25 Option 6B-1 – Flood Diversion Culvert South of Railway and Direct Defences

Description	Comments
Water Rock	
1.26km long 1.8m x 2.4m box culvert from Water Rock watercourse to Owenacurra	Instream works. Proximity to ESB, Irish Rail and proposed IW assets. Removal of vegetation / trees.
Local drainage improvement works downstream of cave system	Instream works. Removal of vegetation / trees.
2.3m high, 236m long embankment upstream of WWTP and retention of the existing floodplain	Instream works. Proximity to IW and ESB assets. Removal of vegetation / trees.
Culvert at existing open channel through WWTP site.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA. Proximity to IW and ESB assets.

5.7.3 Option 6B-2 – Flood Diversion Channel/Culvert South of Railway and Direct Defences

The flood diversion channel/culvert south of the railway line and direct defences option for the Water Rock area is presented in Figure 36 below. A summary of the proposed interventions and existing constraints is provided in Table 26.

This option includes the construction of a flow control structure on Water Rock watercourse upstream of the cave system. Should a blockage in the cave system occur, all flows north of Water Rock House would be diverted by the control structure into a proposed 1.8x2.4m culvert. This culvert would cross under the road north of the railway crossing, and then would perpendicularly cross the existing railway line, prior to running parallel to it on the south side.

The culvert would discharge into an open channel that would run east, parallel to the railway line, passing through agricultural land. It would be culverted again to cross underneath the road south of the second level crossing between agricultural fields, before discharging into an open channel further east. It would finally be culverted again at the beginning of the industrial area before discharging into the Owenacurra floodplain.

This culvert would significantly reduce the fluvial flood risk downstream of the cave system. Where the underground watercourse south of the N25 re-emerges to the surface, local drainage improvement works are proposed. This would serve to mitigate any remaining flood risk to the residential properties north and west of the known spring(s). However it is noted that the location of all the springs may not have been identified.

Downstream, an embankment is proposed to the north of the Midleton Wastewater Treatment Plant (WWTP). This 2.3m high embankment would protect the WWTP during the design event by utilising the existing flood plain within the agricultural land. It is proposed a culvert is to be constructed to replace the existing open channel through the WWTP site and connect with the existing culvert under the N25.

Maintenance would involve the visual inspection of the flow control and culvert structures, with rehabilitation done where necessary. Routine maintenance, such as debris or sediment removal, would also be conducted when required. Typical drainage maintenance works would be completed, when necessary, as would embankment inspection and maintenance. The open channels proposed in this option would require debris to be removed at the transitions to the culverts in order to maintain flow through the network when required. Trashscreens may be required at the culvert entrances.

5.7.3.1 Option 6B-2 – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the flow diversion culvert and downstream embankments and culverts would be designed using the assumptive approach in the present day that can maintain the required standard of protection / risk reduction in a future scenario. There will be minimal future cost or intervention, however there will be an increase in present day capital costs.

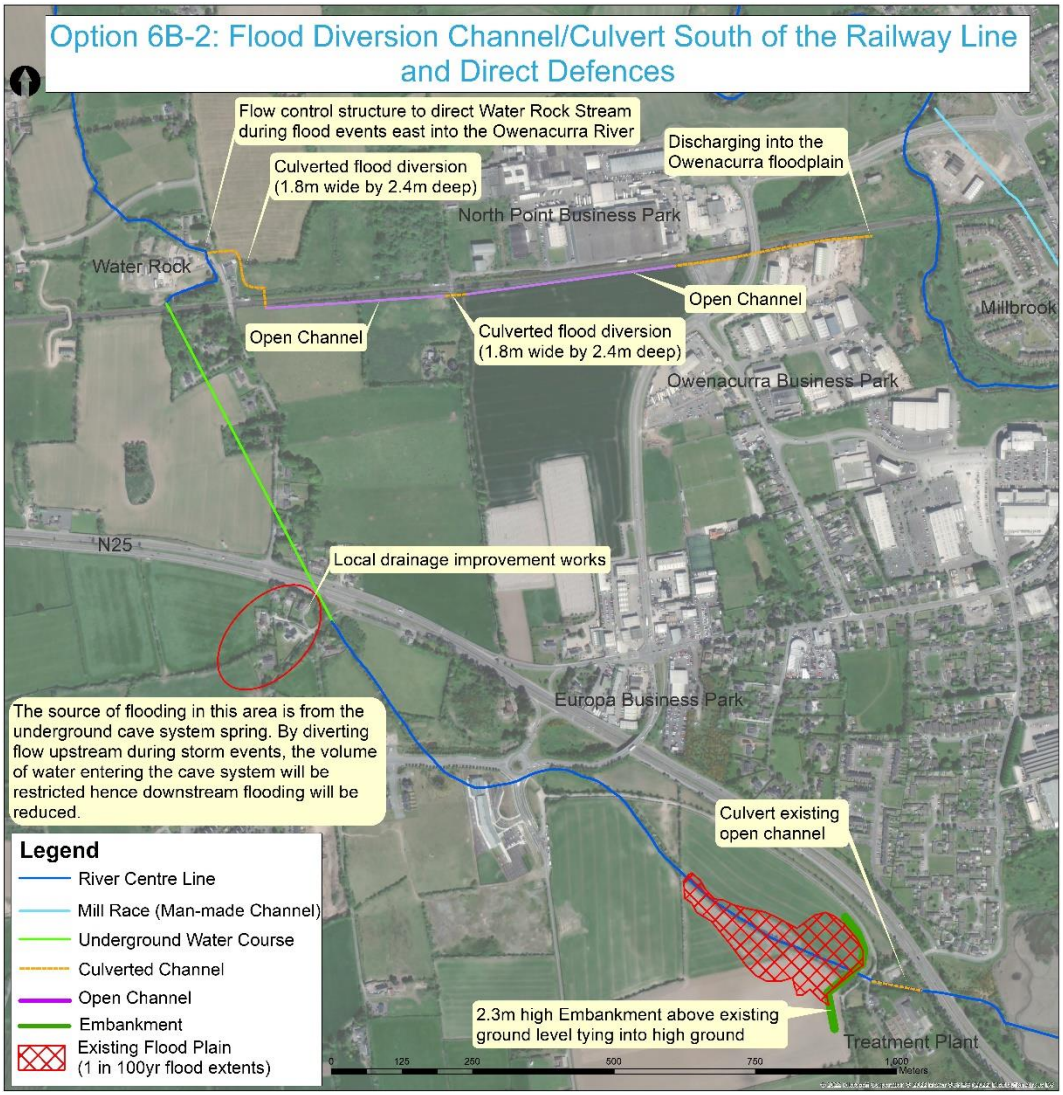


Figure 36 Option 6B-2 – Flood Diversion Channel/Culvert South of the Railway Line and Direct Defences

Table 26 Option 6B-2 – Flood Diversion Channel/Culvert South of the Railway Line and Direct Defences

Description	Comments
Water Rock	
576m long 1.8m x 2.4m box culvert from Water Rock watercourse to Owenacurra	Instream works. Proximity to ESB, Irish Rail and proposed IW assets. Removal of vegetation / trees.
999m long 1.8m x 2.4m open channel from Water Rock watercourse to Owenacurra	Instream works. Removal of vegetation / trees.
Local drainage improvement works downstream of cave system	Instream works. Removal of vegetation / trees.
2.3m high, 236m long embankment upstream of WWTP and retention of the existing floodplain	Proximity to IW and ESB assets.
Culvert at existing open channel through WWTP site.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA.

5.7.4 Option 6C – Flood Diversion Channel (bypassing Cave System) and Direct Defences

The flood diversion channel and direct defences option for the Water Rock area is presented in Figure 37 below. A summary of the proposed interventions and existing constraints is provided in Table 27.

This option includes the construction of a flow control structure on Water Rock watercourse upstream of the cave system. Should a blockage in the cave system occur, all flows north of Water Rock House would be diverted by the control structure into a proposed 1.8x2.4m culvert. This culvert would cross under the road north of the railway crossing, and then would perpendicularly cross the existing railway line, prior to running south through the existing agricultural land via an open channel.

The open channel would be culverted underneath the N25 East Cork Parkway by a 3.6x2.7m culvert. This culvert would discharge into Water Rock Stream to the south of the cave system.

This culvert would significantly reduce the fluvial flood risk downstream of the cave system. Where the underground watercourse south of the N25 re-emerges to the surface, local drainage improvement works are proposed. This would serve to mitigate any remaining flood risk to the residential properties north and west of the known spring(s). However it is noted that the location of all the springs may not have been identified.

Where the culvert discharges into the stream, the stream would be diverted into a new open channel travelling south to the L3619 road. The channel would then turn east and run parallel to the road, north of the wall into the proposed Abbey Wood development site. It would be culverted through a 3.6x2.7m culvert across the proposed entrance to the development site, before returning to open channel as it moves further east.

Northeast of the roundabout adjacent to Gaelscoil Mhainistir Na Corann, the open channel would again be culverted by a 3.6x2.7m culvert before discharging into Water Rock Stream. A 2.3m high embankment would be constructed to the north of the Midleton Wastewater Treatment Plant (WWTP). A culvert would be constructed to replace the existing open channel through the WWTP site and connect to the existing culvert under the N25 East Cork Parkway.

The maintenance requirements for this option are similar to those listed in Section 5.7.3, but are increased due to the presence of an additional culvert and open channel in the design.

5.7.4.1 Option 6C – Climate Change Adaptability

This option is adaptable at moderate to significant cost, difficulty and impact. It provides no impediment to future interventions to address future flood risk.

It is proposed that the flow diversion culvert and downstream embankments and culverts would be designed using the assumptive approach in the present day that can maintain the required standard of protection / risk reduction in a future scenario. There will be minimal future cost or intervention, however there will be an increase in present day capital costs.

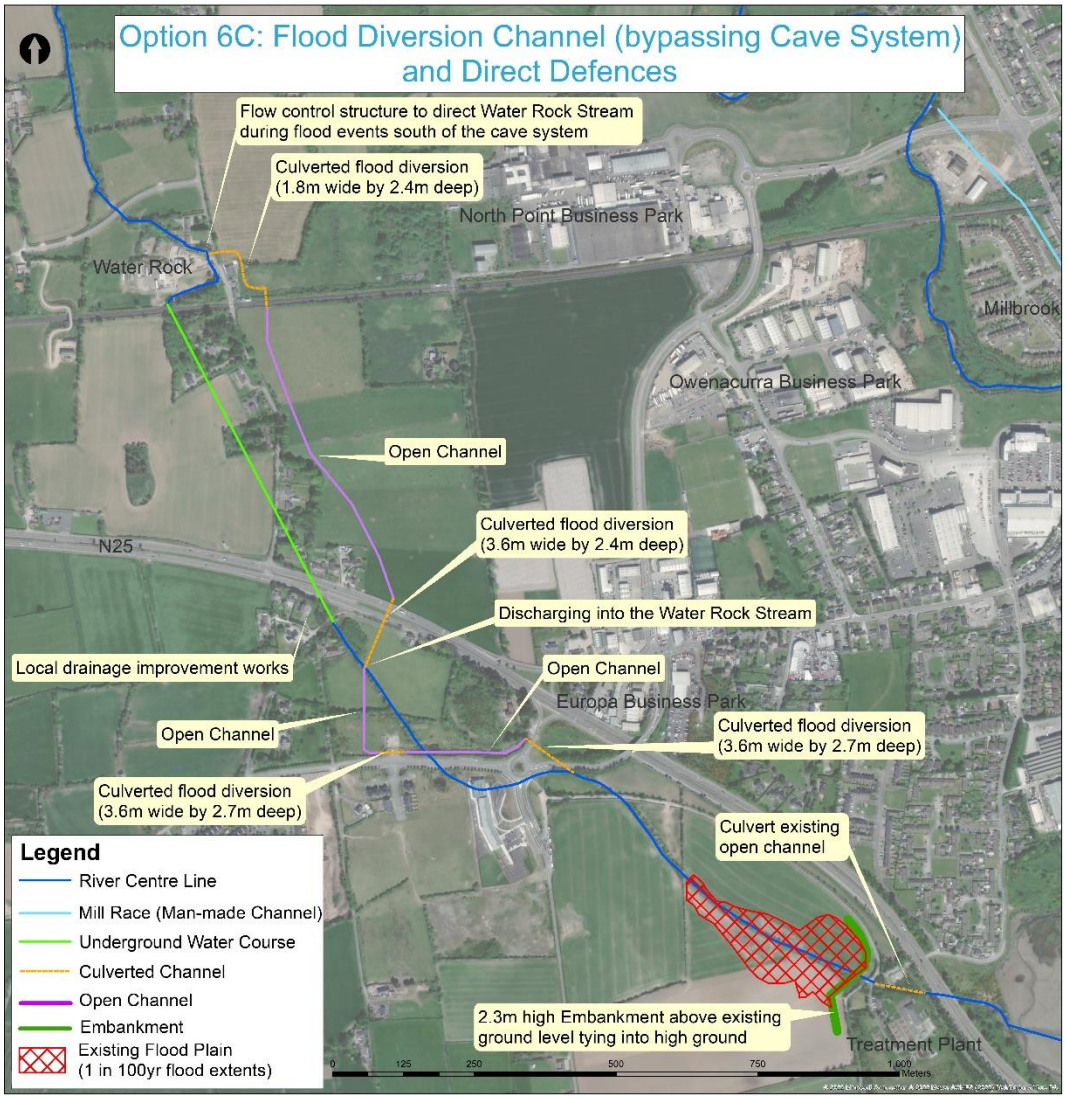


Figure 37 Option 6C – Flood Diversion Channel (bypassing Cave System) and Direct Defences

Table 27 Option 6C – Flood Diversion Channel (bypassing Cave System) and Direct Defences

Description	Comments
Water Rock	
182m long 1.8m x 2.4m box culvert from Water Rock stream to open channel	Instream works. Proximity to ESB and proposed IW assets. Removal of vegetation / trees.
566m long 2m x 2m open channel from connecting culvert to culvert at N25 East Cork Parkway	Proximity to ESB assets. Removal of vegetation / trees.
135m long 3.6m x 2.7m culvert under the N25 from the proposed open channel to the re-emergence of the Water Rock stream	Removal of vegetation / trees. Proximity to IW assets.
Local drainage improvement works downstream of cave system	Instream works. Removal of vegetation / trees.
165m long 2m x 2m open channel from connecting culvert to culvert at Abbey Wood proposed development entrance	Instream works. Removal of vegetation / trees.
43m long 3.6m x 2.7m culvert south of the Abbey Wood proposed development entrance	Instream works. Removal of vegetation / trees.
195m long 2m x 2m open channel from connecting culvert to culvert at roundabout adjacent to Gaelscoil Mhainistir Na Corann	Instream works. Removal of vegetation / trees.
105m long 3.6m x 2.7m culvert east of roundabout adjacent to Gaelscoil Mhainistir Na Corann	Instream works. Removal of vegetation / trees. Proximity to IW, ESB and GNI assets.
2.3m high, 236m long embankment upstream of WWTP and retention of the existing floodplain	Instream works. Proximity to IW, ESB and GNI assets. Removal of vegetation / trees.
Culvert at existing open channel through WWTP site.	Instream works. Proximity to Great Island Channel SAC and Cork Harbour SPA. Proximity to IW, ESB and GNI assets.