Cork County Council

Douglas Flood Relief Scheme (Including Togher Culvert)

Options Report

234335-00

Issue 1 | 19 May 2017

Job number 234335-00

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Douglas Options Report

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Togher Options Report

1 Introduction

1.1 Context

The Office of Public Works (OPW) in partnership with Cork City and Cork County Councils have carried out a Catchment Flood Risk Assessment and Management (CFRAM) Study for the Lee Catchment. Douglas and Togher were included as part of the study as both are located in the Tramore catchment which is a sub catchment of the Lee. The Catchment Flood Risk Management Plan (CFRMP) which was published in January 2014, identified a preferred flood risk management option in Togher but did not identify a preferred scheme for Douglas.

Douglas was however severely flooded in June 2012. As a consequence, Cork County Council, in collaboration with the OPW who are the funding authority, have commissioned a project to develop a Flood Relief Scheme (FRS) for Douglas and Togher.

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 – Environmental Assessment & Planning.
- Stage III - Detailed design and Tender.
- Stage IV – Construction.
- Stage V - Handover of works.

1.2 Scope of the Report

The purpose of this report is to present our assessment of how the preferred options for Douglas and Togher were developed and selected.

As the mechanisms of flooding in Douglas and Togher are independent of each other, the options assessment for both areas have been carried out separately. The preferred options for both areas however are being taking forward together as a single flood relief scheme.

This report is presented in three parts:

- The main body of the report presents an overview of the study area, a brief description of the preferred scheme and the cost benefit analysis of the preferred scheme as a whole.
- Appendix A presents the Options Report for Douglas. It details the process by which alternative options for Douglas were assessed and considered and how the preferred option was selected.
- Appendix B presents the Options Report for Togher. It details the process by which alternative options for Togher were assessed and considered and how the preferred option was selected.

1.3 Overview of the Optioneering Process

1.3.1 Douglas

The Douglas Options report (Appendix A), details the process by which the preferred flood relief option in Douglas was selected. An overview of this process is as follows:

- An initial screening of a long list of possible flood risk management measures against a predetermined set of criteria was carried out in order to determine their feasibility.
- The flood risk management measures potentially deemed feasible from the screening exercise were evaluated in more detail.
- Based on the results of the above assessment, a number of possible flood risk management options (consisting of one or more measures) were developed.
- These flood relief options were then subjected to economic, environmental and multi-criteria assessments, allowing a preferred flood relief option to be selected.

1.3.2 Togher

The Togher Options report (Appendix B), details the optioneering process for Togher. The optioneering for Togher differs to the process for Douglas as the Lee CFRAM Study recommended a flood relief option for Togher which was subsequently adopted by the OPW as the preferred scheme. An overview of the process for Togher is as follows:

- Preliminary assessment of the option proposed by the Lee CFRAM Study (single culvert).
- Preliminary assessment of an open channel alternative.
- Both the single culvert and open channel options were then subjected to economic, environmental and multi-criteria assessments, allowing a preferred flood relief option to be selected.

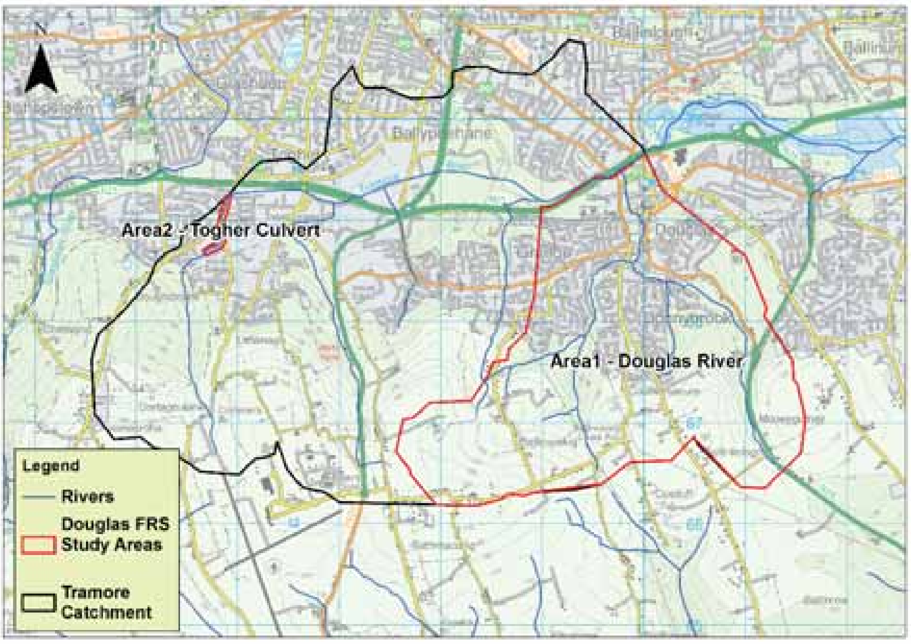
1.4 Study Area

The study areas for the project are presented in Figure 1 and are as follows:

Area 1: The catchment of the Douglas River. The Douglas River is more commonly known as the Ballybrack Stream, and will be referred to as such in this report.

Area 2: The length of the Tramore River between Lehenaghmore Industrial Estate and Greenwood Estate in Togher.

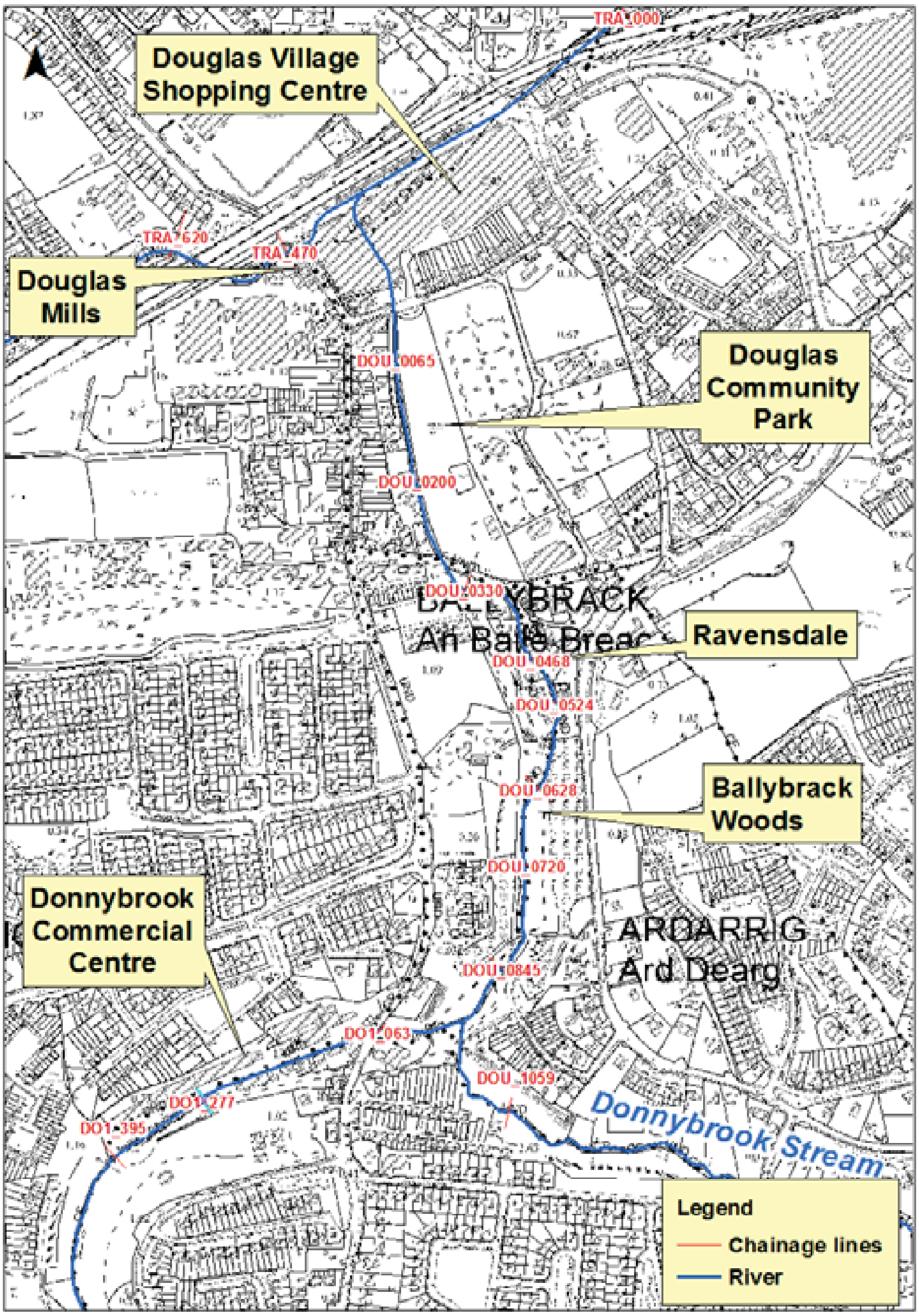
Figure 1: Douglas flood relief scheme (including Togher Culvert) study areas



The Tramore River rises in the southwest of the catchment and flows eastwards into the Douglas River estuary, which discharges into Lough Mahon. A number of tributaries join the Tramore River, the largest of which is the Ballybrack Stream, which flows north through Douglas before joining the Tramore River in a culverted section at Douglas Village Shopping Centre.

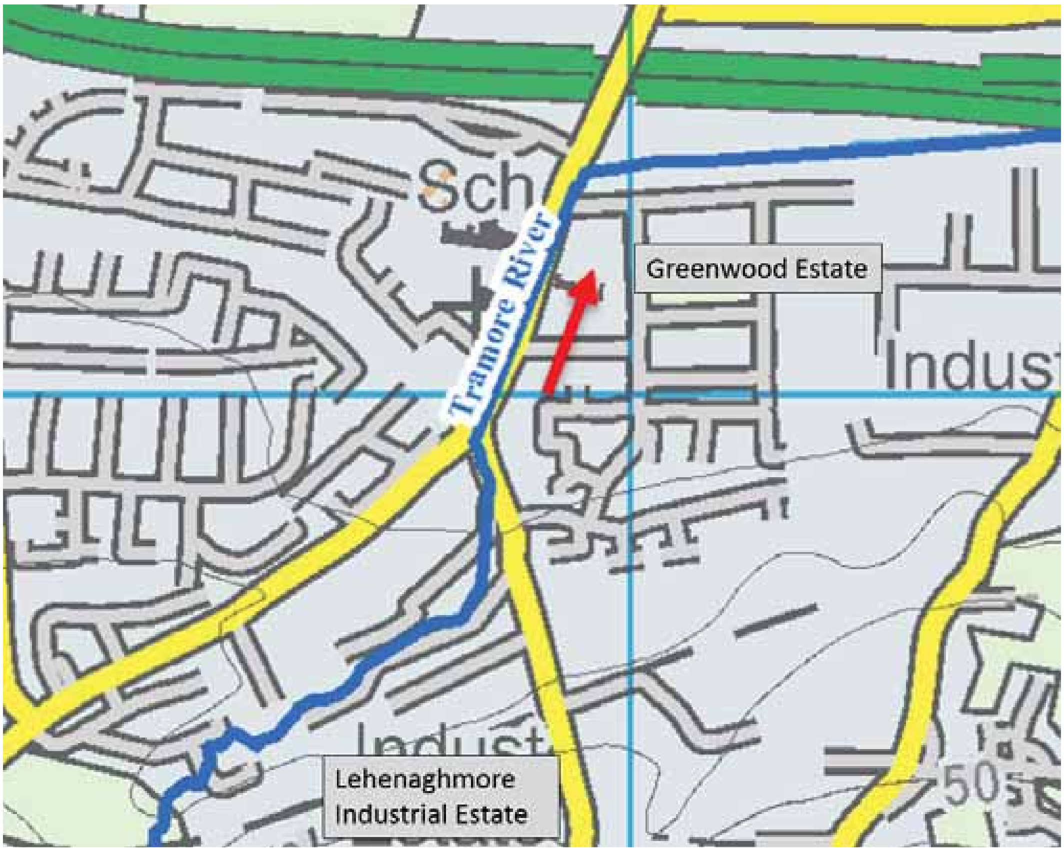
Figure 2 presents a key plan of the critical areas at risk in Douglas. The red labels in the figures correspond to the labels of the cross sections of the hydraulic model developed as part of the study. The labels are comprised of a three character prefix which is unique to the individual channels followed by a channel chainage (in metres). The chainage of each channel commences at Ch.0m at the downstream end of each watercourse and will be used throughout this report in describing the location of proposed flood risk management options.

Figure 2: Douglas key plan



The area of Togher relevant to this study is between Lehenaghmore Industrial Estate and Greenwood Estate and is indicated in Figure 3. The Tramore River flows through this area and is culverted over most the reach.

Figure 3: Area of Togher relevant to the study. The red arrow indicates the direction of flow of the Tramore River.



2 Overview of the Preferred scheme

The proposed Flood Relief Scheme for Douglas and Togher includes the construction of direct flood defences and conveyance improvements along the Ballybrack Stream, Grange Stream and Tramore River.

This Chapter presents an overview of the scheme. For a detailed description of the scheme, the reader is referred to the individual options reports presented in Appendix A and Appendix B for both Douglas and Togher respectively.

2.1 Proposed works in Douglas

The proposed scheme for Douglas consists of works in three separate areas:

- **Area 1:** Ballybrack Stream through Douglas.
- **Area 2:** Tramore River through St Patrick's Mills, Douglas
- **Area 3**: Grange Stream (tributary of Ballybrack Stream) through Donnybrook Commercial Centre

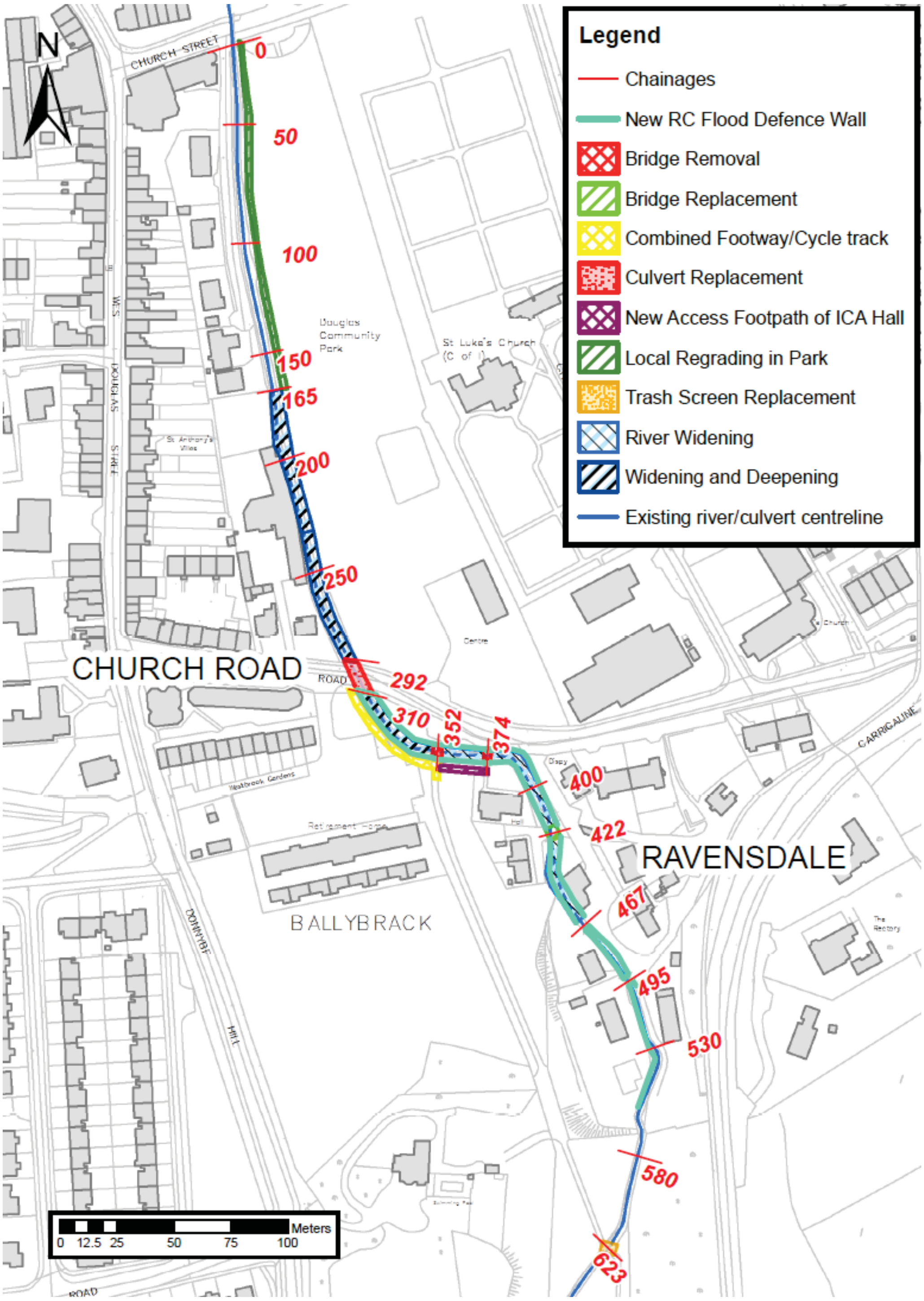
An overview of the works proposed for each of these three areas is presented below.

2.1.1 Area 1 – Ballybrack Stream through Douglas

The works along the Ballybrack stream through Douglas are presented in Figure 4. It can be seen from the figure that the works consist of:

- Construction of new stone clad flood defence along the lengths of the channel as indicated.
- Widening and deepening of the Ballybrack channel as indicated.
- Local re-grading along the right bank of the Ballybrack in the northern half of the Community park.
- Upgrade of a number of culverts along the reach as well as the removal of a number of bridges.
- The upgrade of a coarse trash screen in Ballybrack Woods.

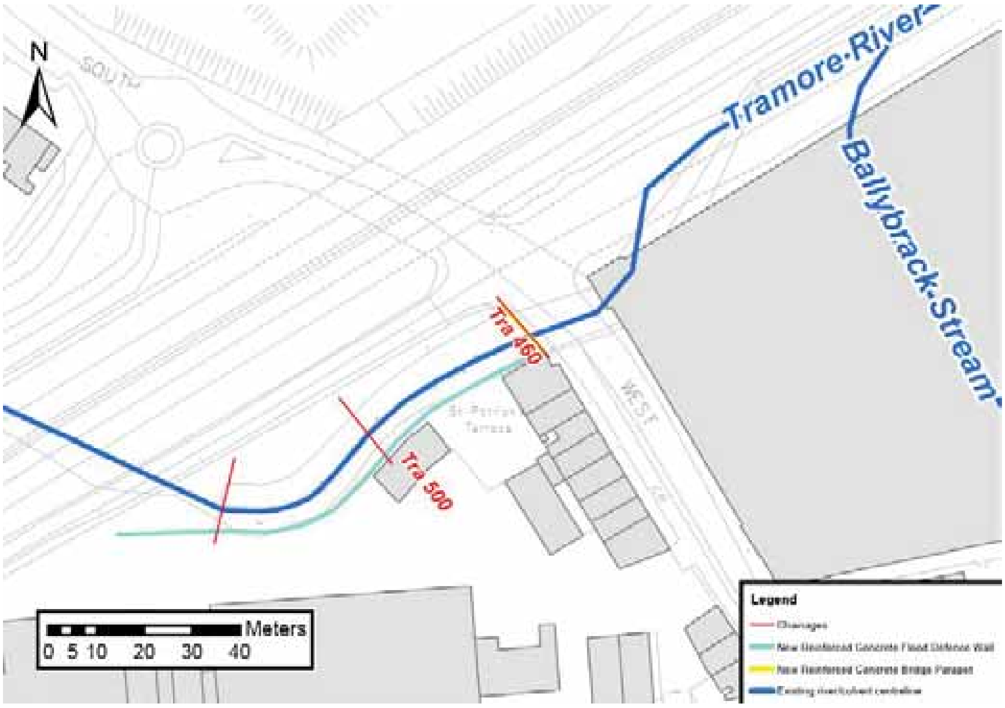
Figure 4: Area 1 Ballybrack Stream through Douglas



2.1.2 Area 2 – St. Patrick's Mills

The proposed works at St. Patrick's Mills are presented in Figure 5 and consist of a new flood defence wall along the right bank of the Tramore River.

Figure 5: Area 2 – St. Patrick's Mills

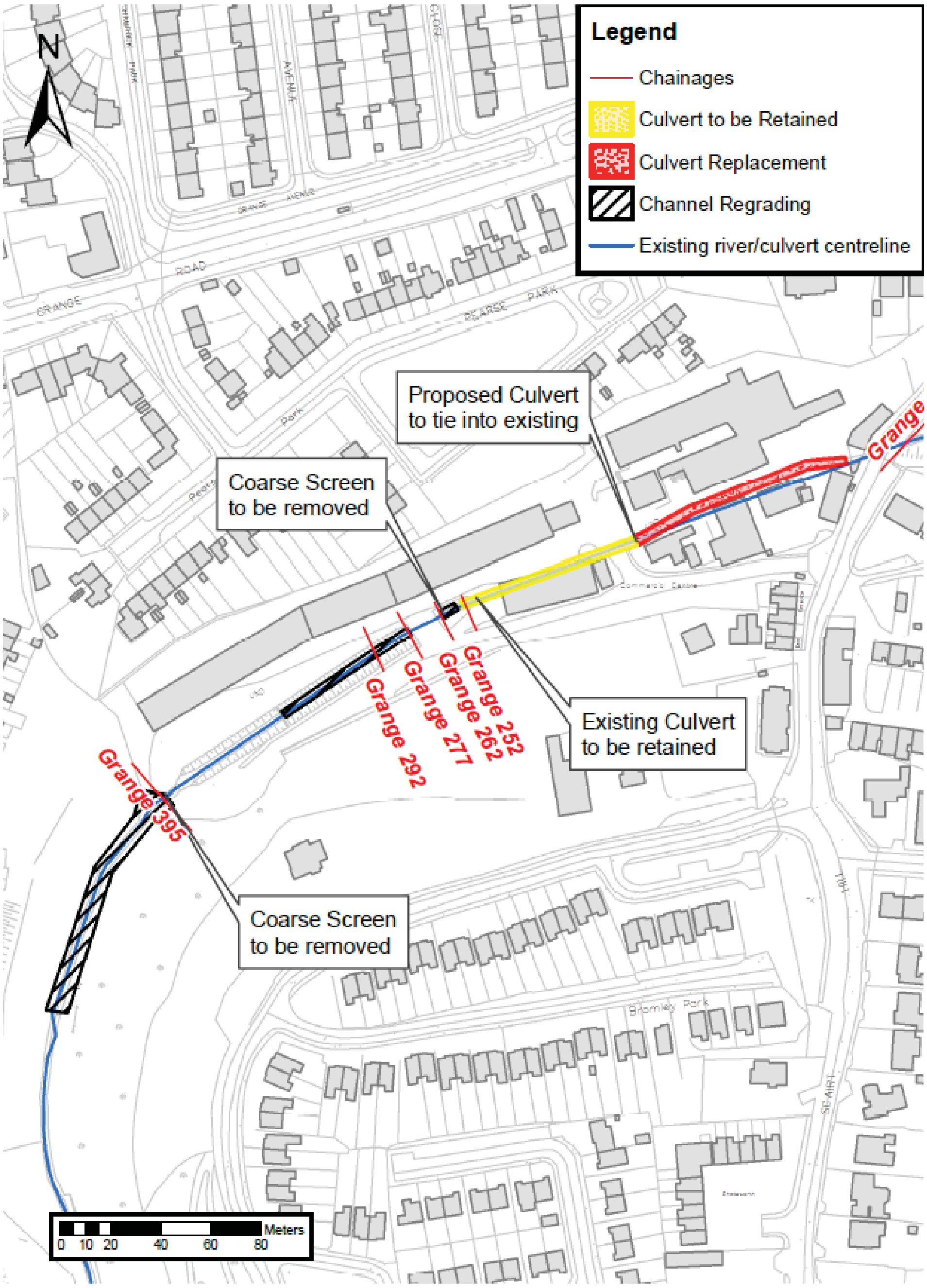


2.1.3 Area 3 – Donnybrook Commercial Centre

The proposed works in Donnybrook Commercial Centre are presented in Figure 6 and consist of:

- Upgrade of the lower section of the existing culvert with a new 97m long culvert that is 2.4m wide x 1.8m high.
- Removal of coarse screens and local minor re-grading of the channel.

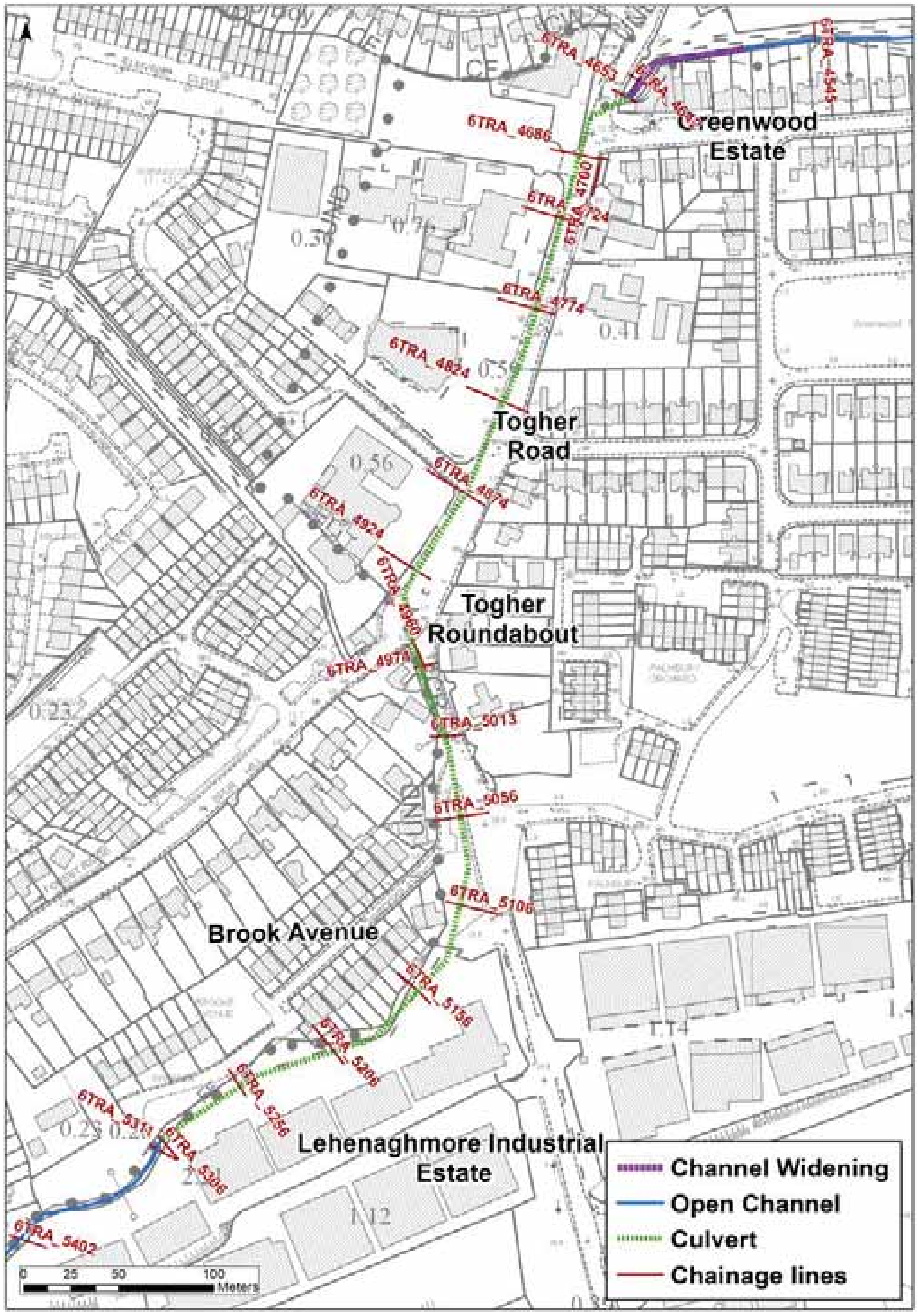
Figure 6: Area 3 – Donnybrook Commercial Centre



2.2 Proposed works in Togher

The proposed works for Togher are presented in Figure 7 and consists of a replacement culvert along Togher Road. A new trash screen and inlet structure is also to be constructed at the entrance to the culvert in Lehenaghmore Industrial Estate.

Figure 7: Proposed works for Togher



3 Cost Benefit Analysis of Scheme

3.1 Baseline Cost Benefit

Table 1 presents the Cost Benefit Analysis for the entire scheme (Douglas and Togher combined) based on a discount rate of 4%. It can be seen from the table that the Benefit Cost Ratio of the scheme is 3.53. The scheme is therefore strongly cost beneficial.

Detailed calculations are provided in the individual options reports in Appendix A and Appendix B.

Table 1: Cost benefit analysis summary for the Scheme

	Preferred Scheme (€m)
Present Value Costs (PVc)	11.89
Present Value Benefit (PVb)	42.13
Net Present Value (NPV)	30.23
Benefit Cost Ratio (BCR)	3.54

3.2 Cost Benefit Sensitivity Analysis

The control of all risks is impossible and therefore the economic robustness of the scheme has been investigated using sensitivity analysis. In order to investigate the least credible level of benefits the following sensitivities have been undertaken:

- 5% reduction in flood damage benefits (for the 4% discount rate)
- 3% discount rate
- 5% discount rate

The findings of the analysis are presented in Table 2.

Table 2: Cost benefit analysis Sensitivity Analysis

	5% reduction in benefit (€m)	**3% discount rate**	**5% discount rate**
Present Value Costs (PVc)	11.89	11.89	11.89
Present Value Benefit (PVb)	40.02	49.83	36.21
Net Present Value (NPV)	28.13	37.94	24.32
Benefit Cost Ratio (BCR)	3.37	4.19	3.05

3.3 Togher Economic Benefit

As noted in the Togher Options report in Appendix B, the economic benefit deriving from the scheme in Togher is significantly underestimated as we have utilised the flood damage values calculated as part of the Lee CFRAM in our analysis. The benefit cost ratios quoted in the previous two sections are therefore all stronger than indicated.

We note that our approach to the calculation of the economic benefit of the scheme in Togher was agreed by the Steering Committee of the project, where it was deemed unnecessary to undertake further detailed damages assessment for Togher given the very strong Cost benefit ratio for the Scheme as a whole and that Togher was clearly cost beneficial in its own right.

3.4 Conclusion of Benefit Cost Analysis

Benefits and costs for all options were compared with those of the “Do Minimum” case to provide a convenient common baseline against which the proposed scheme can be assessed.

The Benefit Cost ratio for the entire scheme is strongly beneficial with a BCR of 3.54.

Appendix A

Douglas Options Report

Cork County Council

Douglas Flood Relief Scheme (Including Togher Culvert)

Douglas Options Report

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Economic Assessment of Options

Appendix B

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1 Introduction

1.1 Context

The Office of Public Works (OPW) in partnership with Cork City and Cork County Councils have carried out a Catchment Flood Risk Assessment and Management (CFRAM) Study for the Lee Catchment. Douglas and Togher were included as part of the study as both are located in the Tramore catchment which is a sub catchment of the Lee. The Catchment Flood Risk Management Plan (CFRMP) which was published in January 2014, identified a preferred flood risk management option in Togher but did not identify a preferred scheme for Douglas.

Douglas was however severely flooded in June 2012. As a consequence, Cork County Council, in collaboration with the OPW who are the funding authority, has now commissioned a project to develop a Flood Relief Scheme (FRS) for Douglas. The detailed design of the recommended scheme in Togher also forms part of this project.

The overall scheme will consist of flood alleviation measures along the Tramore River, Ballybrack Stream and Grange Stream in Douglas which provide the required standard of protection.

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 – Environmental Assessment & Planning;
- Stage III - Detailed design and Tender;
- Stage IV – Construction;
- Stage V - Handover of works.

This 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 Douglas.

The development of the Togher elements of the scheme is reported on separately.

1.2 Scope of the Report

The purpose of this report is to assess all of the possible flood relief options that could be implemented in Douglas and to outline the procedure for how the preferred option was developed and selected.

The process for the selection of the preferred flood relief options is as follows:

- An initial screening of a long list of possible flood risk management measures against a predetermined set of criteria was carried out in order to determine if they were feasible for Douglas;

- The flood risk management measures potentially deemed viable from the screening exercise were evaluated in more detail;
- Based on the results of the above assessment, a number of possible flood risk management options (consisting of one or more measures) were developed;
- These flood relief options were then subjected to economic, environmental and multi-criteria assessments, allowing a preferred flood relief option to be selected.

1.3 Study Area

The study areas for the project are:

Area 1: The catchment of the Douglas River. The Douglas River is more commonly known as the Ballybrack Stream, and will be referred to as such in this report.

Area 2: The length of the Tramore River between Lehenaghmore Industrial Estate and Greenwood Estate in Togher.

The study areas are shown in Figure 1. It can be seen that both areas are located south of the Cork City South Ring Road. The flood relief measures for Togher are discussed in the accompanying Togher Options report.

Figure 1: Douglas Flood Relief Scheme (including Togher Culvert) study areas

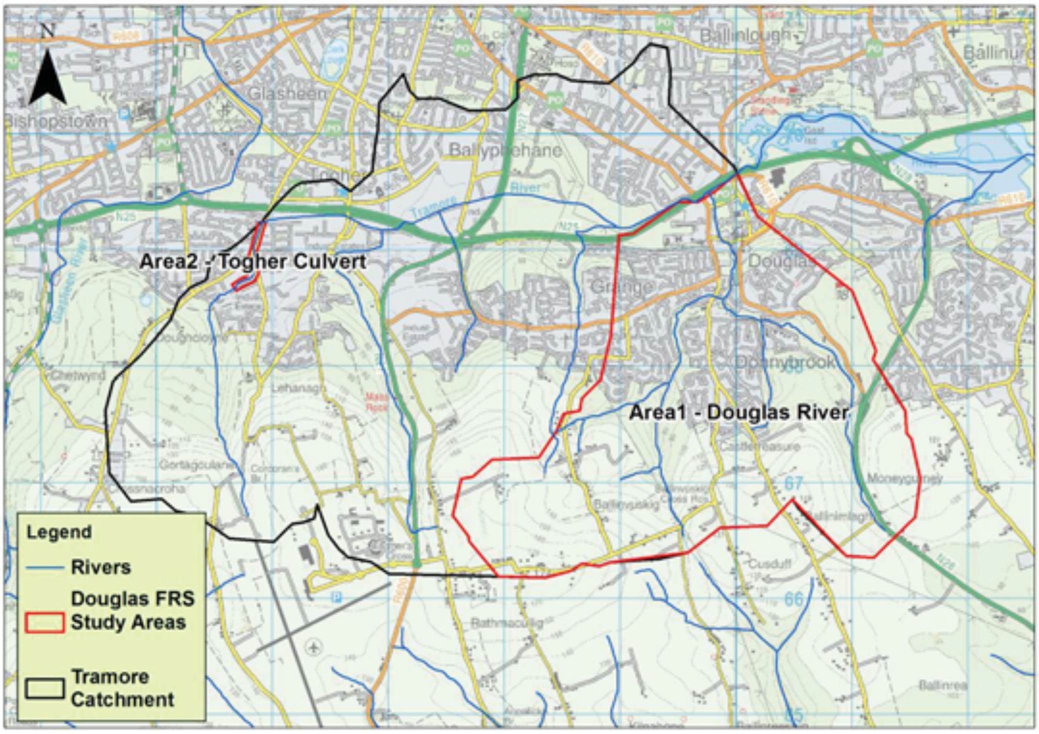

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Figure 2 and Figure 3 show key plans of the critical areas at risk in Douglas.

The red labels in the figures correspond to the labels of the cross sections of the hydraulic model developed as part of the study. The labels are comprised of a three character prefix which is unique to the individual channels followed by a channel chainage (in metres). The chainage of each channel commences at Ch.0m at the downstream end of each watercourse and will be used throughout this report in describing the location of proposed flood risk management options.

Figure 2: Douglas Key Plan: The highlighted green area is Ravensdale. It is shown in greater detail in Figure 3

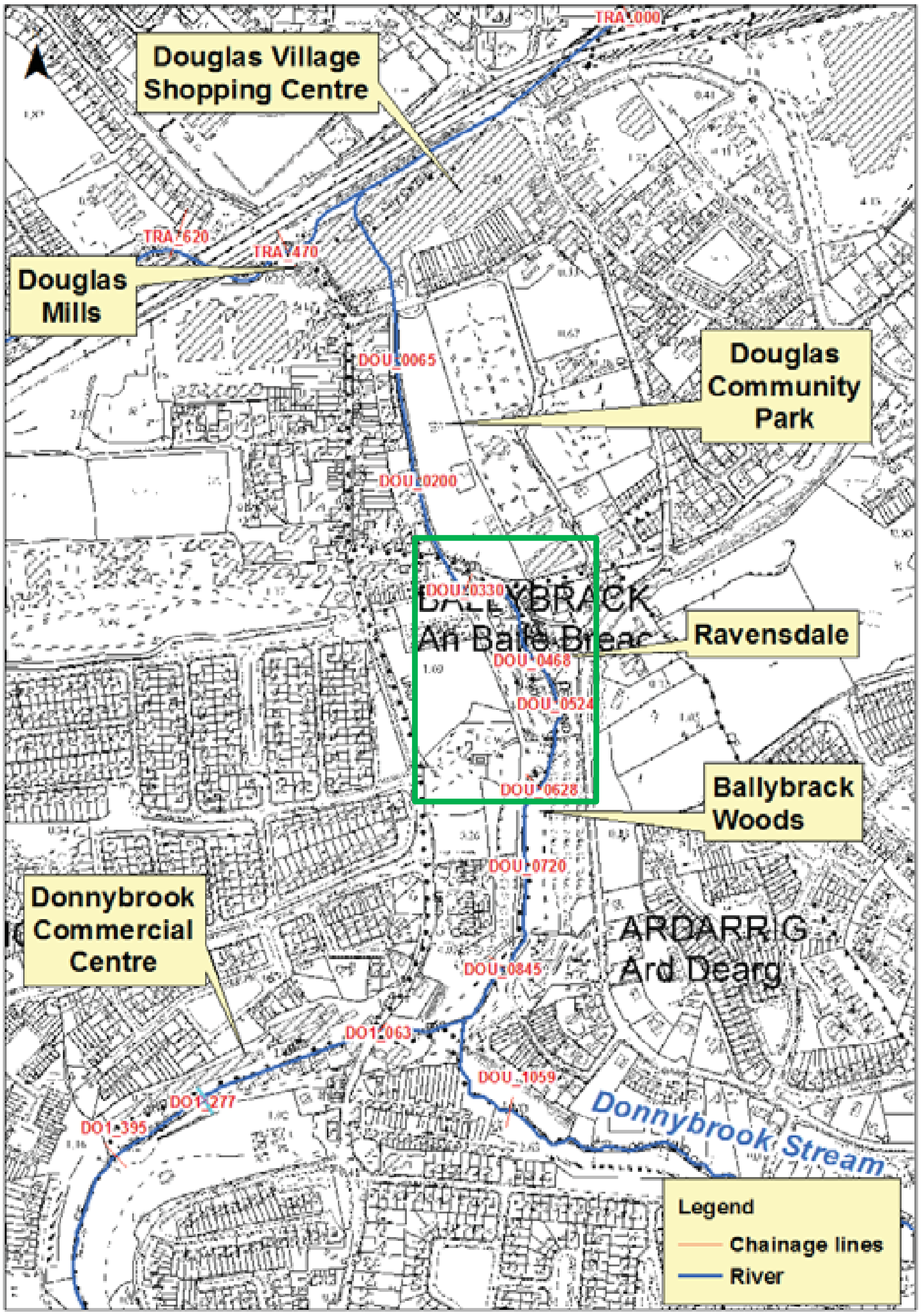
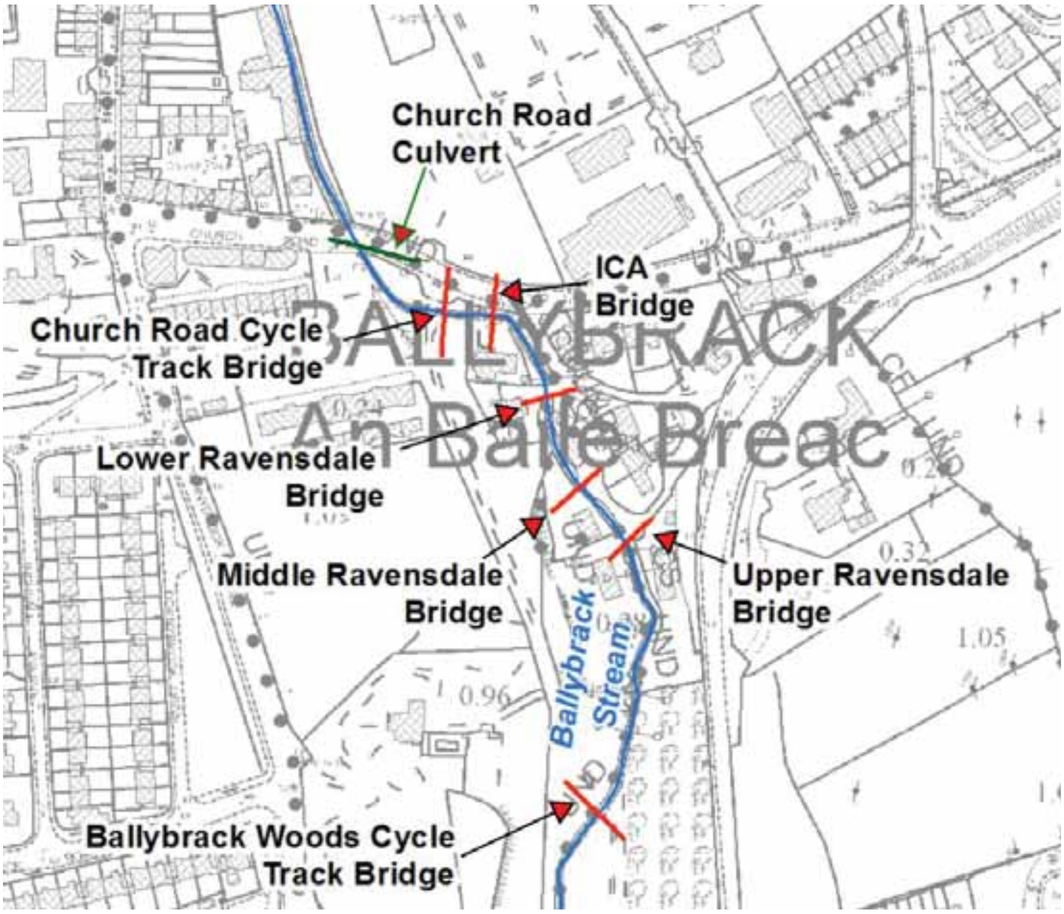


Figure 3: Key plan at Ravensdale



1.4 Scope of the Problem

A hydrological study together with hydraulic modelling of the existing situation 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 detailed in the Hydraulics Report, three separate flood cells were identified for Douglas. These are Douglas Village (

Figure 4), Donnybrook Commercial Centre (Figure 5) and St. Patrick's Mills (

Figure 6) which is also known as Douglas Mills.

Figure 4: Fluvial flood cell for Douglas Village

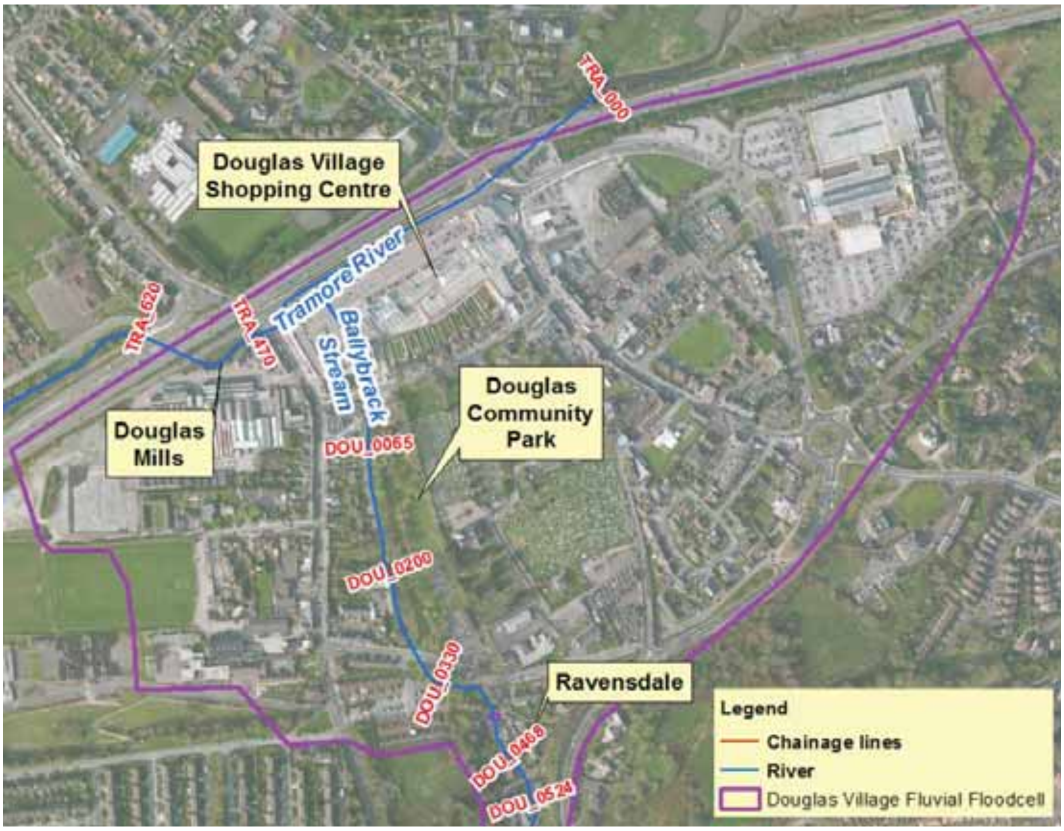
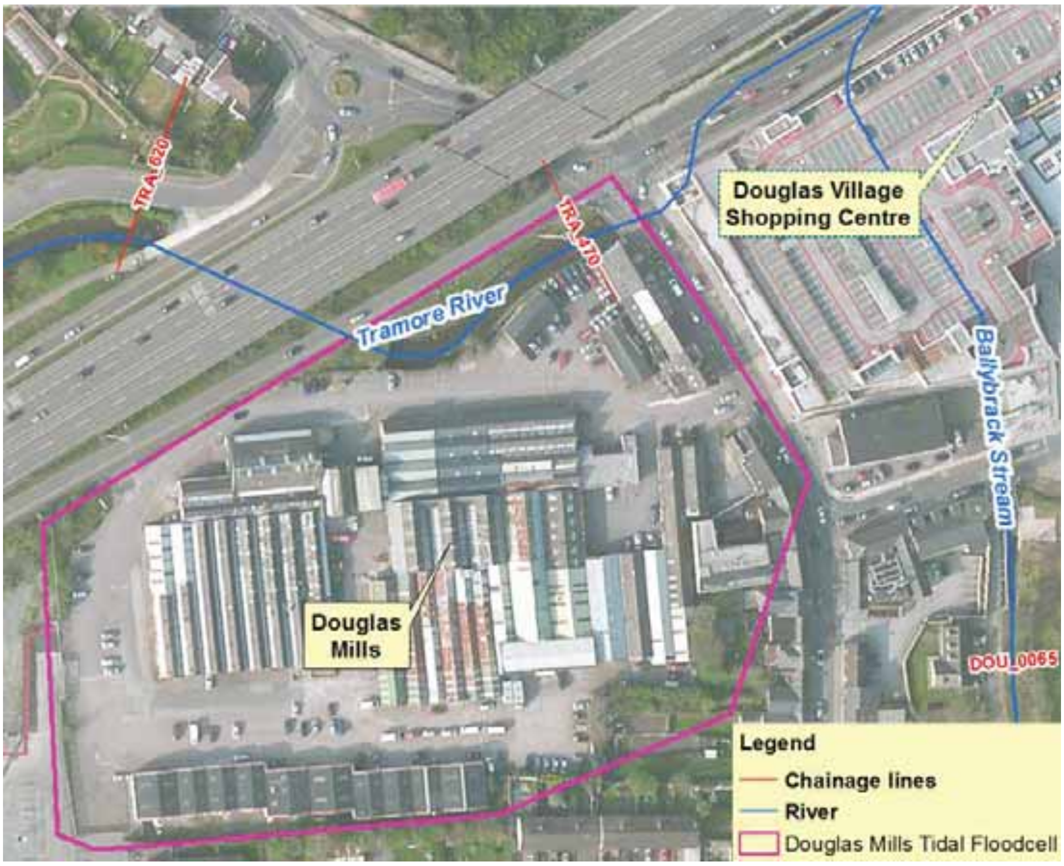


Figure 5: Fluvial flood cell for Donnybrook Commercial Centre

Figure 6: Tidal flood cell for St. Patrick's Mills (Douglas Mills)



It is noted that the design 200 year tidal water level is marginally lower than the left and right channel at this location. Therefore there is no out of bank tidal flooding at this location. The flood relief measures at this location will therefore be designed to account predominately for freeboard, and/or to reinforce existing defences.

2 Stakeholder Input and Constraints

2.1 Constraints Study

A Constraints Study Report was prepared as part of this project. Constraints were assessed under the following headings:

- Human Beings
- Ecology
- Water
- Soils and Geology
- Archaeology, Architectural and Cultural Heritage
- Landscape
- Noise, Air Quality and Climate
- Material Assets.

The constraints identified in the report have been taken into account in the development of the preferred option. The reader is referred to the accompanying Constraints Report for further details.

2.2 Public Information Days

Three separate public information days (PIDs) were held over the course of Phase I of the study.

The first PID was held on Wednesday 26 February 2014 in Douglas Community Centre. The purpose of the PID was to present the Study Area to the general public and to outline the process involved in the preparation of the Douglas FRS. A summary of the submissions received from the public is included in the project Constraints Study report.

The second PID was held on Wednesday 8 October 2014 in Nemo Rangers GAA Club (Trabeg Sports Centre). The purpose of the PID was to present the emerging preferred option for the scheme and invite comments.

The feedback received from both PIDs was taken on board and helped to inform the development of the options and selection of the preferred option.

A third PID was held on 4 April 2017 to present and explain the developed scheme and the statutory approval process to the public and affected residents.

3 Initial Screening of Potentially viable Measures

3.1 Introduction

This chapter details all of the flood relief measures considered during the initial screening stage of the project. These measures were assessed with regard to their viability in terms of the following criteria:

- Applicability to the area;
- Economic (potential benefits, impacts, likely costs etc.);
- Environmental (potential impacts and benefits);
- Social (impacts on people, society and the likely acceptability of the method);
- Cultural (potential benefits and impacts upon heritage and resources).

The flood risk management measures which were initially screened are outlined in Table 1 below.

Table 1: Initial screening of options

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Initial Screening Result	Comment
Do Nothing	Y	N	Y	N	Y	Not Viable	This option provides the baseline for the study and assumes no further work or expenditure on measures to reduce flood risk in Douglas. The Do Nothing scenario is defined as the option 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 sustainable option as it fails to meet the needs of the residents and business owners of Douglas. Using this as the baseline scenario however allows the benefits of all existing measures to reduce the flood risk to be identified. It places the benefit of these measures into true perspective.
Do Minimum	Y	N	Y	N	Y	Not Viable	Flooding starts at high frequency events
Non-structural Measures							
Planning Control/ Land Use Management	Y	Y	Y	Y	Y	Viable	Will assist in ensuring flood risk is not increased by future development. Long time to implement, and would not reduce the current flood risk to an acceptable level in the short term.
Building Regulations	Y	Y	Y	Y	Y	Viable	
SUDS	N					Not Viable	Douglas is already heavily urbanised with little space for attenuation or other SUDS features
Flood Forecasting/Flood Warning System	N					Not Viable	The viability of a flood forecasting system has been assessed as part of this study and is reported on in the Merits of a Flood Forecasting System report. It was not found to be a viable option as the catchment is too small and flashy and the proposed scheme is likely to be a 'passive' scheme and thus would not benefit from a flood forecasting system. Tidal flood risk is not a significant issue.

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Initial Screening Result	Comment
Structural Measures							
Upstream Storage	Y	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment.
Direct Flood Defences	Y	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment.
Permanent Diversion Channels or Culverts	N					Not Viable	No viable location for permanent diversion in Douglas.
Flood Relief channel/culvert (including pumped option)	Y	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment of the option of a flood relief channel/culvert in the vicinity of Ravensdale
Sediment/Debris Control	Y	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment of requirement for sediment/debris Control.
Conveyance Improvements	Y	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment.
Property Relocation/Reconstruction	N					Not Viable	This measure involves the relocation of people and businesses from properties at risk of flooding to a less flood risk area. It is not considered feasible for Douglas, due to the number of properties, and hence people and businesses, at risk.
Individual Property Protection	N					Not Viable	Large number of properties located in the Douglas Area.
Local SW Pumping	Y	Y	Y	Y	Y	Viable	Undertake Technical Assessment of requirement for localised pumping of surface water in the urbanised area of Douglas village.
Tidal Barrier	N						Tidal flooding is not a significant risk
Possible Flood Risk Management Measure	**Applicability**	**Economic**	**Environmental**	**Social**	**Cultural**	**Initial Screening Result**	**Comment**
Public Awareness	Y	Y	Y	Y	Y	Viable	

3.2 Non-Viable Flood Risk Management Measures

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
- Do Minimum
- Property Relocation
- Individual Property Protection
- Non-structural Measures
    - Planning Control
    - Building Regulations
    - SUDS
    - Flood Forecasting
    - Public Awareness
    - Land Use Management

The ‘**Do Nothing’** scenario is defined as the option involving no future expenditure on flood defences or maintenance of existing defences/channels etc. The implication is that the existing risk of flooding persists in the study area. This is not considered to be a sustainable option as it fails to meet the needs of the residents and business owners in Douglas and has therefore been ruled out at the initial screening stage.

The ‘**Do Minimum’** scenario consists predominantly of ongoing maintenance works. This is in order to maintain the existing standard of protection and minimise the risks of blockage of the culvert and river system. Maintaining existing culverts free of debris, clearing channels of vegetation and keeping gullies clear are typical of the do-minimum approach. This is not considered to be a sustainable option as it fails to meet the needs of the residents and business owners in Douglas and has therefore been ruled out at the initial screening stage.

Relocation involves moving the occupiers of properties at risk to new properties constructed outside of the area at risk. Due to the large number of properties at risk in the Douglas area, property relocation has been ruled out at the initial screening stage.

Individual property protection protects properties on an individual basis, and typically involves measures such as demountable barriers on doors and non-return valves on drains. These measures are typically only effective up to approximately 0.6m flood depth. Above this depth, the water pressure on the walls of typical domestic properties may cause structural damage.

Individual property protection measures are not considered feasible for the Douglas area due to the large number of properties at risk and the large predicted flood depths (>0.8m in places). Therefore this option was ruled out at the initial screening stage.

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. This option would take a long time to implement and would not reduce the flood risk to an acceptable level and therefore has not been carried forward for further technical assessment. The proposed scheme would not however, prevent such methods being implemented in the future.

Sustainable Urban Drainage Systems (SUDS) plays a role in the management of flood risk through attenuation of surface runoff from impermeable surfaces. Douglas is a heavily urbanised area with little space for the construction of attenuation or other SUDS features into the landscape. This option has therefore not been carried forward.

Flood forecasting and warning plays a role in flood defence, firstly as a means of avoiding loss of life, and secondly to provide a warning which allows property owners and authorities to take measures to mitigate against the effects of the flood event.

The feasibility of a Flood Forecasting System for Douglas (and Togher) were considered as part of the project and are detailed in the accompanying report entitled “Assessment of potential for Flood Forecasting System”.

As detailed in the report, flood forecasting is not likely to be a viable option for Douglas as the catchment is too small and flashy. Additionally, given that the proposed scheme is likely to be a ‘passive’ scheme, a FFS would not be required in order for the scheme to be effective.

The potential to expand the Lower Lee FRS (Including Blackpool and Ballyvolane) flood forecasting system to include the Tramore River catchment has been identified. This would be advantageous to the Tramore River catchment as setup costs would be somewhat reduced. However, the benefits of the FFS in The Tramore River catchment remain limited.

Tidal flood risk is not a significant risk for Douglas so the requirement for a FFS to predict extreme tidal elevations in the estuary are not likely to prove viable.

3.3 Potentially Viable Flood risk Management Measures

Further to the initial screening, the following flood risk management measures were identified as potentially viable measures for the Douglas and have been taken forward for further technical assessment in Section 4:

- Upstream Storage
- Diversion channel or culverts
- Direct Flood Defences
- Conveyance Improvements
- Pumping
- Combination of the above

4 Further Assessment of Potentially Viable Measures

4.1 Structural Measures for Douglas

4.1.1 Upstream Storage

This measure seeks to store excess flood waters upstream of Douglas by the creation of a designated storage area. If a suitable storage area was available, the peak flow through the channel in the village could be regulated to ensure that the capacity of the existing channel is not exceeded.

It is noted that the project brief specifically requested Arup to assess individually and in combination, the feasibility of implementing storage on the Ballybrack Stream and its tributaries which may form part of the scheme.

The catchment was reviewed for potential storage areas using a LiDAR digital terrain model and by undertaking a site walkover of the catchment.

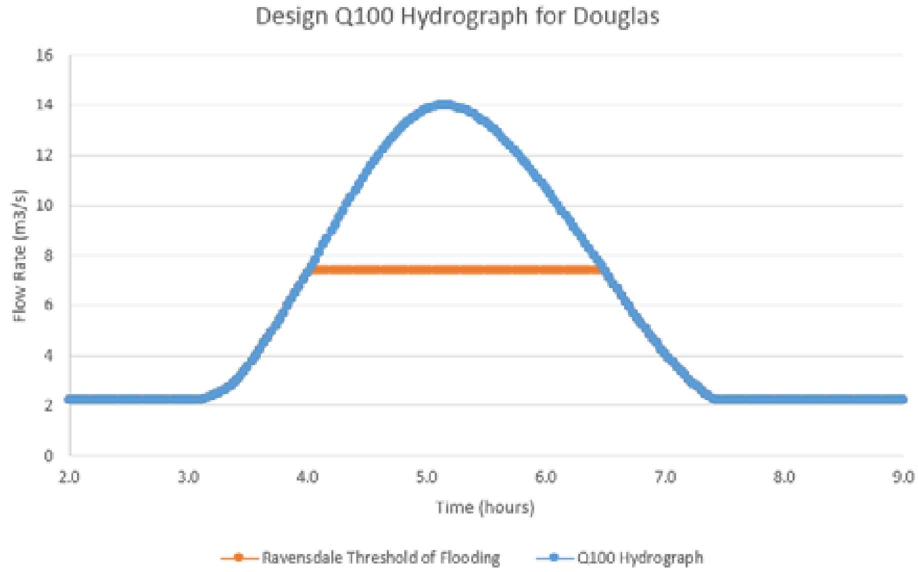
Due to the steep gradient of the channel upstream of Douglas and because of the steep sided nature of the valley, only small volumes of storage could potentially be created unless very high impounding structures were to be created.

In discussions with Cork County Council, three potential areas were identified and initial assessments of the potential benefits were carried out and are outlined in the following sections of the report.

Prior to assessing the potential for upstream storage, it was necessary to establish the likely volume of storage required to satisfactorily pass the resultant design flow through Douglas.

Figure 7 presents the design Q100 hydrograph for the Ballybrack stream, upstream of Ravensdale. The threshold of flooding for Ravensdale is estimated to be approximately 7.4m^3/s which equates to the 1 in 6 year flood event.

Figure 7: Q100 Design Hydrograph and the threshold of flooding



The total volume of the Q100 hydrograph is approximately 178,000m^3. The volume of the Q100 hydrograph below the threshold of flooding is approximately 140,000m^3. The difference between these volumes is 38,000m^3 which equates to the minimum total volume that would need to be stored in the catchment to make storage a viable option from a technical perspective (assuming the storage area was close to the flood risk area).

In estimating the threshold of flooding for Ravensdale it was assumed that all of the garden and boundary walls currently constructed in Douglas have sufficient structural capacity to function as flood relief walls. Should these walls have been removed from the analysis the threshold of flooding would have been less (approx. 5m^3/s). In this instance, the required storage is more significant (approximately 60,000m^3/s).

The required storage volume would increase with increasing distance away from the at-risk areas. It is also worth noting that at the confluence of the Grange and Donnybrook streams, the 1 in 100year design flow from each tributary is 7.28m^3/s and 6.63m^3/s respectively, meaning that upstream of this location, storage would be required on both tributaries to reduce the peak flow at Douglas to below the threshold of flooding. Therefore, it is apparent that any storage location should ideally be located at or downstream of this confluence.

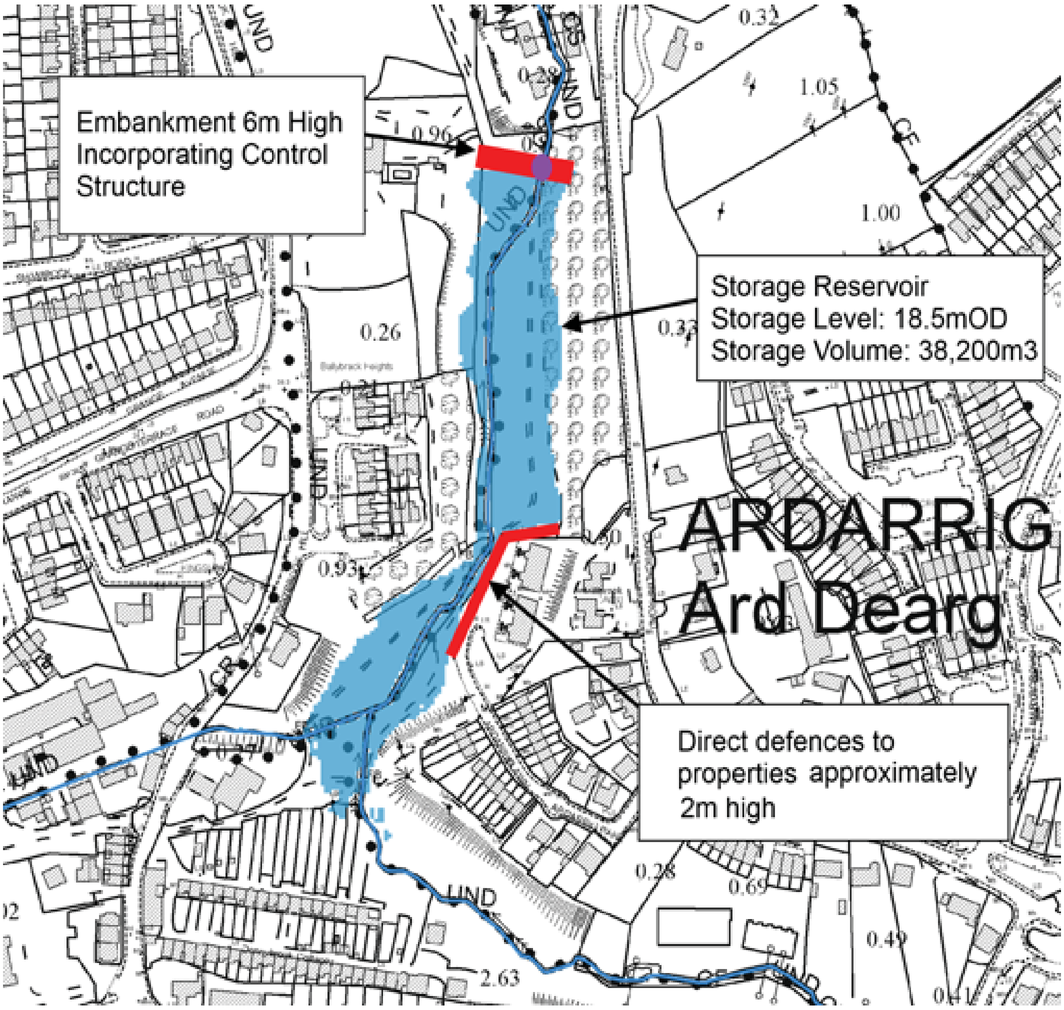
4.1.1.1 Potential Storage at Ballybrack Woods

A potential storage area exists upstream of Ravensdale in the public park known as Ballybrack Woods. In this area, the Ballybrack Stream flows through a relatively flat and wide valley. The only properties in the vicinity are duplex properties on the right bank at Ardarrig Park which are elevated above the floodplain.

Achieving sufficient storage in a singular storage area would require the construction of a circa 50m length of embankment (including a control structure) at the northern end of the Park.

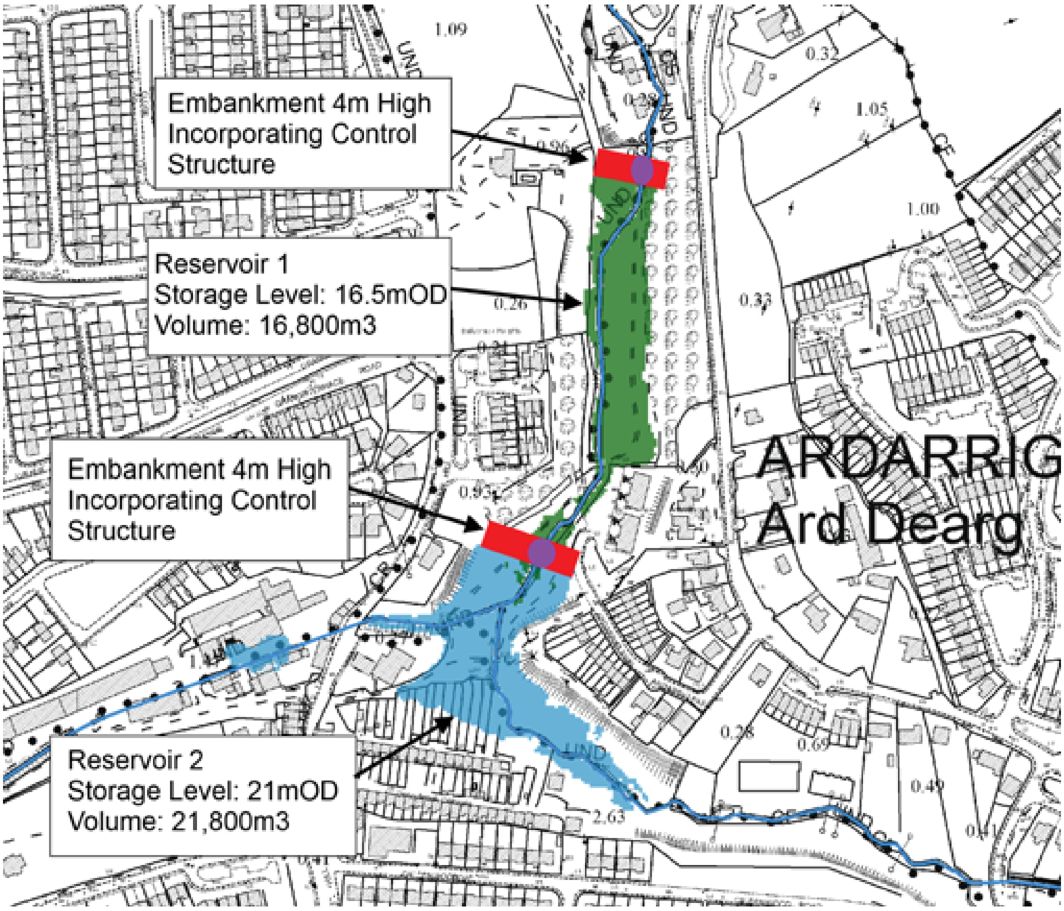
The embankment would need to be up to 6m in height to achieve a storage volume of circa 38,000m^3 as indicated in Figure 8. This allows for a storage level of 18.5mOD which would also require localised defences up to 2m in height around the duplex apartments at Ardarrig Park.

Figure 8: Potential upstream storage area at Ballybrack Woods (Option 1)



An alternative to the above option would be to utilise a twin storage area as indicated in Figure 9.

Figure 9: Potential upstream storage area at Ballybrack Woods (Option 2)



This option requires the construction of 2 no. approximately 4m high impounding structures incorporating control structures. The two areas combined would provide circa 38,000m^3 of storage. This option avoids the need for localised defences around Ardarrig Park and also reduces the height of the required impounding structures.

While the singular storage area could incorporate a relatively simple and passive 'hydrobrake' flow control type control structure, the twin system would require a more 'intelligent' telemetered system to ensure the combined storage volume can be fully utilised at the peak of the event, or alternatively a controlled spillway at the upper storage area.

A significant negative aspect of this option is its impact on the recently constructed cycle/pedestrian amenity route. Significant modifications would be required to 'ramp' over the proposed impounding structures to maintain continuity of the route and this would require careful detailing. Such ramping would reduce the available storage volume by an estimated 2,000m^3. The available storage is therefore very marginal. Even if this storage was to be achieved, some works would still be required through Ravendale as far as Church Road to ensure that the residual peak flow of circa 7.4m^3/s could be safely passed with a suitable freeboard.

There would also be safety concerns associated with the construction and maintenance of large impounding structures, holding large volumes of flood water, upstream of such a highly urbanised centre.

Significant environmental constraints also exist for this option, in that any structures on the river would adversely affect aquatic life.

In summary, whilst the above solution may be technically viable, it is considered that its social and environmental impacts would be detrimental and therefore it has not been considered further.

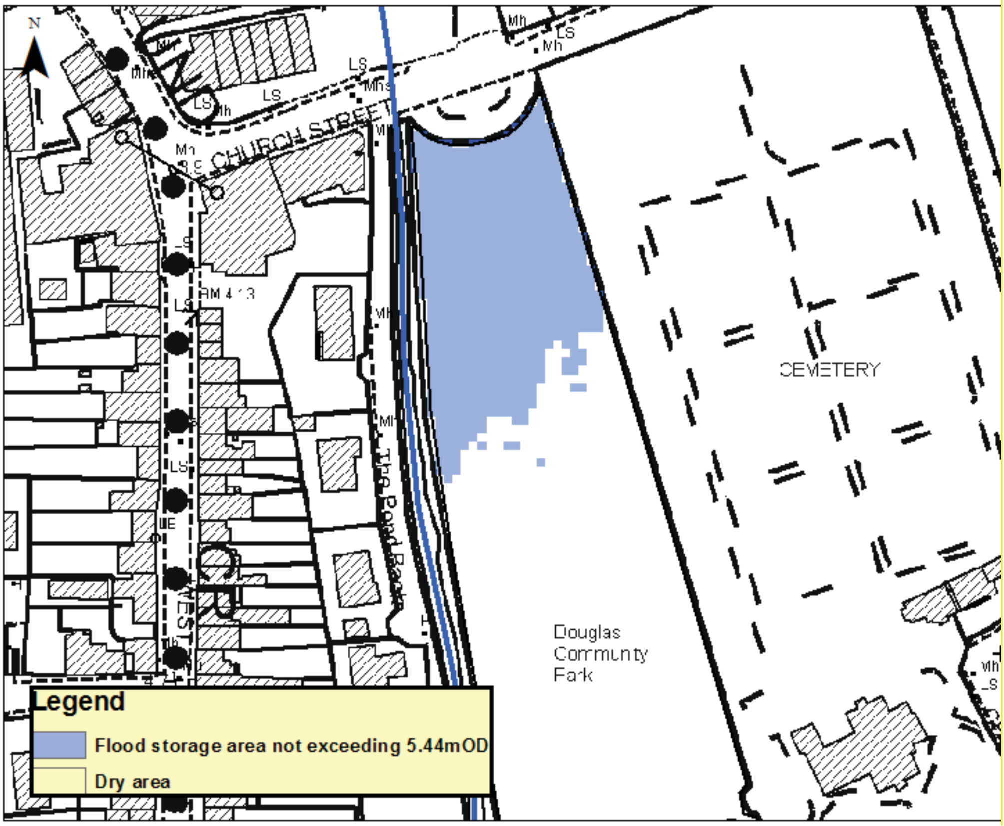
4.1.1.2 Douglas Community Park

There is an existing storage area on the Ballybrack Stream at the downstream end of Douglas Community Park. The “impoundment” is formed by the boundary walls of the park. The wall has two entrances from Church Street, which have flood gates installed to close off the openings. It is estimated that the total storage volume up to the top level of the existing wall is approximately 600m^3. It is noted that it is technically possible to increase the available storage by raising the existing walls.

As there is no flood warning on the Ballybrack Stream, the reliability of the existing storage area is limited, since the flood gates must be manually closed. The reliability could be improved by replacing the flood gates with ramped entrances. However, given the limited available volume, such an investment is not considered prudent.

It is important to note that this storage area is downstream of Ravensdale where the main capacity issue exists and so would not diminish the flood risk there.

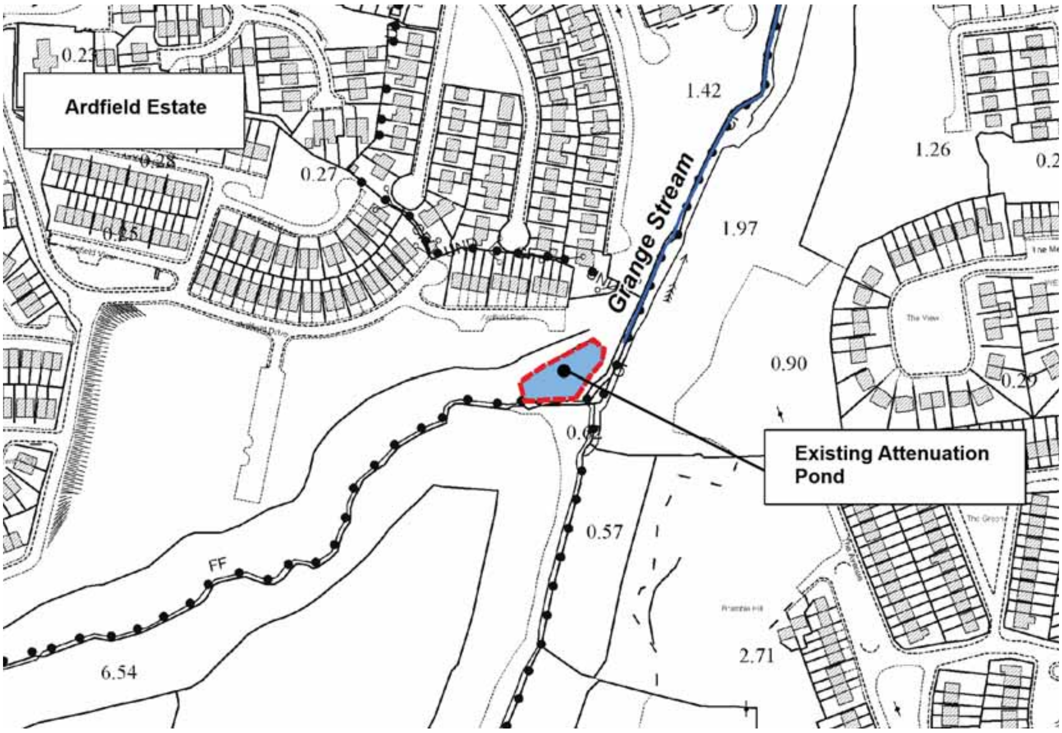
Figure 10: Existing storage area at Douglas Community Park



4.1.1.3 Grange Stream at Ardfield Estate

CCC identified that it may be beneficial to carry out repairs to the existing stormwater attenuation pond at Ardfield Estate in order to provide some attenuation to flows on the Grange Stream. The location of the pond is shown in Figure 11.

Figure 11: Existing attenuation pond at Ardfield Estate



The existing pond is constructed on a slope, with the eastern and southern sides of the pond being formed by a raised earth bund.

CCC reported that the eastern bund was breached during the 2012 flood event. It is evident on site that the western tributary of the Grange Stream now flows directly through the pond. Similarly, the surface water drainage from Ardfield Estate also flows through un-attenuated.

A topographic survey of the existing bund was carried out and the following details were established:

- The plan area of the pond is approximately 1130m^2.
- The minimum height of the bund (excluding the breached section) is approximately 1.6m.
- Therefore, the maximum storage available in the pond is approximately 1800m^3 (or approximately 1500m^3 allowing for 300mm freeboard).

It is also worth noting that the sub-catchment to this location accounts for less than 40% of the total catchment to Douglas and therefore, as noted earlier, cannot provide sufficient storage in its own right to mitigate flood risk in Douglas, regardless of the available storage volume.

It is acknowledged however that the attenuation pond should be repaired as soon as possible so that it serves its design function of attenuating peak runoff from the Ardfield development.

4.1.2 Construction of Diversion or Flood Relief Channels or Culverts

This measure involves diverting excess flood flow away from the main river channel during the design flood event. It typically consists of the construction of a flood relief channel/culvert that remains dry in low flow conditions. When the water level rises above a certain threshold, water spills into the channel/culvert and is conveyed downstream separately to the main channel. At a suitable point downstream, the diverted flow re-joins the main river.

Excess flood flow can also be diverted away from the main river channel during the design flood event by allowing it flow overland on existing ground.

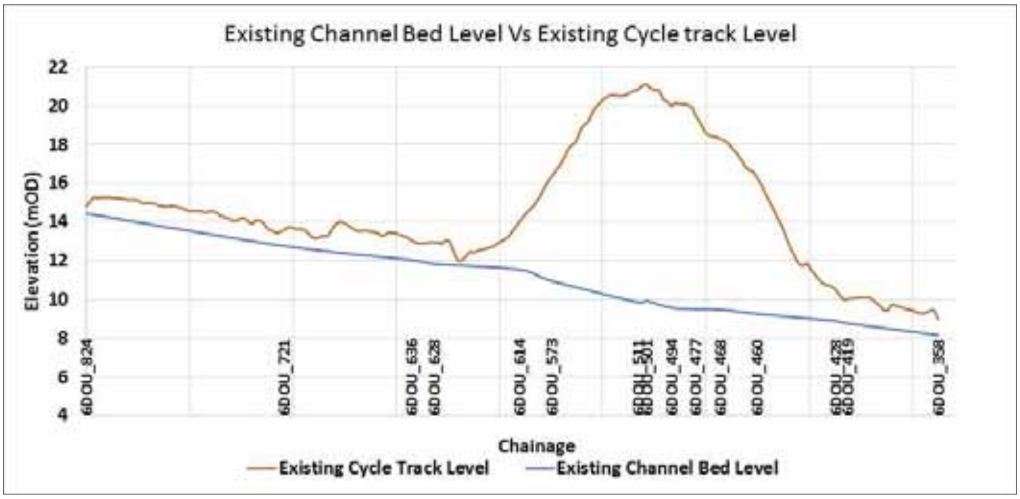
In order to give the maximum benefit, it would appear that the optimum flow diversion route would begin just upstream of Ravensdale, and would convey flow just beyond Ravensdale. This would allow high flows to be kept in-bank where the Ballybrack channel capacity is lowest. The diverted flows would rejoin the Ballybrack Stream at a point downstream where channel capacity is greater.

Unfortunately, the Ballybrack Stream valley is quite narrow and heavily developed through Ravensdale, which removes most potentially feasible route options.

One possible option considered however would be to construct a flood relief culvert from Ballybrack Woods adjacent and parallel to the route of the existing footpath/cycle track just west of Ravensdale. The route is approximately 220m long and would rejoin the Ballybrack channel just upstream of the Church Road culvert. However, the ground along this route is significantly elevated as illustrated in Figure 12 which presents a longitudinal plot of bed level of the Ballybrack and the existing ground level of the cycle track. It can be seen from the figure that existing ground levels along the cycle track peak at approximately 20mOD, compared with 12mOD at the offtake location. This option would therefore require very deep excavation, construction of several deep manholes, major temporary works, etc. Therefore this option was ruled out due to the high cost involved and the very disruptive nature of the works.

Alternatively, a culvert could be constructed along the route through directional drilling. This however would likely involve very significant costs and has therefore also been ruled out.

Figure 12: Long section of Channel bed level versus the existing cycle track levels.



4.1.3 Pumping

The purpose of this measure would be very similar to the option of diversion channels or culverts. However, whereas the other option would require water to fall by gravity and therefore can be limited by the existing topography, the pumped option is not bound by the same constraint.

The predicted 1 in 100 year flow on the Ballybrack is approximately 14m³/s.

As noted above, the threshold of flooding in Ravensdale is circa 7.4m^3/s. To reduce the peak flow below this threshold would require a peak pump rate of up to 6.6m^3/s assuming a small storage volume/wet well.

Alternatively, as the location of the pumping station upstream of Ravensdale would be located at the downstream end of the potential Ballybrack Woods Storage Area, it would be possible to reduce the required pumped rate by combining the pumped option with that of storage. It is estimated that utilising a reasonable storage area in Ballybrack Woods would allow the pump rate to be reduced to circa 3m^3/s.

Whilst the above is technically feasible, it would require the construction of a large pumping station and rising main with an estimated cost of circa €2m to €3m.

As well as the high capital cost, this measure would generate high ongoing maintenance costs. This measure would also likely have significant negative environmental and social impacts.

Based on the above it is evident that pumping is not a viable option and it is therefore not considered further.

It is noted however that localised pumping of surface water and/or ground water is likely to be included to the rear of any direct defences included as part of the scheme.

4.1.4 Construction of Direct Flood Defences

This measure involves the construction of direct defences along the sides of the existing river to contain peak flood flows within the river channel.

This measure was considered feasible for Douglas and is assessed further in the detailed options selection.

4.1.5 Conveyance Improvements

Along the length of the Ballybrack Stream, certain sections of channel constrict the flow and increase upstream flood levels. There is also evidence to suggest that a number of existing bridges/culverts in the vicinity of Ravensdale have caused blockage issues in the past. If conveyance improvement measures were undertaken, these could result in an appreciable reduction in water levels and blockage risk.

The potential measures identified include:

- Enlargement of the channel cross section along certain lengths.
- Replacement or removal of bridges and other structures that significantly elevate water levels in flood conditions.

These measures were considered to be potentially viable for Douglas and are assessed further in the detailed option selection.

Further, it is noted that conveyance improvements are also considered viable for Donnybrook Commercial Centre and are considered further in the detailed option selection.

4.1.6 Measures to Control Debris

Blockages of hydraulic structures by water-borne debris is known to have been a mechanism of flooding during past flood events in the catchment – notably the Church Street trash screen and a bridge at Ravensdale during the 2012 event, and also multiple times at the inlet to the Tramore culvert in Togher. Measures to alleviate this risk include the construction of suitably sized structures in the channel to capture the debris at a point upstream of where it could cause major issues such as blockage of a bridge or culvert barrel.

While this measure could not alleviate flood risk by itself, the option was reviewed as a potential additional measure to minimise any residual risk following construction of the scheme.

Since the 2012 event, the trash screen at the entrance to the Church Street culvert has been removed. As part of this study, the trash screen location was reassessed to establish whether it would be appropriate to install an upgraded screen. The location has several drawbacks, including:

- The location is downstream of Ravensdale, and therefore would not mitigate the residual risk in a critical location.

- The consequences of a blockage of a trash screen at this location are severe, as experienced in 2012.

Alternative locations for trash screens/roughing screens were reviewed. There is an existing screen in Ballybrack Woods as shown in Figure 13 below.

Figure 13: Existing roughing screen at Ballybrack Woods

This screen has a number of deficiencies in terms of detailing. However, if the screen could be upgraded and these deficiencies removed, the site has a number of positives as follows:

- The consequences of overtopping of the screen would not be severe, as water would return to the channel instead of immediately flooding properties.
- The site is upstream of the critical locations at risk.
- Access to the screen is readily available via the existing cycleway/footpath.

This measure was considered feasible for Douglas and is assessed further in the detailed option selection.

4.2 Structural Options for Donnybrook Commercial Centre

Three options have been considered for Donnybrook Commercial Centre:

- Provision of upstream storage to limit the flow rate into the culvert;
- Sealing all the exits from the culvert and allowing it to surcharge in order to pass the design flow;
- Upsize the lower section of the culvert to remove the constriction.

Each of these options are discussed hereafter.

4.2.1 Provision of Upstream Storage to Limit the Flow Rate into the Culvert

The results of our hydraulic modelling indicate that the threshold of flooding for the culvert (i.e. the flow rate at which water starts to surcharge above the manholes for the no blockage scenario) is circa $5.0m^3/s$.

The total volume of the Q100 hydrograph on the Grange Stream is circa $85,000m^3$. The volume below the threshold of flooding of the culvert (circa 5.0m3/s) is estimated as circa $45,000m^3$. The difference between these two volumes is circa $41,000m^3$ and represents the minimum volume required in order to make storage a viable option.

As detailed in Section 4.1.1 of this report, the Douglas catchment was reviewed for potential storage areas using the LiDAR digital terrain model and by undertaking a site walkover. Due to the steep gradient of the channel upstream of Douglas and because of the steep sided nature of the valley no suitable storage areas were identified. However, an existing stormwater storage pond at Ardfield Estate was considered as it could potentially provide some storage in the reach. The total storage volume of the pond was estimated to be $1,800m^3$.

This volume however is clearly inadequate to provide the necessary storage so as to sufficiently reduce the flow rate entering the culvert. Storage is therefore deemed to be technically non-viable and is not considered further in the analysis.

4.2.2 Sealing all the Exits from the Culvert and Allowing it to Surcharge in Order to Pass the Design Flow

All the manholes and any additional exits from the culvert could be sealed such that in the design flood event the flow would be unable to escape the culvert and flood the Commercial Centre. In this instance, flow in the culvert would be pressurised and the entrance to the culvert would likely be surcharged.

This option however would be very problematic structurally as the existing culvert is old and has not been designed to accommodate pressurised flow. Its structural integrity could be compromised during the design event and would therefore need to be strengthened throughout its reach which would be very problematic to implement.

This option has therefore been discounted and is not considered further.

4.2.3 Upsize the Lower Section of the Culvert to Remove the Constriction

This option involves the upsizing of the lower section of the culvert to remove the constriction. This option is deemed to be the only technically viable option for the commercial centre and has been brought forward as the preferred option.

As part of this option it is also proposed to remove two minor trash screens upstream of the culvert which currently collect debris and elevate water levels in the channel. It is also proposed to undertake some localised channel regrading in the reach.

This option is considered to be the most viable option and is considered further in Section 10.4.

4.3 Summary

The options for Douglas which were shortlisted for further development and assessment are:

- Direct defences.
- Conveyance improvements.
- Direct Defences and Conveyance improvements combined.

The option for Donnybrook Commercial Centre which was shortlisted for further assessment is:

- Upsizing of the Lower Section of the Culvert to remove the Constriction.

5 Development of Flood Relief Options

5.1 Introduction

Flood relief options have been examined and developed where they are considered technically feasible, for the three areas for which measures are required as follows:

- Ballybrack Stream through Douglas Village;
- St. Patrick's Mills (Tidal Risk);
- Donnybrook Commercial Centre.

An allowance of 0.5m has been assumed for freeboard in this analysis. A detailed assessment of the freeboard requirement for the preferred option is provided in Chapter 11 where the validity of this assumption is considered.

5.2 Ballybrack Stream through Douglas Village

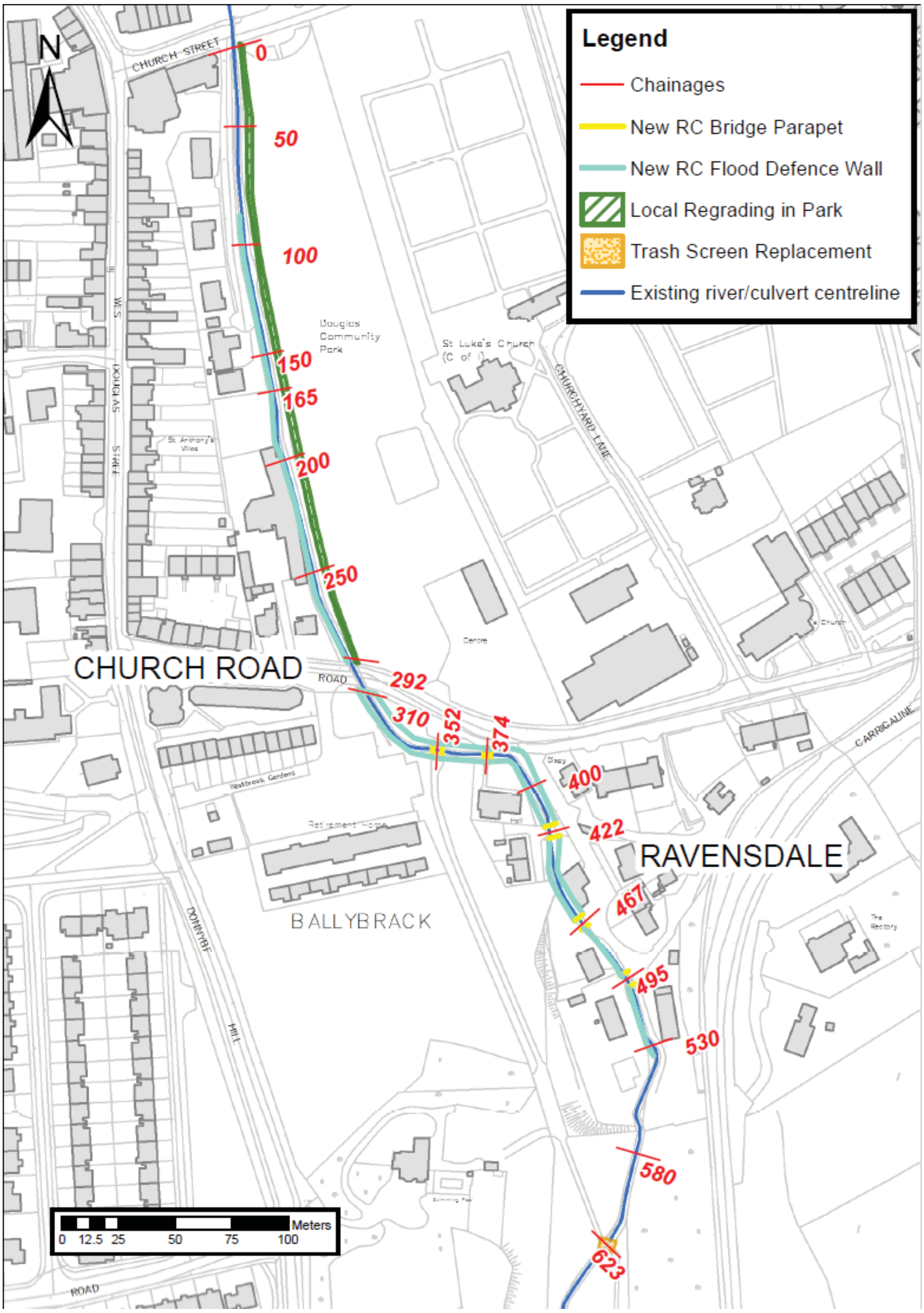
Three options were considered along the Ballybrack Stream through Douglas as follows:

- **Option 1 –** Direct defences only;
- **Option 2 –** Conveyance improvements only;
- **Option 3 –** Combination of Direct Defences and Conveyance improvements;

5.2.1 Option 1 - Direct Defences Only

This options involves the construction of Direct Defences along both sides of the Ballybrack as presented in Figure 14, Figure 15 and Figure 16. The scheme is described in detail in Table 2 below.

Figure 14: Option 1 – Ravensdale and Douglas Park Area



This option assumes no improvements to conveyance along the channel and assumes that affluxes at bridge structures are addressed by constructing solid parapets to defend against flooding of the bridge decks.

The main positive of this option is that it avoids in channel works. However, the required heights of defence walls would be greater than 3.5m above ground level immediately upstream of Lower Ravensdale Bridge, directly adjacent to residential properties and so is likely to have a detrimental impact on the landscape and visual character of this location.

The wall heights correspond to the minimum required height assuming a freeboard allowance of 0.5m. The heights have been calculated by subtracting the bank level from the sum of the maximum Q100 water level and 0.5m freeboard allowance:

Wall Hgt = Q100 water level + 0.5m Freeboard – Minimum Bank Level

Furthermore, it is probable that a number of bridge structures would need to be replaced as the existing structures may not be able to withstand the resulting surcharge forces. Alternatively they may have to be adapted to incorporate solid parapets. A typical cross section is shown below in Figure 15. It is noted that the wall heights indicated in the figure are not the highest that would be required throughout the reach.

Figure 15: Option 1 - Typical channel cross section: ICA Bridge to Ravensdale Lower Bridge

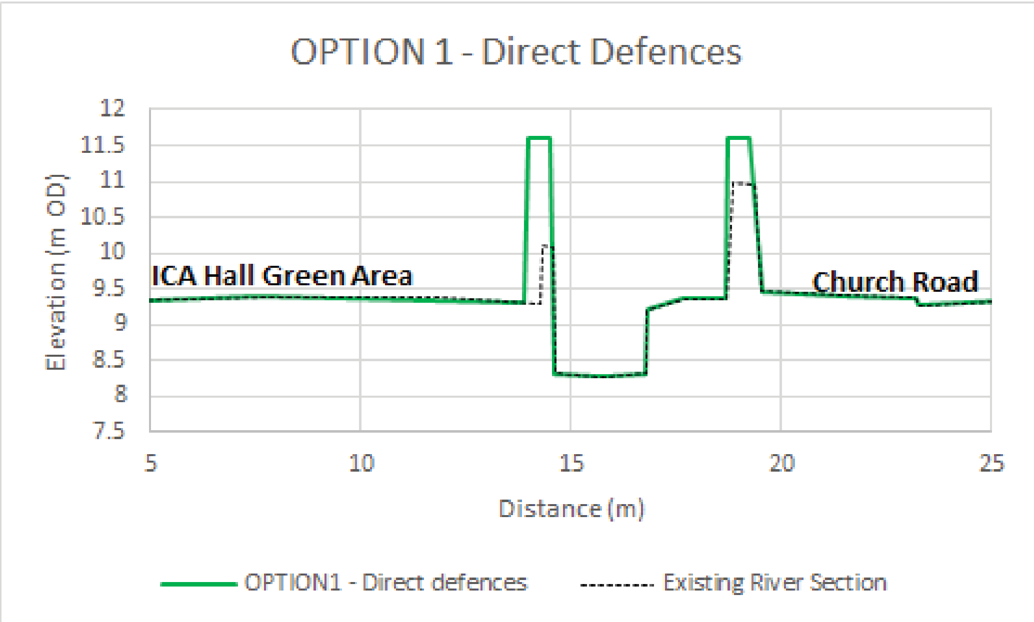


Figure 16: Option 1 – Indicative longitudinal section through Ballybrack channel showing proposed direct defences. The max water level corresponds to the design Q100 flood. The proposed defence walls assume a 0.5m allowance for freeboard.

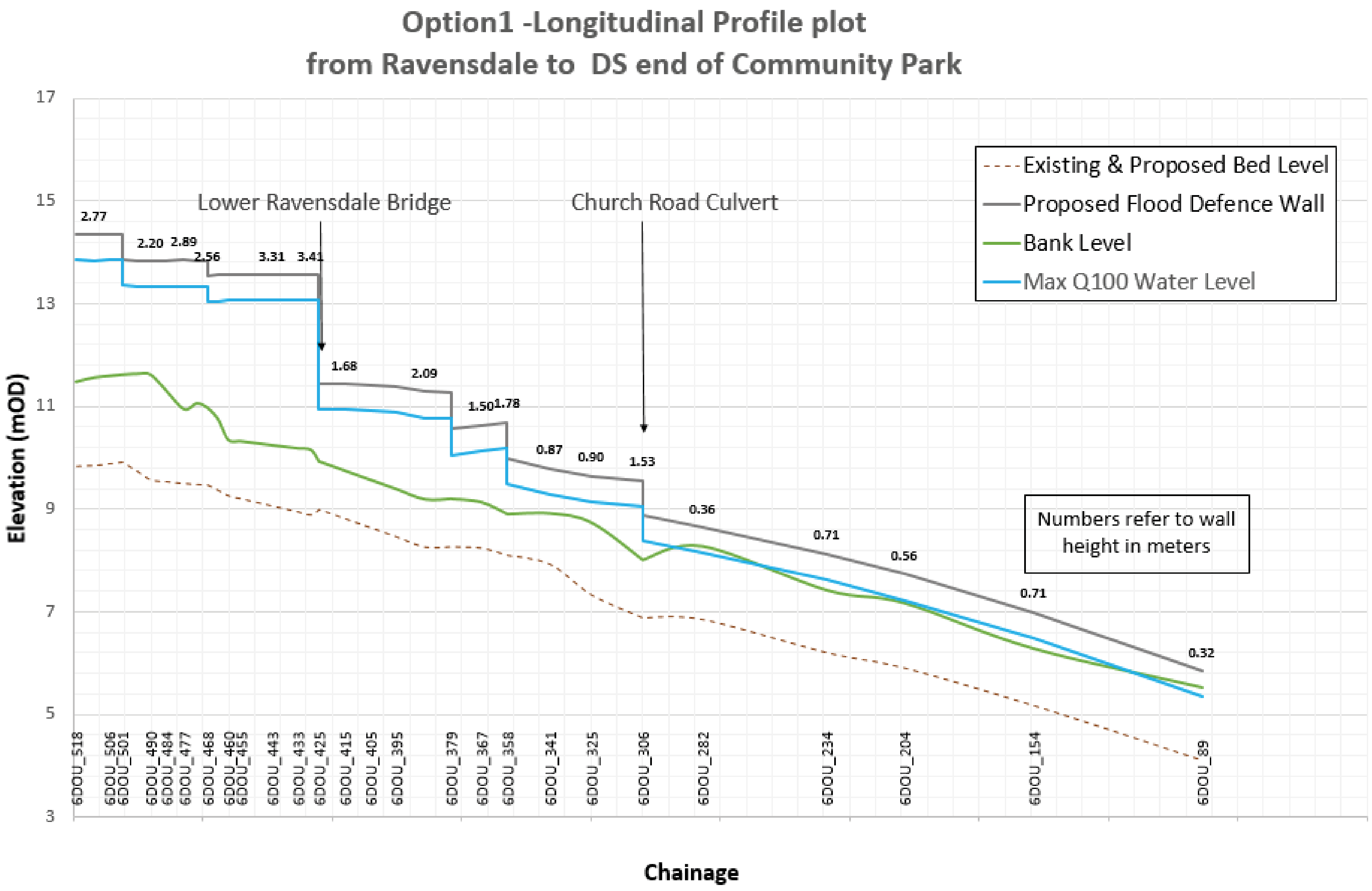


Table 2: Description of Option 1 works (direct defences only) – Ballybrack Stream

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Douglas Community Park (Approximately 290m)	Ballybrack Stream	0m – 290m	Local re-grading along the right bank of the Ballybrack (max 200mm plus freeboard)	Re-grading of ground levels along the right bank is necessary to ensure no out of bank flow and adequate freeboard. The works would not be expected to involve removal of any trees along the bank.
Douglas Community Park (Approximately 200m)	Ballybrack Stream	90m – 290m	Construction of a new stone clad flood defence wall along the left bank.	This wall is directly adjacent to a number of commercial properties.
Church Road culvert (Approximately 13m)	Ballybrack Stream	@ 300m	New 1.55m high solid RC parapets to be constructed.	The culvert will be surcharged during the design flood event. It is assumed that the culvert could structurally withstand the surcharge force, however this will need to be checked.
Church Road to Church Road Cycle track bridge (Approximately 42m)	Ballybrack Stream	310m – 352m	Construction of new stone clad flood defence walls along both banks. The top of the new flood defence walls will be 1.8m (maximum) above existing ground level.	There is an existing ESB kiosk on the left bank which will need to be relocated to facilitate the works. Several existing trees and vegetation along both banks will need to be cleared to facilitate the works.
Church Road Cycle track bridge	Ballybrack Stream	@ 352m	New 1.8m high solid RC bridge parapets to be constructed.	The bridge will be surcharged during the design flood event. It is assumed that the bridge could structurally withstand the surcharge force, however this will need to be checked.
Church Road Cycle track bridge to ICA bridge (Approximately 22m)	Ballybrack Stream	352m – 374m	Construction of new stone clad flood defence walls along both banks. The top of the new flood defence walls will be on average 1.7m (maximum 2.1m) above existing ground level.	Several existing trees and vegetation along both banks will need to be cleared to facilitate the works.
ICA bridge	Ballybrack Stream	@ 374m	New 2.1m high solid RC bridge parapets to be constructed.	The bridge will be surcharged during the design flood event. It is assumed that the bridge could structurally withstand the surcharge force, however this will need to be checked.

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
ICA bridge to Lower Ravensdale Bridge (Approximately 48m)	Ballybrack Stream	374m – 422m	Construction of new stone clad flood defence walls along both banks. The top of the new flood defence walls will be on average 2.1m (maximum 3.6m) above existing ground level.	The works in this reach will take place in close proximity to existing buildings, in particular the ICA Hall. Residents of Ravensdale will experience disruption during construction due to construction traffic. All of the existing trees and vegetation along the right bank will need to be cleared to facilitate the works.
Lower Ravensdale Bridge	Ballybrack Stream	@ 422m	New 3.6m high solid RC bridge parapets to be constructed above existing ground level.	The bridge will be surcharged during the design flood event. It is assumed that the bridge could structurally withstand the surcharge force, however this will need to be checked. It may be necessary to provide a temporary access to No 1 and No 2 Ravensdale while the bridge parapet works are being carried out. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Lower Ravensdale Bridge to Middle Ravensdale Bridge (Approximately 45m)	Ballybrack Stream	422m – 467m	Construction of new stone clad flood defence walls along both banks. The top of the new flood defence walls will be on average 3.2m (maximum 3.6m) above existing ground level.	The works in this reach will take place in close proximity to existing buildings. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Middle Ravensdale Bridge	Ballybrack Stream	@ 467m	New 2.9m high solid RC bridge parapets to be constructed.	The bridge will be surcharged during the design flood event. It is assumed that the bridge could structurally withstand the surcharge force, however this will need to be checked.
Middle Ravensdale Bridge to Upper Ravensdale Bridge (Approximately 28m)	Ballybrack Stream	467m – 495m	Construction of new stone clad flood defence wall along both banks. The top of the new flood defence walls will be on average 2.6m (maximum 2.9m) above existing ground level.	The works in this reach will take place in close proximity to existing buildings. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Upper Ravensdale Bridge	Ballybrack Stream	@ 495m	New 2.7m high solid RC bridge parapets to be constructed.	The bridge will be surcharged during the design flood event. It is assumed that the bridge could structurally withstand the surcharge force, however this will need to be checked.

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Upper Ravensdale Bridge to Ballybrack Woods (Approximately 128m)	Ballybrack Stream	495m – 623m	Construction of new stone clad flood defence wall along both banks The top of the new flood defence walls will be on average 2.4m (maximum 2.9m) above existing ground level	The works in this reach will take place in close proximity to existing buildings. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Ballybrack Woods Cycle Track Bridge	Ballybrack Stream	@ 623m	Replacement of the existing bridge and installation of a larger trash screen	This work is being carried out to minimise the risk of blockage downstream

5.2.2 Option 2 - Conveyance Improvements only

This options involves the widening and deepening of the Ballybrack channel through Douglas, as well as removal of constrictions at several hydraulic structures (bridges, culverts, etc.).

This option does not involve the construction of any flood defence walls. Instead, the channel is to be widened and deepened and a number of the bridges are to be either removed or replaced. The details of this option are:

- Remove the ICA Bridge and provide a new access route to the hall;
- Remove the Church Road Cycle Track Bridge and provide a new access route for cyclists/pedestrians;
- Increase the width of the channel by 2m and deepen it by 0.3m from model chainage 390 to 450 (see accompanying map). This necessitates the replacement of Lower Ravensdale Bridge;
- Increase the width of the channel by 3m and deepen it by 0.3m from model chainage 280 to 390 (see accompanying map). This necessitates the replacement of the Church Road culvert;
- Construct a new access route to the cycleway for cyclists and to the ICA Hall for pedestrians (see accompanying map).

To maintain a good ecological environment within the Ballybrack stream for this option, it is proposed that the widened section be a compound channel. This would involve incorporating both a low and high flow section into the channel. The low flow section will convey flows below a certain threshold and flows above this threshold would be accommodated within the full channel section. An indicative cross section of this arrangement is shown in Figure 18.

It is noted that the diagram is illustrative. The exact dimensions of the compound channel would be designed as part of the detailed design stage of the project.

The proposed works are presented in Figure 17 and described in detail in Table 3. A long section showing the extent of river deepening is shown in Figure 19.

The main positive of this solution is that no flood defences would be required as the upgraded channel would convey the design flood event in bank.

The primary negative is the option does not provide for adequate freeboard at certain critical sections of the reach.

Additionally the required conveyance improvements would be extensive and involve both deepening and widening. The required widening may be difficult to achieve within such a confined corridor through Ravensdale. Such a large channel would also require careful detailing to maintain velocities during normal low flows.

Figure 17: Option 2 – Ravensdale and Douglas Park Area

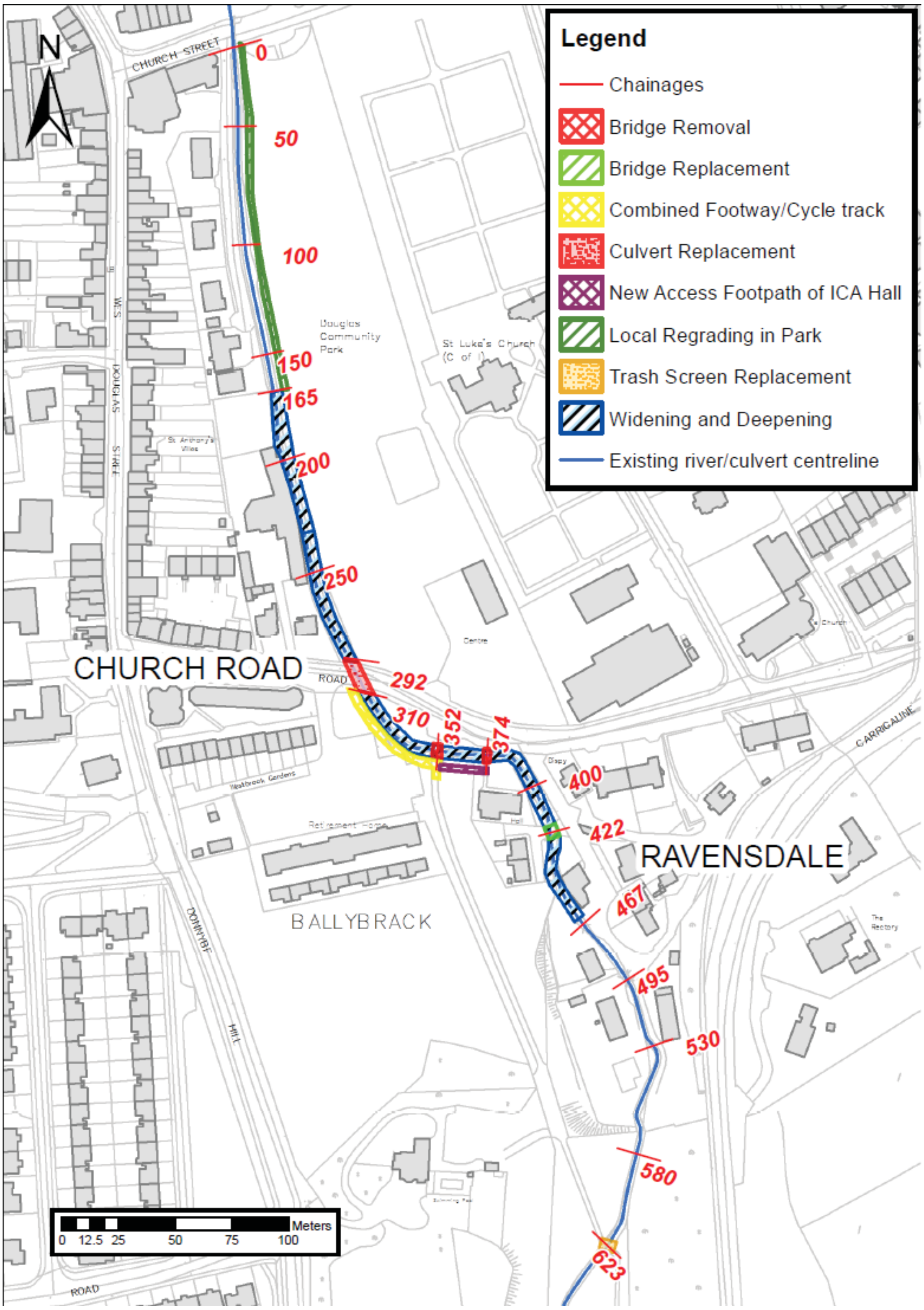


Figure 18: Option 2 - Typical channel cross section: ICA Bridge to Ravensdale Lower Bridge

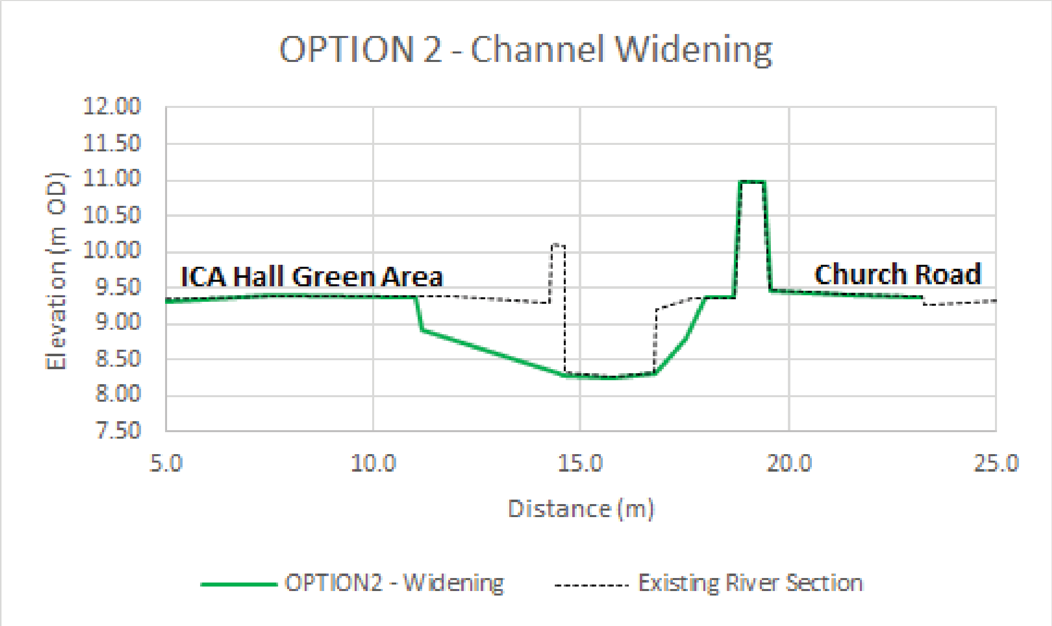


Figure 19: Option 2 – Indicative longitudinal section through Ballybrack channel showing proposed deepening. The max water level corresponds to the design Q100 flood

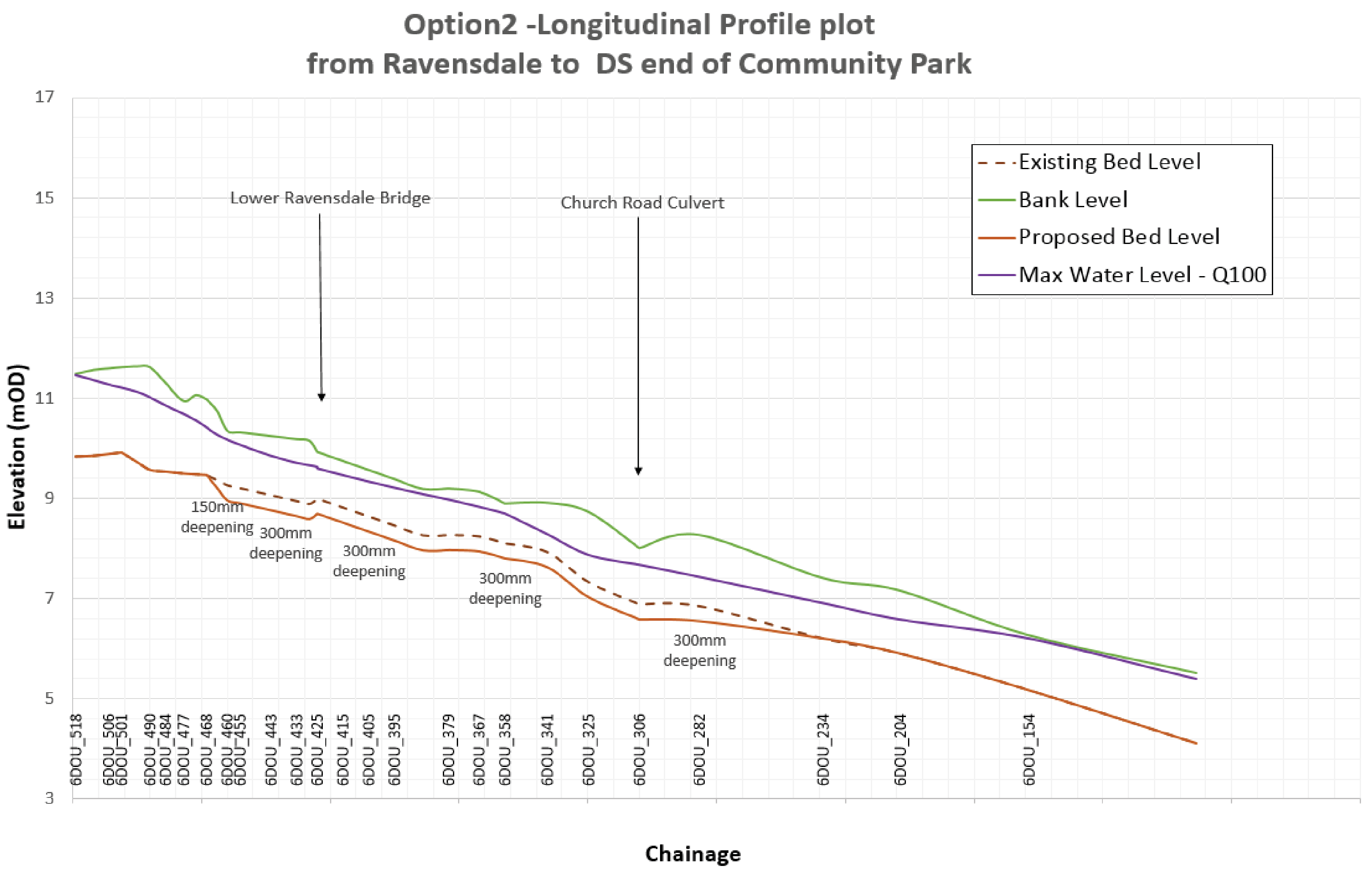


Table 3: Description of Option 2 works – Ballybrack stream

Location (and Total Length of Channel Affected)	Channel	Chainage	Description	Comments
Douglas Community Park (Approximately 290m)	Ballybrack Stream	0m – 180m	Local re-grading along the right bank of the Ballybrack in the northern half of the park (max 200mm + freeboard).	Re-grading of ground levels along the right bank is necessary to ensure that water does not get out-of-bank and adequate freeboard is maintained along the reach. The works would not be expected to involve any removal of any trees along the bank.
	Ballybrack Stream	180m – 290m	Widening and deepening of the Ballybrack channel in the southern half of the park. The widening will increase the width of the channel by approximately 3 m. The deepening will increase the depth of the channel by approximately 300 mm.	The existing channel along this reach was found to be causing a backwater effect which propagated upstream into the Ravensdale area. The conveyance improvements are intended to eliminate the backwater effect. The widening works would take place on the right bank only due to the proximity of existing buildings to the left bank. The existing bed width of the channel will be maintained, i.e. the widening will be carried out only above bed level. The widening works would involve the removal of a number of trees along the right bank to facilitate excavation.
Church Road culvert (Approximately 13m)	Ballybrack Stream	@ 300m	Existing 1.39 m wide (average width) x 1.2 m high culvert to be replaced with a 4.45 m wide x 1.32 m high culvert.	There are a number of services running along Church Road which cross over the existing culvert. Based on site visits and drawings received from the utility providers, these services include: • Eircom (U/G) • Watermain • UPC fibre optic (U/G) • Bord Gáis 75 mbar pipe (U/G) • Bord Gáis 4 bar pipe (overground, attached to the southern face of the culvert) • ESB MV/HV (running across Church Road i.e. along the length of the culvert) • ESB O/H LV • 225mm foul drain There is expected to be significant cost associated with upholding or temporarily diverting these services to facilitate the works Significant traffic management will be required during the works

Location (and Total Length of Channel Affected)	Channel	Chainage	Description	Comments
Church Road Culvert to Church Road Cycle track bridge (Approximately 42m)	Ballybrack Stream	310m – 352m	Widening and deepening. The widening will increase the width of the channel by approximately 3 m The deepening will increase the depth of the channel by approximately 300 mm	Existing channel is under capacity. The works are intended to improve conveyance and reduce blockage risk. Several existing trees and vegetation along both banks will need to be cleared to facilitate the works. There is an existing ESB kiosk on the left bank which will need to be relocated to facilitate the works. The existing concrete channel bed will be replaced with a gravel bed.
Church Road Cycle track bridge	Ballybrack Stream	@ 352m	Removal of existing cycle track bridge	The works are intended to improve conveyance and reduce blockage risk. An alternative access to the cycle track will be provided from Church Road.
Church Road Cycle track bridge to ICA bridge (Approximately 22m)	Ballybrack Stream	352m – 374m	Widening and deepening. The widening will increase the width of the channel by approximately 3 m The deepening will increase the depth of the channel by approximately 300 mm	Existing channel is under capacity. The works are intended to improve conveyance and reduce blockage risk. Several existing trees and vegetation along both banks will need to be cleared to facilitate the works. The existing concrete channel bed will be replaced with a gravel bed.
ICA bridge	Ballybrack Stream	@ 374m	Removal of existing ICA bridge	The works are intended to improve conveyance and reduce blockage risk. An alternative access to the ICA hall will be provided from Church Road.
ICA bridge to Lower Ravensdale Bridge (Approximately 48m)	Ballybrack Stream	374m – 422m	Widening and deepening. The widening will increase the width of the channel by approximately 2 m. The deepening will increase the depth of the channel by approximately 300 mm.	Existing channel is under capacity. The works are intended to improve conveyance and reduce blockage risk. The works in this reach will take place in close proximity to existing buildings, in particular the ICA Hall. Residents of Ravensdale will experience disruption during construction due to construction traffic. All of the existing trees and vegetation along the right bank will need to be cleared to facilitate the works. The existing concrete channel bed will be replaced with a gravel bed.

Location (and Total Length of Channel Affected)	Channel	Chainage	Description	Comments
Lower Ravensdale Bridge	Ballybrack Stream	@ 422m	Existing Ravensdale Lower Bridge to be replaced with a wider bridge. The existing bridge has a cross sectional area of 3.75 m^2. The replacement bridge will have a cross sectional area of 6.65m^2	The works are intended to improve conveyance and reduce blockage risk The works in this reach will take place in close proximity to existing buildings. It may be necessary to provide a temporary access to No 1 and No 2 Ravensdale while the bridge replacement works are being carried out. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Lower Ravensdale Bridge to Middle Ravensdale Bridge (Approximately 45m)	Ballybrack Stream	422m – 467m	Widening and deepening. The widening will increase the width of the channel by approximately 2 m The deepening will increase the depth of the channel by approximately 300 mm	Existing channel is under capacity. The works are intended to improve conveyance. The works in this reach will take place in close proximity to existing buildings. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Ballybrack Woods Cycle Track Bridge	Ballybrack Stream	@ 623m	Replacement of the existing bridge and installation of a larger trash screen.	This work is being carried out to minimise the risk of blockage downstream.

5.2.3 Option 3 - Combination of Direct Defences and Conveyance Improvements

This options involves a combination of both direct defences and conveyance improvements of the Ballybrack stream through Douglas. Table 4 gives an outline description of the works. Figure 20 to Figure 24 present indicative drawings of the option.

Figure 20: Option 3 – Ravensdale and Douglas Park Area

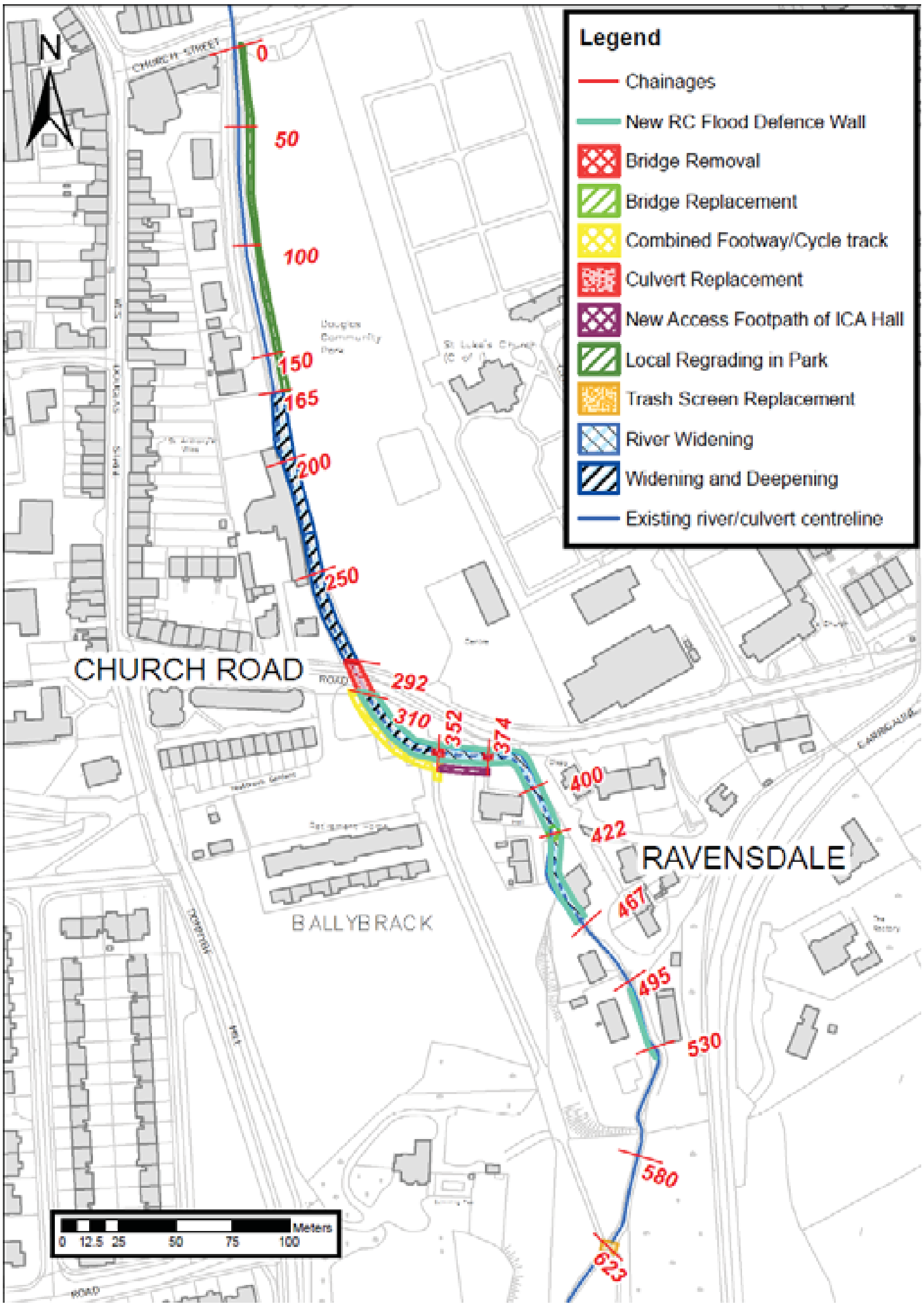
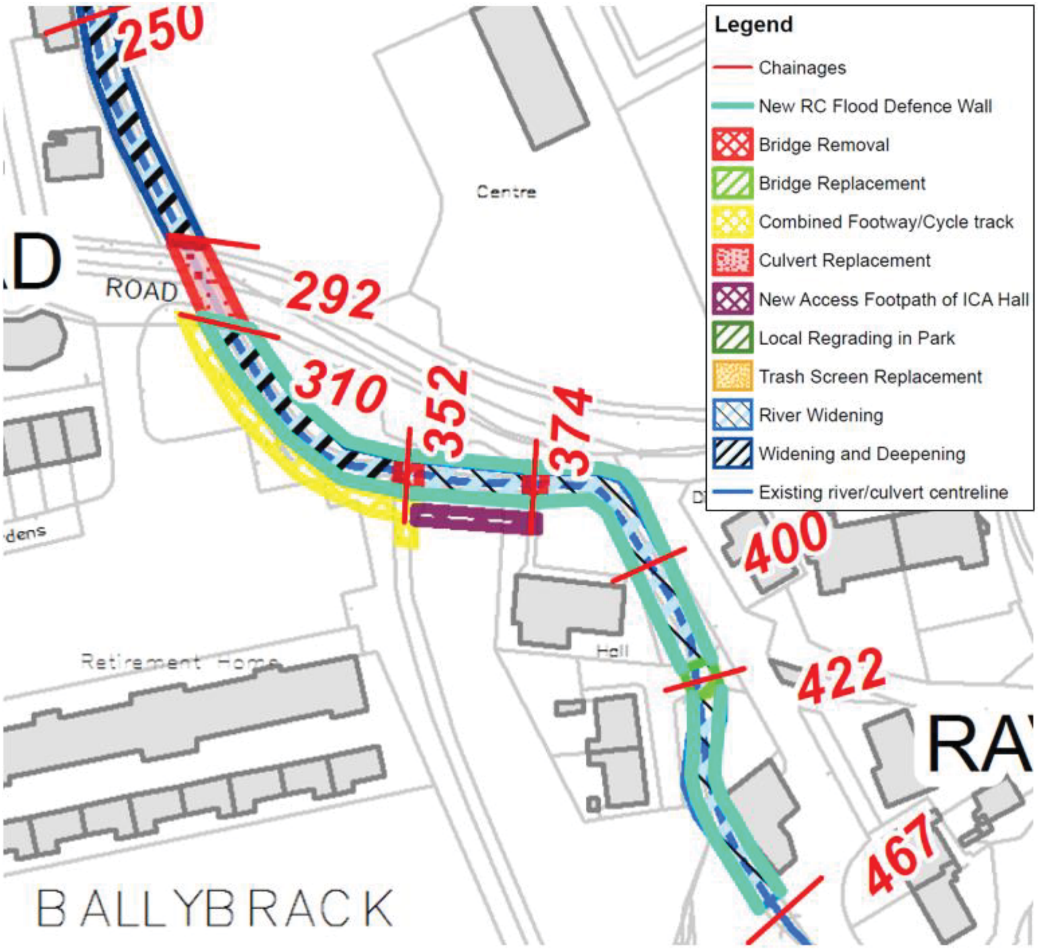


Figure 21: Option 3 – Close up view of the works in the critical area of Ravensdale



A typical section of the proposed works is presented in Figure 22. A long section showing the extent of the proposed river deepening is shown in Figure 23 below.

It can be seen from the figure that the minimum required wall height varies throughout the reach:

- Immediately upstream of Church Road culvert the results of the model indicate that no wall is required as the design water level is greater than 0.5m below the level of the bank;
- In the vicinity of the ICA Hall the required wall height is 0.8m;

To provide safe guarding height for pedestrians, the minimum wall height proposed is 1.2m above existing ground levels. The wall will tie into higher ground where necessary.

The 0.5m freeboard allowance used in the analysis is considered further in Section 11 of this report.

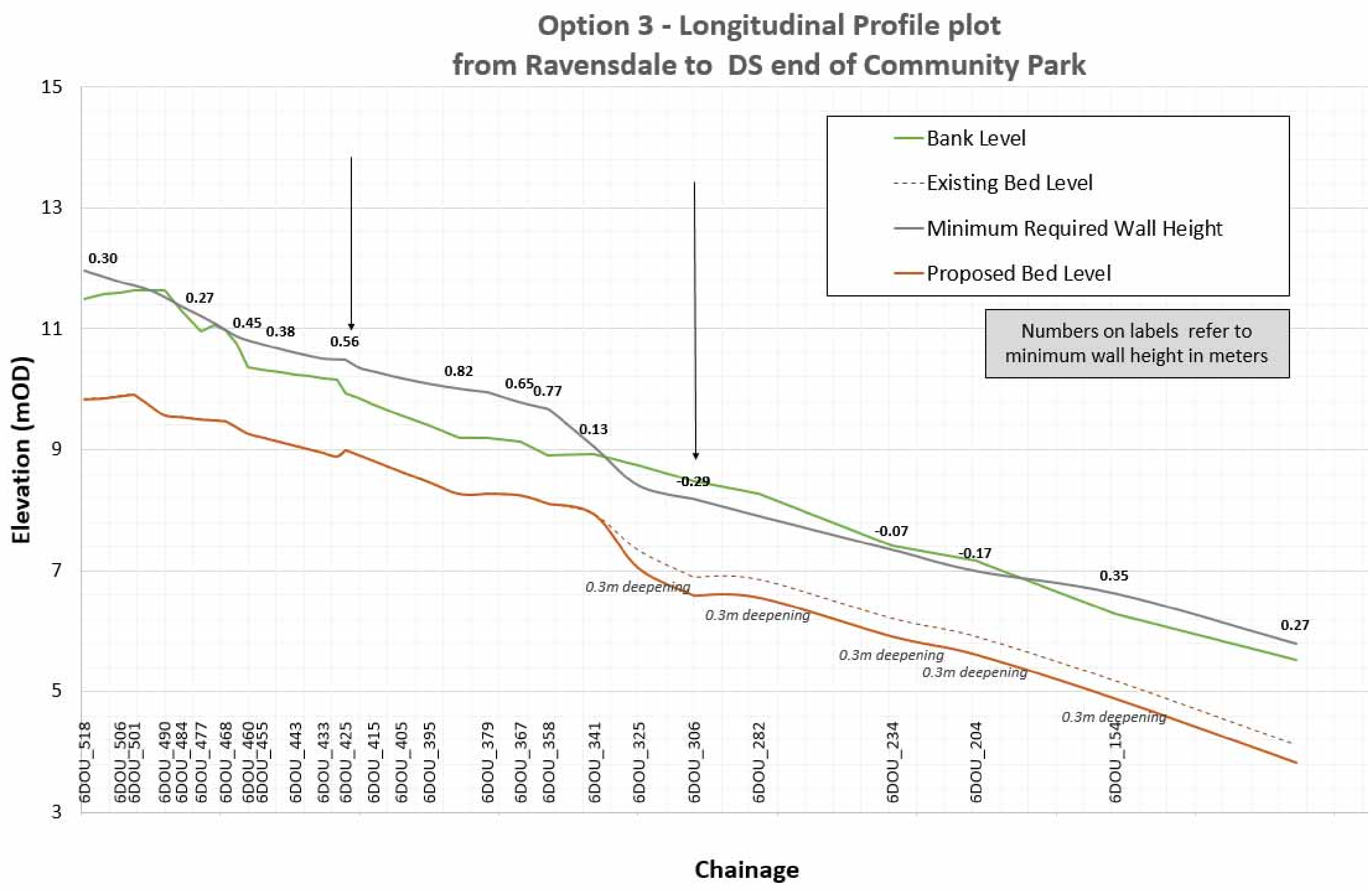
This option has considerable benefits over the previous two options and represents the best balance between all the options:

- The wall heights of 1.2m would not be a significant negative from the visual amenity aspect;

- It would minimise the requirements for conveyance measures as it would involve less widening and deepening of the channel. This would be beneficial for fisheries considerations, and is likely to be more sustainable.
- It will minimise the land take required for widening.

Figure 22: Option 3 - Typical channel cross section: ICA Bridge to Ravensdale Lower Bridge

Figure 23: Option 3 – Longitudinal profile plot



A 'before' and 'after' photomontage of Option 3 is presented in Figure 24 below

Figure 24: Photomontage of proposed Option 3

Before

After

Table 4: Description of Option 3 works – Ballybrack stream

Location (and Total Length of Channel Affected)	Channel	Chainage	Description	Comments
Douglas Community Park (Approximately 290m)	Ballybrack Stream	0m – 180m	Local regrading along the right bank of the Ballybrack in the northern half of the park (max (200mm plus freeboard)	Regrading of ground levels along the right bank is necessary to ensure no out of bank flow and adequate freeboard. The works would not be expected to involve any removal of any trees along the bank.
	Ballybrack Stream	180m – 290m	Widening and deepening of the Ballybrack channel in the southern half of the park. The widening will increase the width of the channel by approximately 3.0m. The deepening will increase the depth of the channel by approximately 300mm.	The existing channel along this reach was found to be causing a backwater effect which propagated upstream into the Ravensdale area. The conveyance improvements are intended to eliminate the backwater effect. The widening works would take place on the right bank only due to the proximity of existing buildings to the left bank. The existing bed width of the channel will be maintained, i.e. the widening will be carried out only above bed level. The widening works would involve the removal of a number of trees along the right bank to facilitate excavation.

Location (and Total Length of Channel Affected)	Channel	Chainage	Description	Comments
Church Road culvert (Approximately 13m)	Ballybrack Stream	@ 300m	Existing 1.39 m wide(average width) x 1.2 m high culvert to be replaced with a 1.3 m high x 4.5 m wide culvert	There are a number of services running along Church Road which cross over the existing culvert. Based on site visits and drawings received from the utility providers, these services include: • Eircom (U/G) • Watermain • UPC fibre optic (U/G) • Bord Gáis 75 mbar pipe (U/G) • Bord Gáis 4 bar pipe (overground, attached to the southern face of the culvert) • ESB MV/HV (running across Church Road i.e. along the length of the culvert) • ESB O/H LV • 225mm foul drain There is expected to be significant cost associated with upholding or temporarily diverting these services to facilitate the works Significant traffic management will be required during the works
Church Road Culvert to Church Road Cycle track bridge (Approximately 42m)	Ballybrack Stream	310m – 352m	Channel widening and construction of new stone clad flood defence walls along both banks. The widening will increase the width of the channel by approximately 2.0 m. The top of the new flood defence walls will be 1.2m above existing ground level. (the minimum required wall height is on average 0.7m through this reach) (1.0 m maximum) above existing ground level	Existing channel is under capacity. The works are intended to improve conveyance and reduce blockage risk. There is an existing ESB kiosk on the left bank which will need to be relocated to facilitate the works. Several existing trees and vegetation along both banks will need to be cleared to facilitate the works. The existing concrete channel bed will be replaced with a gravel bed.
Church Road Cycle track bridge	Ballybrack Stream	@ 352m	Removal of existing cycle track bridge.	The works are intended to improve conveyance and reduce blockage risk. An alternative access to the cycle track will be provided from Church Road.

Location (and Total Length of Channel Affected)	Channel	Chainage	Description	Comments
Church Road Cycle track bridge to ICA bridge (Approximately 22m)	Ballybrack Stream	352m – 374m	Channel widening and construction of new stone clad flood defence walls along both banks. The widening will increase the width of the channel by approximately 2.0 m. The top of the new flood defence walls will be 1.2 0.9m above existing ground level.	Existing channel is under capacity. The works are intended to improve conveyance and reduce blockage risk. Several existing trees and vegetation along both banks will need to be cleared to facilitate the works. The existing concrete channel bed will be replaced with a gravel bed.
ICA bridge	Ballybrack Stream	@ 374m	Removal of existing ICA bridge.	The works are intended to improve conveyance and reduce blockage risk. An alternative access to the ICA hall will be provided from Church Road.
ICA bridge to Lower Ravensdale Bridge (Approximately 48m)	Ballybrack Stream	374m – 422m	Channel widening and construction of new stone clad flood defence walls along both banks. The widening will increase the width of the channel by approximately 2.0 m. The top of the new flood defence walls will be 1.2m above existing ground level.	Existing channel is under capacity. The works are intended to improve conveyance and reduce blockage risk. The works in this reach will take place in close proximity to existing buildings, in particular the ICA Hall. Residents of Ravensdale will experience disruption during construction due to construction traffic. All of the existing trees and vegetation along the right bank will need to be cleared to facilitate the works. The existing concrete channel bed will be replaced with a gravel bed.
Lower Ravensdale Bridge	Ballybrack Stream	@ 422m	Existing Ravensdale Lower Bridge to be replaced with a wider bridge. The existing bridge has a cross sectional area of 3.75 m^2. The replacement bridge will have a cross sectional area of 6.65 m^2.	The works are intended to improve conveyance and reduce blockage risk The works in this reach will take place in close proximity to existing buildings. It may be necessary to provide a temporary access to No 1 and No 2 Ravensdale while the bridge replacement works are being carried out. Residents of Ravensdale will experience disruption during construction due to construction traffic.

Location (and Total Length of Channel Affected)	Channel	Chainage	Description	Comments
Lower Ravensdale Bridge to Middle Ravensdale Bridge (Approximately 45m)	Ballybrack Stream	422m – 467m	Channel widening and construction of new stone clad flood defence walls along both banks. The top of the new flood defence walls will be 1.2m above existing ground level.	Existing channel is under capacity. The works are intended to improve conveyance. The works in this reach will take place in close proximity to existing buildings. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Upstream of Upper Ravensdale Bridge (Approximately 36m)	Ballybrack Stream	494m – 530m	Construction of new stone clad flood defence wall along the left bank. The top of the new flood defence walls will be 1.2m above existing ground level and tie into higher ground as necessary.	The works in this reach will take place in close proximity to existing buildings. Residents of Ravensdale will experience disruption during construction due to construction traffic.
Ballybrack Woods Cycle Track Bridge	Ballybrack Stream	@ 623m	Replacement of the existing bridge and installation of a larger trash screen.	This work is being carried out to minimise the risk of blockage downstream.

5.3 St. Patrick's Mills

As the flood risk in this area is tidally driven, i.e. level driven, Direct Defences is the only option considered. As detailed in the accompanying Hydraulics report, the 200 year tidal level is at or just below the level of the bank at this location. Defences at this location are therefore primarily required for freeboard and/or to reinforce existing defences.

The proposed Direct Defences at St. Patrick's Mills are presented in Figure 25 and described in Table 5 below.

Figure 25: Proposed defence walls at St. Patrick's Mills

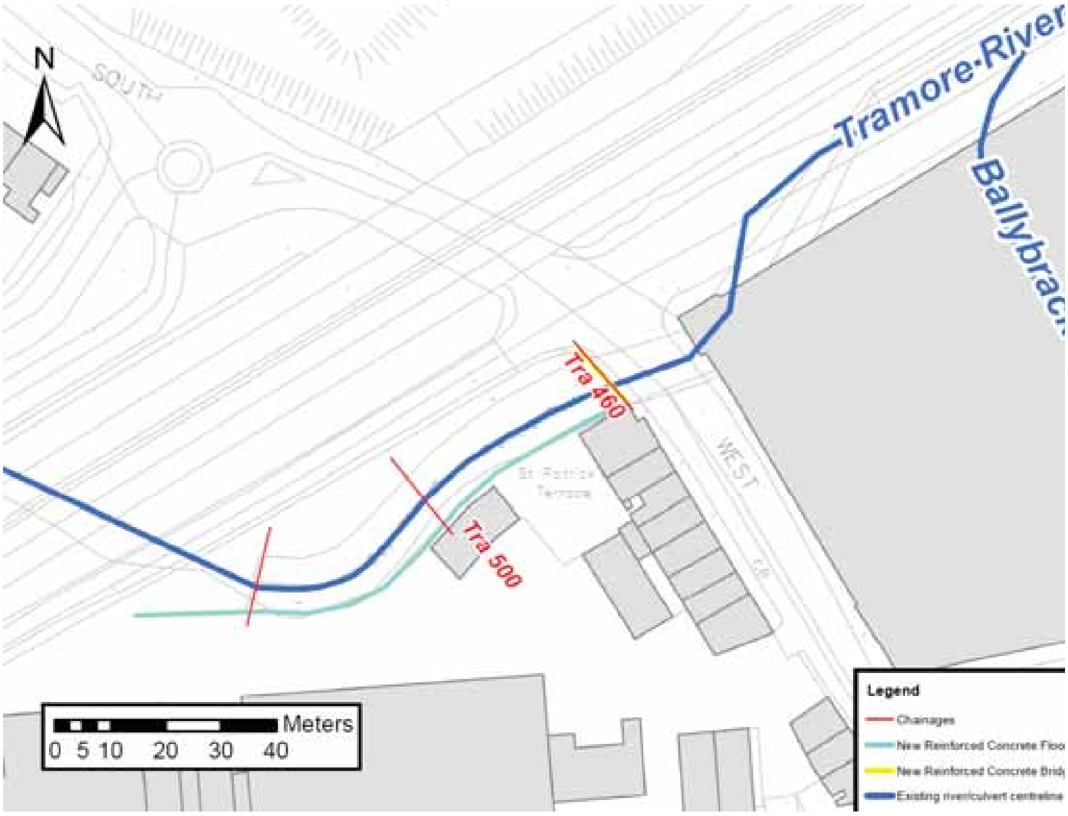


Table 5: Description of works (direct defences only) – St. Patrick's Mills

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description
St. Patrick's Mills (Approximately 75m. The wall is to tie into high ground)	Tramore	460m – 550m	New 1.2m high flood defence wall along the right bank of the Tramore River. Stone clad on dry side only. New reinforced concrete bridge parapets 1.2m high.

5.4 Donnybrook Commercial Centre

5.4.1 Preferred Option for the Donnybrook Commercial Centre

A drawing of the proposed measures for Donnybrook is presented in Figure 26 and described in Table 6.

It is proposed to upsize the lower section of the existing culvert to address the risk of surcharging from the culvert. From successive runs of the hydraulic model undertaken to determine the minimum size of culvert required to prevent surcharging and also meet with Section 50 requirements, it was found that a 2.4m wide by 1.8m high culvert 97m in length is required.

The bed of the proposed culvert is lower than the existing culvert bed level in order to avoid any ground raising within the site. The maximum difference in bed levels is 0.6m circa 30m upstream of the exit from the culvert. The amended bed and culvert levels are shown in Figure 27. Design water levels through the culvert for both the Q100 and S50 scenarios are also presented on the plot.

Figure 26: Option 1 – Donnybrook Commercial Centre Area

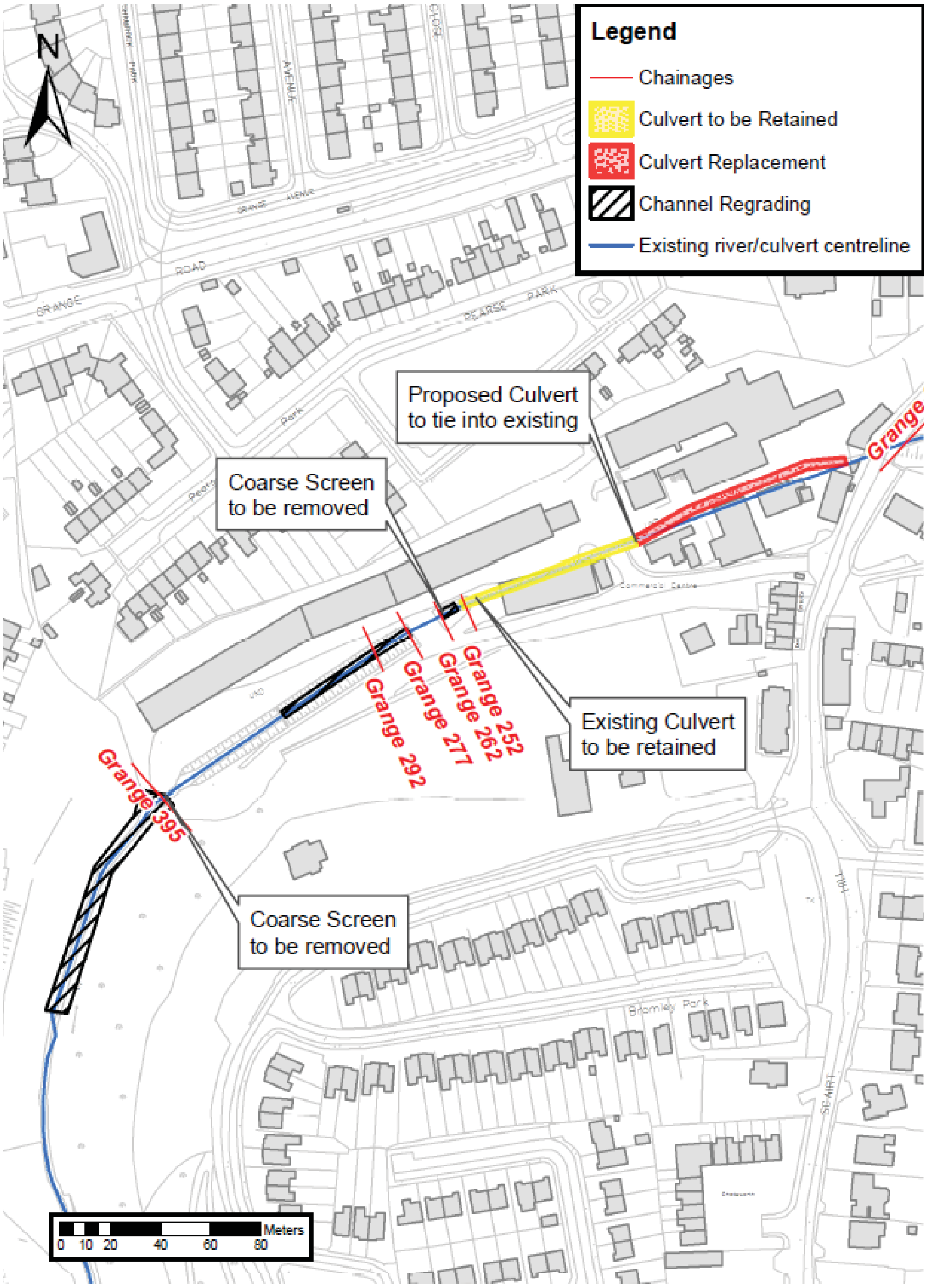


Figure 27: Amended bed levels and design water levels for upsized culvert

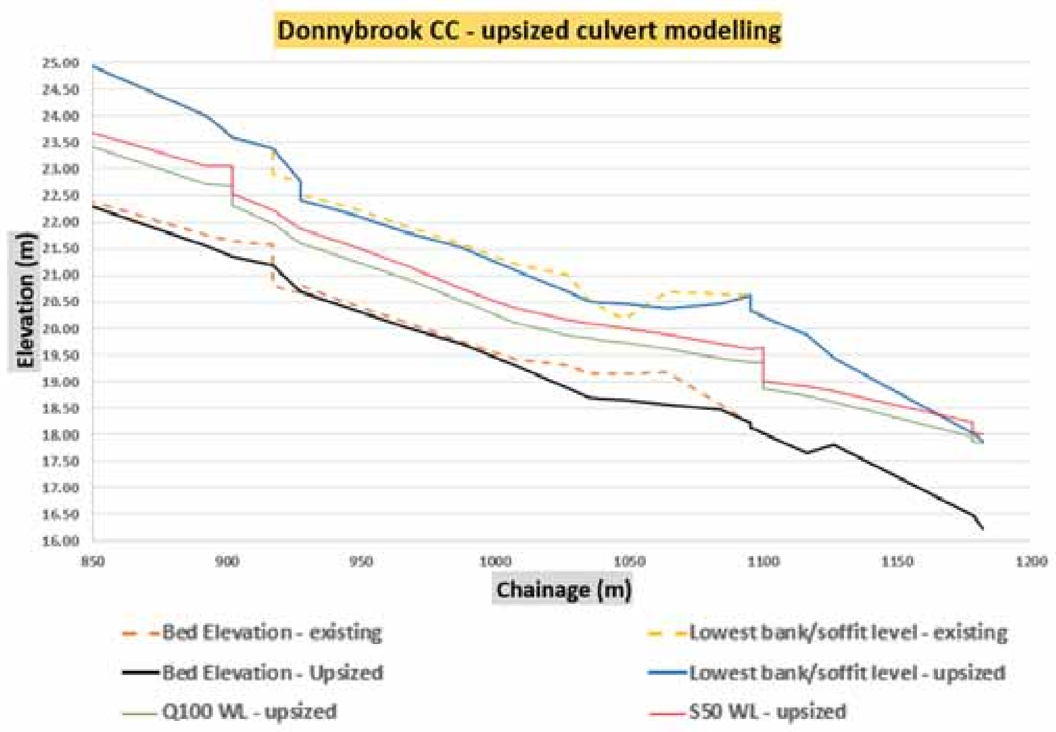


Table 6: Description of Option 1 works – Donnybrook commercial centre

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description
Donnybrook Commercial Centre	Grange Stream	78m – 175m	Upgrade of the lower section of the existing culvert with a new 2.4m wide * 1.8m high culvert that is 97m long
Donnybrook Commercial Centre	Grange Stream	@ 395m	Removal of coarse screen
Donnybrook Commercial Centre	Grange Stream	@ 262m	Removal of coarse screen
Donnybrook Commercial Centre	Grange Stream	395m – 495m	Local minor regrading of the channel to account for the removal of the trash screens and culvert replacement

6 Economic Assessment of Shortlisted Options

6.1 Cost Estimate of Shortlisted Options

6.1.1 Introduction

The viable flood relief options for Douglas Village are:

- Direct defences;
- Conveyance improvements;
- Direct Defences and Conveyance improvements combined.

The only viable option for Donnybrook Commercial Centre is to upgrade a section of the existing culvert and channel regrading.

The only viable option for St. Patrick's Mills is RC flood protection walls.

This chapter details the cost of implementing each option.

6.1.2 Methodology

When building up cost estimates for a scheme of this nature, it is important that the expected whole life costs of the works and its management are developed and not just the scheme capital costs. The following list outlines the areas that were considered when developing cost estimates for this project:

- Construction costs, including the Contractor's general items and overheads.
- Design and site supervision costs.
- Site Investigation and survey costs.
- Environmental mitigation costs.
- Land purchase and compensation costs.
- Maintenance costs.
- Risk based costs.
- Allowance for Art.

The following costs were excluded:

- Value Added Tax.
- Land Remediation.
- Cost of OPW/CCC staff time on the project.

6.1.2.1 Construction Costing Method

Base costs for construction elements of the scheme were obtained from the following sources:

- Estimates and tendered rates from similar civil engineering contracts.
- Published cost databases, including the NRA unit cost database and the draft OPW unit cost database

The base data provided labour, plant and material rates that were amended to provide likely out-turn unit costs for flood alleviation construction work. Constructability issues such as access, ground conditions, reduced productivity for plant and labour due to restricted working practices etc. and current prevailing market conditions were the main considerations when amending data.

To address climate change, the foundations of all walls will been designed to allow for future raising of the walls to cater for the predicted effect of climate change.

The following assumptions have been made when compiling the construction cost estimates:

- Normal working week for construction personnel and plant.
- No exceptional adverse weather.

6.1.2.2 Environmental/Archaeological Monitoring, Mitigation Works And Improvement Works

Environmental and archaeological monitoring will be required during the construction of the works. It is also likely that some environmental mitigation and improvement works will be necessary. A provisional allowance of 15% has been included in the cost estimate.

6.1.2.3 Site Investigation and other Surveys

A site investigation, topographic survey, archaeological survey and CCTV drainage survey will all need to be carried out for the scheme. The total cost of these investigation and surveys is estimated to be approximately €75,000 and has been included in the cost estimate.

6.1.2.4 Design and site Supervision costs

An allowance of 10% of the construction cost has been made for design and site supervision costs, reflecting the agreed design fees and assuming an 18 month contract requiring supervision.

6.1.2.5 Land Purchase and Compensation

OPW have advised that 15% should be added to the costs of the schemes to allow for:

- Land purchases and compensation.
- Planning, highway and other third party costs.
- Administration and legal costs associated with land exchanges, statutory approvals, planning applications, service diversions, highway adoptions etc.

- Loss of revenue to adjacent or affected buildings

6.1.2.6 Maintenance Works Costs

The maintenance regime has anticipated costs associated with the following items:

Table 7: Scheme maintenance items costs

Element	Maintenance Task
Embankments	Mowing (5 x year)
Floodwalls	Inspection (1 x year)
	Sealant replacement (1 x 5 years)
Filter drains	Inspection (1 x 5 years)
	CCTV review (1 x 10 years)
	Granular Fill Replacement (1 x 20 years)
Flap Valves	Inspection (1 x 5 years)
	Replacement (1 x 25 years)
Pumping Stations	Inspection (1 x 5 years)
	Electrical Works Replacement (1 x 20 year)
Deepened channel	Inspection (1 x 5 years)
	Removal of excessive deposition (1 x 10 years)
Entire Scheme	Periodic inspection after major flood events greater than 1 in 25 years (say every 10 years)

Maintenance Costs were estimated in two ways as follows:

- Building up the estimated costs using an estimated cost for each of the above items particular to the proposed scheme multiplied by the annual frequency of occurrence.
- Assuming an annual maintenance cost of 1.5% of the Construction Cost.

The latter generally resulted in the higher figure and has therefore conservatively been used.

6.1.2.7 Contingency/Optimism Bias

There can be a tendency for budget cost estimates for flood defence schemes to be overly optimistic. In a project of this nature, including a robust contingency in the cost estimate is essential.

A contingency/optimism bias of 20% of the construction cost has been included in the whole project cost.

6.1.2.8 Allowance for art

The “per cent for art” scheme is compulsory for all major public works contracts. For this size of project, the required allowance for art is 1% of the capital cost up to a maximum of €38,000. For each of the three options the allowance for art is less than the maximum limit of €38,000. The allowances work out as:

- Option 1 – €44,763 (capped at €38,000)
- Option 2 – €21,408
- Option 3 – €29,943

6.1.3 Summary of costs for Douglas

Detailed cost buildups are contained in Appendix A. Table 8 shows the summary of the total costs for each of the viable options. As there is only one option proposed for both Donnybrook Commercial Centre and St. Patrick's Mills, the cost of implementing these options cost has been included in each of the three options.

Table 8: Summary of costs

	Option 1: **- Direct Defences along Ballybrack** **- Culvert upgrade DB CC** **- Direct Defences at St Patrick's Mills**	**Option 2:** **- Conveyance Improvements along Ballybrack** **- Culvert upgrade DB CC** **- Direct Defences at St Patrick's Mills**	**Option 3:** **- Direct Defences and Conveyance Improvements along Ballybrack** **- Culvert upgrade DB CC** **- Direct Defences at St Patrick's Mills**
	€	**€**	**€**
Gross Construction Cost Estimate	2,883,306	1,378,924	1,928,676
Prelims (15%)	432,496	206,839	289,301
Unmeasured Items (20%)	576,661	275,785	385,735
Subtotal	**3,892,464**	**1,861,548**	**2,603,713**
Archaeology & Environmental (15%)	583,870	279,232	390,557
Baseline Construction Cost	**4,476,333**	**2,140,780**	**2,994,270**
Contingency / Optimism Bias (20%)	895,267	428,156	598,854
Construction Cost Subtotal	**5,371,600**	**2,568,936**	**3,593,124**
Land Acquisition (15%)	671,450	321,117	449,140
Fees and Supervision (10%)	447,633	214,078	299,427
Art (1% or cap)	38,000	21,408	29,943

	Option 1: - Direct Defences along Ballybrack - Culvert upgrade DB CC - Direct Defences at St Patrick's Mills	**Option 2:** - Conveyance Improvements along Ballybrack - Culvert upgrade DB CC - Direct Defences at St Patrick's Mills	**Option 3:** - Direct Defences and Conveyance Improvements along Ballybrack - Culvert upgrade DB CC - Direct Defences at St Patrick's Mills
	€	**€**	**€**
Site Investigation & Surveys	75,000	75,000	75,000
Capital Cost Total	**6,603,683**	**3,200,539**	**4,446,634**
Maintenance (NPV)	1,442,409	734,812	964,844
Project Cost Total	**8,046,092**	**3,890,363**	**5,411,478**

6.2 Damages Assessment

6.2.1 Overview

The benefit to be derived from the flood protection works is the reduction in risk of flooding to land and property. This risk is quantified as the reduction in the expected damage to property that would occur over the lifetime of the scheme.

6.2.2 Approach

The adopted approach assesses the damages for the Douglas study area as a whole. It is recognised that individual properties and areas may have a positive or negative impact on the overall scheme based on their individual valuation of benefit and the cost. These differences are spread across the scheme to provide a comprehensive assessment.

The damages assessment has not made allowance for the additional depths of flooding caused by climate change, while climate change provision has been included in the scheme costs where feasible. This introduces an element of conservatism into the cost benefit analysis.

6.2.3 Guidance

The analysis has been carried out in accordance with the OPW guidance document "Lower Lee, Douglas and Glashaboy Flood Relief Schemes: Economic Damage Assessment and Cost Benefit Analysis (Rev B)".

This guidance document sets out a common approach to the calculation of monetised economic flood damages and the economic benefits of flood risk management options, and for undertaking a cost-benefit analysis.

Flood damage data has been assessed from the “The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques (2014)” published by the Flood Hazards Research Centre at Middlesex University. This document is often referred to as the “Multicoloured Manual” (MCM).

The application of the flood damage data, which are UK derived, to Ireland and the assumptions in the cost benefit analysis has been undertaken generally in accordance with the guidance of the report prepared by Goodbody Economic Consultants for the OPW in February 2001 entitled “A Review of Cost Benefit Procedures for Flood Relief Schemes”, where applicable.

The flood area and depth of flooding were assessed on the basis of a detailed 1D-2D hydraulic model representing the existing scenario.

6.2.4 Assumptions

6.2.4.1 Damage Assessment

The calculation of flood damage for both residential and commercial properties can be classified into two broad categories:

Tangible damages

These can be quantified in monetary terms and are divided into direct and indirect damages.

Direct tangible damages result from the physical contact of flood water with property. The damage magnitude may be taken as the cost of the property restoration to its condition prior the flood event, or its loss in market value if restoration is not worthwhile. Direct damages are a function of many variables including the physical make-up of the property and the characteristics of the flood event, including the depth and duration of flooding.

The unit damages for residential properties used the MCM “initial appraisal” approach. This is because the MCM 2014 “full-scale appraisal” only includes damages broken down by social class. As per OPW guidance, social class is to be excluded from the damages assessment for this project.

The unit damages for non-residential properties uses the standard depth/damage curves from chapter 5 of the MCM 2014.

Indirect tangible damages are losses caused by disruption of physical and economic linkages to the local/national economy.

Examples include the costs of emergency services of a flood event, and the interruption of traffic flows. MCM 2014 estimates the cost of emergency services as between 5.6% and 10.7% of the direct tangible damages (direct tangible damages are referred to as the “Principal Direct Damages” (PDD) in the OPW guidance note).

OPW guidance directs that an allowance of 8.1% of the PDD be included in the damages assessment to account for emergency services. OPW guidance states that this allowance is deemed to include evacuation costs.

An allowance of 20% of the PDD has been included to account for damage to infrastructural utility assets.

The cost of interruption of traffic flows is more difficult to determine, therefore as a conservative assumption this element of the indirect tangible damages has been ignored.

As per OPW guidance, loss of business costs for commercial properties, damage to roads, damage to parked cars, environmental damage, personal evacuation costs, temporary accommodation and extra heating costs have also been ignored.

The damage costs associated with risk to life have also been excluded as per OPW guidance. This has been excluded as loss of life due to flood events is very rare in Ireland.

Intangible damages

These are difficult to quantify in monetary terms as they include human stress and anxiety, inconvenience and ill health associated with frequent, repeat flooding.

In accordance with OPW guidance, the flood damage assessment undertaken for the scheme has used the PDD as a guide to estimating the Intangible Damages. The guidance distinguishes between residential and non-residential properties:

- For residential properties the intangible flood damages are set equal to the total direct property damage;
- For commercial properties it is assumed that the intangible flood damages are zero. This assumption is valid for commercial premises that are not family owned such as office spaces, retail outlets and chain stores. It is noted that there are some commercial properties in Douglas which could be categorised as small family-owned. However, as a conservative assumption, no intangible damages have been assigned to these commercial properties.

6.2.4.2 Thresholds of Flooding

The threshold of flooding is the level at which flooding will start to occur. For this scheme, the threshold of flooding for each property is determined based on the 2D hydraulic model results, and the assumed/surveyed floor level for each property. Note that where no threshold survey information was available, it was assumed that the ground floor level of each property is 150mm above the Lidar ground level.

No allowance has been made to identify any benefit of the scheme in reducing the impact of flood events of return period greater than 1 in 100 year.

Such benefits will exist, but are very difficult to quantify and as they are achieved so infrequently they do not make a significant contribution to the overall benefit.

6.2.5 Damage Assessment GIS tool

Arup has developed an in-house GIS tool which was used to support the calculation of flood damages for the study area. The tool creates a single dataset of all the residential and commercial properties in the study area and estimates the flood depths for the various return period at each property using the 2D hydraulic model results. The tool then assigns flood damages to each property using the flood damage data in the MCM.

The datasets used by the tool are:

- **Geodirectory dataset** – for determining the building use (Residential or commercial) and building type (MCM code).

  In the Geodirectory, the economic activity associated with each property is held as a NACE code (Nomenclature of Economic Activities). NACE is the European statistical classification of economic activities. The NACE code was used to derive the MCM code for each property. Where discrepancies were found, the properties were inspected on site or through use of “street view” imagery freely available online;
- **OSi NTF dataset –** for calculating the area of the commercial properties;
- **2D hydraulic modelling results –** water levels to OD Malin for eight separate return period events are used by the tool to determine the extent and level of flooding in Douglas. Subtraction of the property threshold level from the water level yields the depth of flooding at each property for all the return period events;
- **Lidar data –** for estimating the ground level of all the properties in Douglas. It has been assumed that the threshold level of all the properties is 150mm above the Lidar ground level.
- **Threshold surveys –** The finished floor level (ffl) of 10 properties were available from the Lee CFRAM dataset and have been used in the damages assessment. The ffl of Douglas Village Shopping Centre was available from the as-built drawings of the development and was also used in the assessment.

It was noted that some discrepancies exist between the Geodirectory and NTF datasets. The property dataset therefore required some manual editing to ensure it correctly represented the properties in Douglas.

The FHRC damage figures have been converted from UK Sterling to Euro by means of Purchasing Power Parity (PPP) as per OPW guidance. As the damages data in the MCM is dated 2014, it was deemed to be unnecessary to adjust for inflation.

Capping values for both residential and commercial properties were determined using the residential property price register and commercial leases register. Following OPW guidance the commercial capping values were calculated as ten times the current rateable value of the property.

6.2.6 Douglas Village Shopping Centre

Douglas Village Shopping Centre was represented in the Douglas FRS model by:

- Specifying a high manning's n for the plan area of the building;
- Setting the finished floor level as per the 'as-built' drawings;
- Specifying the external perimeter wall of the building as a Z line in Tuflow (indicated with the red line in Figure 28). This implies that no flow will pass through this line in the model. As a consequence flow can only flow into and out of DVSC through the entrance on Church Street and the entrance on Douglas East. These are indicated by the gaps in the red line;

Representing the DVSC in this way gave a good calibration of the model against the June 2012 event.

Representing DVSC in this manner ensured that the water levels along Douglas West in the model were greater than inside the area bounded by DVSC.

The GIS damages tool reads the water levels for a particular return period along the boundary of each property and selects the maximum value as the flood level for the property for that return period. The floor level of the property is then subtracted from this water level to give the flood depth at the property. While this estimation of flood depth is valid for most properties, in the case of DVSC it leads to an overestimation of the flood depth and hence the damage calculation as the maximum water level along the boundary is greater than the water level inside the property.

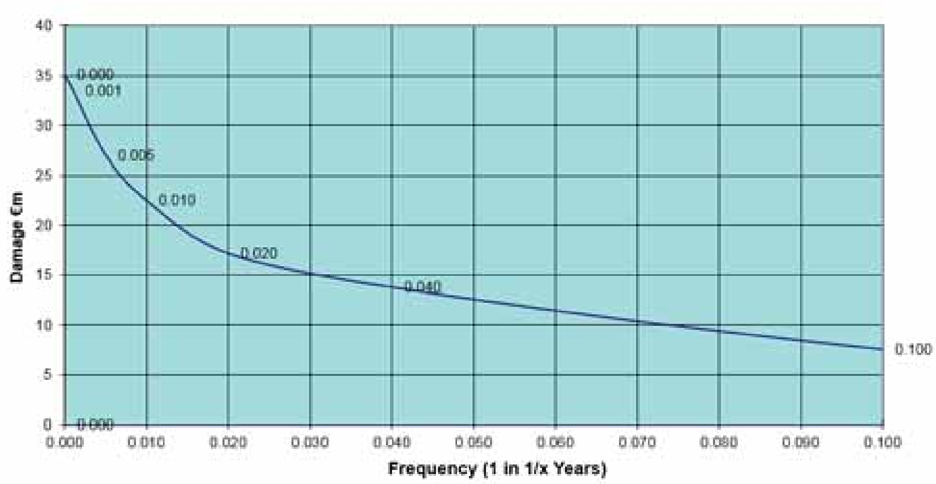
To allow a realistic estimation of flood damages for the DVSC, the Douglas FRS model was therefore adjusted: the perimeter wall around the building was removed from the model allowing flow to enter and exit the building at any point along its perimeter.

Figure 28: DVSC perimeter wall

6.2.7 Damage Analysis Results

A graph of damage against frequency is prepared for each return period. Figure 29 presents the damage-frequency graph for Douglas. The Annual Average Damage is equal to the area beneath the curve.

Figure 29: Damage-frequency graph for Douglas



The various elements of the flood damages are presented in Table 9.

Table 9: Summary of flood damages

Category	Damage for 1%AEP Fluvial Event (€m)	Annual Average Damage (€m)	Present Value Damage - 50 year time horizon (€m)
Direct Residential	0.627	0.0254	0.567
Direct Non-Residential	16.400	1.366	30.511
Principal Direct Damages	**17.084**	**1.391**	**31.078**
Intangible	0.627	0.0257	0.567
Emergency Services	1.380	0.112	2.519
Utilities	3.410	0.278	6.220
Total	**22.50**	**1.80**	**40.384**

6.3 Cost Benefit Analysis of the Options

6.3.1 Costs

6.3.1.1 Present Value Costs

The Present Value Costs provide an indication of the cost today of the works over their lifetime.

6.3.1.2 Capital Works Costs

The present value of costs is based on a 50-year design life that is capable of protecting against a 1 in 100 year flood event. The Capital Works Costs have been calculated as described in Section 6.1.

We have adopted a conservative approach in our Cost Benefit Analysis (CBA) and assumed that the full cost of the scheme is expended in the Year 0 (2018).

6.3.1.3 Maintenance Costs

The maintenance costs have been spread over the 50 year life span of the schemes, starting in 2019 coinciding with the completion of the schemes.

6.3.2 Economic Comparison

OPW have advised that the appropriate discount rate to be applied should be 4%.

6.3.3 St. Patrick's Mills and Donnybrook Commercial Centre Costs

For the purpose of calculating the benefit cost ratio, the costs associated with implementing the proposed flood relied solutions at St. Patrick's Mills and Donnybrook Commercial Centre has been added to the cost of each of the three options for Douglas.

6.3.4 Benefit cost Analysis Summary

Detailed cost-benefit calculations are contained in Appendix A.

Table 10 represents the Cost Benefit Analysis based on Discount Rate of 4%.

Table 10: Cost benefit analysis summary

	Option 1 (€m)	Option 2 (€m)	Option 3 (€m)
Present Value Costs (PVc)	8.046	3.89	5.41
Present Value Benefit (PVb)	35.170	35.170	35.170
Net Present Value (NPV)	27.124	31.280	29.759
Benefit Cost Ratio (BCR)	4.371	9.041	6.500

6.3.5 Sensitivity Analysis

The control of all risks is impossible and therefore the economic robustness of the scheme has been investigated using sensitivity analysis. In order to investigate the least credible level of benefits the following assumption has been made:-

- 4% discount rate with 5% reduction in flood damage benefits
- 3% discount rate
- 5% discount rate

Table 11: Sensitivity analysis for 4% discount rate & 5% reduction in benefit

	Option 1 (€m)	Option 2 (€m)	Option 3 (€m)
Present Value Costs (PVc)	8.046	3.89	5.41
Present Value Benefit (PVb)	33.420	33.420	33.420
Net Present Value (NPV)	20.000	26.960	24.420
Benefit Cost Ratio (BCR)	2.490	5.170	3.710

Table 12: Sensitivity analysis for 3% discount rate

	Option 1 (€m)	Option 2 (€m)	Option 3 (€m)
Present Value Costs (PVc)	8.046	3.89	5.41
Present Value Benefit (PVb)	41.630	41.630	41.630
Net Present Value (NPV)	33.584	37.740	36.219
Benefit Cost Ratio (BCR)	5.174	10.702	7.694

Table 13: Sensitivity analysis for 5% discount rate

	Option 1 (€m)	Option 2 (€m)	Option 3 (€m)
Present Value Costs (PVc)	8.046	3.89	5.41
Present Value Benefit (PVb)	30.230	30.230	30.230
Net Present Value (NPV)	22.184	26.340	24.819
Benefit Cost Ratio (BCR)	3.757	7.771	5.587

6.4 Conclusion of Benefit Cost Analysis

Benefits and costs for all options were compared with those of the "Do Minimum" case to provide a convenient common baseline against which the proposed scheme can be assessed.

The Cost Benefit Analysis was tested for sensitivity versus a 5% reduction in benefit, and also a varied discount rate.

The Cost Benefit Analysis shows that all options are cost-beneficial with very strong cost-benefit ratios. The options are listed below in order of strongest to weakest cost-benefit ratios.

- Option 2 – 9.04
- Option 3 – 6.5
- Option 1 – 4.3

7 Environmental Assessment of the Shortlisted Options

7.1 Introduction

This chapter considers the key environmental constraints which were identified during the constraints study in relation to the flood relief options considered in this report. The potential impacts arising from each of the shortlisted flood defence options are discussed under the following headings:

- Terrestrial ecology
- Aquatic ecology
- Archaeology, Architectural and Cultural Heritage
- Soils, Geology and Hydrogeology
- Human Beings

A detailed multi-criteria analysis (MCA) of the shortlisted options was carried and is discussed and presented in Section 9 of this report. The flood risk management options considered in the MCA included environmental objectives. Each objective was weighted to reflect their importance and/or sensitivity, and to ensure that the objectives most relevant to the location under consideration were given priority in the decision-making process. The reader is referred to 9 for full details.

7.2 Potential Impacts of the Shortlisted Options

7.3 Introduction

As discussed in Section 5, shortlisted flood defence options for three areas have been developed, as follows:

Area 1: Ballybrack Stream through Douglas Village

- Option 1: Direct Defences only
- Option 2: Conveyance improvements only
- Option 3: Combination of direct defences and conveyance improvements

Area 2: St. Patrick's Mills

- Option 1: Direct Defences only

Area 3: Donnybrook Commercial Centre.

- Option 1: Culvert upgrade

The flood defence options considered for are discussed in more detail in Section 5.

7.4 Aquatic and Terrestrial Ecology

The potential aquatic and terrestrial ecology impacts arising from the flood defence options are described in the tables below. Where appropriate, mitigation measures have been suggested.

7.4.1 Aquatic Ecology

7.4.1.1 Area 1: Ballybrack Stream through Douglas Village

Table 2.2.1.1: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Direct defences only	Fixed direct defences may have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative short term impacts. As this option would not necessitate significant in-stream works, there is less probability that high silt levels will impact on designated sites downstream within Cork Harbour. High walls could affect the movement of otters. Loss of overhanging vegetation can result in less food resources and cover for fish populations.	Avoidance of significant in-stream works or changes in channel structure, will minimise the impact on fish populations. Detailed control measures will be required for silt control and to prevent minor hydrocarbon spills.

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 2: Conveyance improvements only	Improved channel conveyance may have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative short term impacts. In-stream works could introduce high levels of silt, which although unlikely, could theoretically impact negatively on Natura 2000 sites downstream of the proposed works. Impacts on fish populations can reduce prey availability for otter and piscivorous birds such as heron. Deeping and widening the channel will impact directly on fish, macro-invertebrate species and aquatic flora. If not controlled, high levels of silt may have indirect impacts. Widening of the channel will result in the loss of riparian vegetation which may have indirect impacts on fish populations. Although a compound channel will be utilised there may be difficulties in maintaining a normal flow regime during periods of low flow. Culverts and trash screens can impact on fish movement within the watercourse. The replacement of the existing concrete channel bed with a more natural gravel bed is expected to have a net beneficial impact on fish populations.	Detailed control measures will be required for silt control and to prevent minor hydrocarbon spills. To minimise potential impacts on potential spawning areas for salmonids and/or juvenile fish, works will be restricted to the June to September period. Fish rescue procedures may be required under licence to minimise direct impacts on fish populations. Trash screens and culverts will be designed to facilitate fish passage. Restoration of the stream bed will take into account the original structure of the river bed including the rock type present. Sufficient flow must be maintained in the altered channel during low flow conditions.

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 3: Combination of direct defences and conveyance improvements	Improved channel conveyance may have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative short term impacts. In-stream works could introduce high levels of silt, although unlikely, this could theoretically impact negatively on Natura 2000 sites downstream of the proposed works. Deeping and widening the channel will impact directly on fish, macro-invertebrate species and aquatic flora. If not controlled, high levels of silt may have indirect impacts. Widening of the channel will result in the loss of riparian vegetation which may have indirect impacts on fish populations. Although a compound channel will be utilised there may be difficulties in maintaining a normal flow regime during periods of low flow and maintaining a natural substrate. Culverts and trash screens can impact of fish movement within the watercourse. The replacement of the existing concrete channel bed with a more natural gravel bed is expected to have a net beneficial impact on fish populations. Impacts on fish populations can reduce prey availability for otter and piscivorous birds such as heron.	Detailed control measures will be required for silt control and to prevent minor hydrocarbon spills. To minimise potential impacts on potential spawning areas for salmonids and/or juvenile fish, works will be restricted to the June to September period. Fish rescue procedures may be required under licence to minimise direct impacts on fish populations. Trash screens and culverts will be designed to facilitate fish passage. Restoration of the stream bed will take into account the original structure of the river bed including the rock type present. Sufficient flow must be maintained in the altered channel during low flow conditions.

7.4.1.2 Area 2: St. Patrick's Mills (tidal risk)

Table 2.2.1.2: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Direct defences only	Fixed direct defences and improved channel conveyance have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative impacts. As this option would not necessitate significant in-stream works there is less probability that high silt levels will impact on designated sites downstream within Cork Harbour. Avoidance of in-stream works or changes in channel structure, will minimise the impact on fish populations. Minor loss of riparian vegetation is unlikely to significantly impact on fish populations.	Avoidance of in-stream works or changes in channel structure, will minimise the impact on fish populations. Detailed control measures will be required for silt control and to prevent minor hydrocarbon spills.

7.4.1.3 Area 3: Donnybrook Commercial Centre

Table 2.2.1.3: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Culvert upgrade	In-stream works could introduce levels of silt. In-stream works could also have the potential to spread Japanese knotweed downstream.	Detailed control measures will be required for silt control and to prevent minor hydrocarbon spills. Detailed control measures will be implemented to prevent the spread of Japanese Knotweed.

7.4.2 Terrestrial Ecology

7.4.2.1 Area 1: Ballybrack Stream through Douglas Village

Table 2.2.2.1: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Direct defences only	The development of high concrete walls will result in the minor loss of riparian vegetation. Riparian vegetation can provide feeding and nesting habitat for birds. Loss of riparian vegetation can impact on feeding, roosting habitat and commuting routes for bats. However this option has the potential to spread Japanese knotweed downstream and theoretically this species could become established within Natura 2000 sites downstream of the proposed works.	Detailed control measures will be implemented to prevent the spread of Japanese Knotweed. Impacts on riparian vegetation will be minimised. Any replacement planting will focus on native species. A preconstruction for survey for otter and kingfisher is recommended prior to the commencement of works.

Option Description	Potential Impacts	Suggested Mitigation Measures
	The development of high concrete walls will result in the loss of riparian vegetation. Loss of riparian vegetation can impact on feeding, roosting habitat and commuting routes for bats. Riparian vegetation can also provide feeding and nesting habitat for birds.	
Option 2: Conveyance improvements only	Widening works has the potential to spread Japanese Knotweed downstream and theoretically this species could become established within Natura 2000 sites downstream of the proposed works. Loss of riparian vegetation may impact on feeding and nesting habitat for birds. Loss of riparian habitat can impact on feeding, roosting habitat and commuting routes for bats. Impacts on fish populations can reduce prey availability for otter and piscivorous birds such as heron.	Detailed control measures will be implemented to prevent the spread of Japanese Knotweed. Impacts on riparian vegetation will be minimised. Any replacement planting will focus on native species. A preconstruction for survey for otter and kingfisher is recommended prior to the commencement of works.
Option 3: Combination of direct defences and conveyance improvements	The development of high concrete walls will result in the minor loss of riparian vegetation. Riparian vegetation can provide feeding and nesting habitat for birds. Loss of riparian vegetation can impact on feeding, roosting habitat and commuting routes for bats. Widening and in-stream works have the potential to spread Japanese knotweed downstream and theoretically this species could become established within Natura 2000 sites downstream of the proposed works. Loss of riparian vegetation may impact on feeding and nesting habitat for birds. Loss of riparian habitat can impact on feeding, roosting habitat and commuting routes for bats. Impacts on fish populations can reduce prey availability for otter and piscivorous birds such as heron.	Detailed control measures will be implemented to prevent the spread of Japanese Knotweed. Impacts on riparian vegetation will be minimised. Any replacement planting will focus on native species. A preconstruction for survey for otter and kingfisher is recommended prior to the commencement of works.

Option Description	Potential Impacts	Suggested Mitigation Measures

7.4.2.2 Area 2: St Patrick's Mills (tidal risk)

Table 2.2.2.2: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Direct defences only	The development of high concrete walls will result in the very minor loss of riparian vegetation. This is unlikely to have a significant ecological impact.	Impacts on riparian vegetation will be minimised and any replacement planting should focus on using native species. A preconstruction for survey for otter and kingfisher is recommended prior to the commencement of works.

7.4.2.3 Area 3: Donnybrook Commercial Centre -

Table 2.2.2.3: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Culvert upgrade	Loss of riparian vegetation upstream of culvert may impact on feeding and nesting habitat for birds. Loss of riparian habitat can impact on feeding, roosting habitat and commuting routes for bats. In-stream works have the potential to spread Japanese knotweed downstream	Impacts on riparian vegetation will be minimised. Specific bat mitigation measures will be carried out during vegetation removal Detailed control measures will be implemented to prevent the spread of Japanese Knotweed.

7.5 Archaeology, Architectural and Cultural Heritage

Impacts on sites of archaeological, architectural and cultural heritage interest will need to be considered, in the course of this project. The assessments for archaeology, architectural and cultural heritage were made against the following objectives:

- Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.
- Avoid damage to or loss of features of architectural value and their setting, and improve their protection from extreme floods where this is beneficial.
- Avoid damage to or loss of features of archaeological value and their setting, and improve their protection from extreme floods where this is beneficial.

The potential archaeology, architectural and cultural heritage impacts arising from the flood defence options, as well as proposed mitigation measures, are described for each of the areas in the tables below.

Sections of the Douglas River and Ballybrack Stream are, as rivers, considered to be Areas of Archaeological Potential. It is likely that the rivers have been impacted in localised areas in the past when they were used as a power source for various mills and industrial activities. It is recommended that further proposed works to the rivers should be archaeologically assessed in advance of works taking place.

7.5.1.1 Area 1: Ballybrack Stream through Douglas Village

Table 2.3.1.1: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Direct defences only	Area of Archaeological Potential (AAP) of Ballybrack Stream will be affected by the construction of concrete flood defence walls and concrete bridge parapet walls and local regrading works in the park, although these are small in scale.	Where works adjacent to the river may impact the bed or banks of the river a licensed archaeological wading survey and where necessary a full dive survey may be required. Licensed archaeological monitoring of the ground disturbance associated with the proposed works (including the regrading works) may be appropriate. Any features revealed should be fully resolved to professional standards following consultation with the relevant authorities.
Option 2: Conveyance improvements only	AAP of Ballybrack Stream will be affected by the widening and deepening of the river bed and banks and culvert replacement. The setting of the river will be impacted by the local regrading works in the park, new access footpaths, cycleway/footway, bridge removal and replacement.	Licensed archaeological wading survey and where necessary a full dive survey may be required. In the case of proposed dredging of the river, archaeological monitoring of all or a portion of the dredging process may be appropriate.

Option Description	Potential Impacts	Suggested Mitigation Measures
		Licensed archaeological monitoring of the ground disturbance associated with the proposed works may be appropriate. Any features revealed should be fully resolved to professional standards following consultation with the relevant authorities.
Option 3: Combination of direct defences and conveyance improvements	AAP of Ballybrack Stream will be affected by the widening and deepening of the river bed and banks and culvert replacement. The setting of the river will be impacted by the construction of concrete flood defence walls, local regrading works in the park, new access footpaths, cycleway/footway, bridge removal and replacement.	Licensed archaeological wading survey and where necessary a full dive survey may be required. In the case of proposed dredging of the river, archaeological monitoring of all or portions of the dredging process may be appropriate. Licensed archaeological monitoring of the ground disturbance associated with the proposed works may be appropriate. Any features revealed should be fully resolved to professional standards following consultation with the relevant authorities.

7.5.1.2 Area 2: St. Patrick's Mills (tidal risk)

Table 2.3.1.2: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Direct defences only	Curtilage of the protected structures and recorded monument will be changed by the construction of the concrete flood defence wall (RPS 00482 and RPS 01243 Douglas Woollen Mills and St Patricks Woollen Mills Industrial Estate and CO074-095 Graigue Woollen Mills). The construction of the concrete flood defence wall adjacent to the Tramore River (AAP) will impact the bed and bank(s) of the river.	Where works adjacent to the river may impact the bed or banks of the river a licensed archaeological wading survey and where necessary a full dive survey may be required. Licensed archaeological monitoring of the ground disturbance associated with the proposed works may be appropriate. Any features revealed should be fully resolved to professional standards following consultation with the relevant authorities.

7.5.1.3 Area 3: Donnybrook Commercial Centre

Table 2.3.1.3: Potential Impacts and Suggested Mitigation Measures

Option Description	Potential Impacts	Suggested Mitigation Measures
Option 1: Culvert upgrade	The construction of the culvert will involve extensive ground disturbance within an area which has been previously disturbed. It is unlikely that in situ archaeological deposits survive in the area, however, any such deposits will be negatively impacted by the works. The elimination of future flooding events from impacting the buildings will have a significant positive impact on them. Construction works will be carried out in proximity to millhouses associated with the milling complex at Donnybrook Commercial Park (RPS 00566).	Intermittent archaeological monitoring/inspections of subsurface disturbance will be carried out. All construction works will be securely fenced off and separated by a buffer zone from the Protected Structures. Intermittent archaeological monitoring and inspection of the buildings will be undertaken.

7.6 Soils, Geology and Hydrogeology

Aquifers in the Study Area are classified on GSI online mapping (Groundwater Public viewer) as '*Li – Locally Important Aquifer – Bedrock which is Moderately Productive only in Local Zones*' and '*RKd – regionally Important Aquifer – Karstified (diffuse)*'. GSI online data indicates that the aquifer vulnerability in the vicinity of the Douglas River comprises 'X- Rock at or near Surface or Karst', 'E - Extreme' '*High*' and '*M- Moderate*'.

The predominant impacts on soils, geology and hydrogeology will likely be the same for each of the options. They relate primarily to physical excavation works which will disturb the soil. Where the channel needs to be widened or deepened to build the direct defence walls or to carry out conveyance, this will have an impact on the ground. Any regrading or in-channel works will also impact on soils and may cause instability.

A relevant construction environmental management plan (CEMP) will be drawn up in order to correctly manage the soils and ground. The CEMP will make provision for the safe and proper reuse or disposal of any soils requiring removal from site as a result of excavation.

7.7 Human Beings

Socio-economic constraints relate primarily to impacts on human beings and quality of life. In designing the proposed scheme, the value (both cultural and economic) of any buildings close to watercourses, or likely to be adversely affected by the scheme should be taken into account. This includes public amenity areas, housing, schools, commercial properties and also tourism. Construction-related impacts such as disruption to traffic, access/egress to schools, crèches, homes and businesses is possible. Mechanical works alongside the river are likely to impact temporarily on the parks, cycle tracks and riverside walks adjacent to the Ballybrack stream.

Possible mitigation includes the preparation and implementation of a traffic management plan, including assessment of car parking allowance and measurements of disruption to traffic in particular across bridges. A project specific Health & Safety Plan should also be prepared and implemented.

7.8 Cumulative Impacts

Cumulative impacts are those resulting from a combination of two or more of the flood alleviation measures. Many of the cumulative impacts of a flood relief scheme are positive. However, these are not covered in the context of the environmental constraints. The following is a list of the constraining cumulative impacts likely to arise as a result of the proposed scheme:

- Disruption to local road users and utilities as a result of the construction works. The duration of this is therefore short-term.

- The works may generate suspended solids and possibly hydrocarbon pollution depending on the design and management of the construction works. This can have negative short-term impacts on aquatic flora and fauna. Salmonids are particularly vulnerable to any cement solids or hydrocarbon residues that may be introduced into the waterways.
- Mechanical works alongside the river bank can have adverse, long-term impacts on in-channel flora and fauna. Works along the river can have impacts downstream, e.g. fluvial transport of remnants of Japanese Knotweed that may introduce the plant to areas where it was not present previously.

7.9 Conclusions and Recommendations

The provisional analysis of the environmental impacts has highlighted that the impacts can be classified on the basis of severity and duration. Many of the potential negative impacts are likely to be short-term and not significant. The construction of flood defence walls is not expected to cause significant disruption to any of the categories of constraint analysed. The scheme will take into account the key environmental constraints in order to reduce these negative impacts by design.

8 Climate Change Adaptability

In considering the merits of the potential options, it is important that the short term proposals are considered in the context of a longer term strategy which is flexible and adaptive to changes in the climate and its potential impact on flood risk.

The measures considered are as follows:

- Ballybrack Stream through Douglas:
    - Option 1 – Direct Defences;
    - Option 2 – Conveyance Improvements;
    - Option 3 – Direct Defences and Conveyance Improvements;
- St. Patrick's Mills:
    - Option 1 – Direct Defences;
- Donnybrook Commercial Centre:
    - Option 1 – Culvert upgrade;

The adaptability of the above measures are discussed below.

8.1 Ballybrack Stream through Douglas

8.1.1 Option 1 - Direct Defences

Normally, in OPW flood defence schemes, defence walls are designed so that they can be extended in the future to take account of the potential effects of climate change.

For Option 1 in Douglas, it is not envisaged that the defence heights through Ravensdale could be reasonably extended in the future to account for climate change.

As discussed in Chapter 5 of the report, Option 1 (Direct Defences only) involves the construction of very high walls (3.6m) through Ravensdale for the current scenario. It therefore may not be feasible from an environmental or landscaping aspect to further increase the heights of these walls as part of a climate change adaptation strategy, if in fact such wall heights would be acceptable to begin with.

Climate change can be accounted for in this option by undertaking conveyance improvements on the Ballybrack Stream:

- The bed of the channel can be deepened to increase the capacity of the channel and allow a greater flow be conveyed through the reach;
- The channel can also be widened to increase its capacity. It will however only be feasible to implement such widening if the line of the direct defences is set back from the banks of the channel.

The existing properties and roads in Lower Ravensdale will limit the distance by which the flood walls can set back from the channel through this critical reach. There is greater scope to set the walls back from the channel in the green area adjacent to Church Road given the absence of properties.

8.1.2 Option 2 – Conveyance Improvements

Option 2 can be made adaptable to climate change by undertaking two separate measures:

- Undertaking further conveyance improvements on the channel;
- Constructing direct defences at either side of the channel.

The extent of future conveyance improvements for Option 2 are constrained by environmental considerations and existing properties and roads:

- The option presently involves channel deepening of 300mm through Lower Ravensdale. Further deepening (i.e. > 300mm deeper than present levels) may have negative implications for fish and the aquatic environment through the reach;
- Option 2 maximises channel widening in Lower Ravensdale. Further widening through this reach is therefore highly problematic as it would involve demolition of the ICA hall and/or land take from the access road to Lower Ravensdale. Channel widening through the green area adjacent to Church Road is however feasible.

The construction of direct defences through Ravensdale can be utilised as a climate change adaption strategy for this option. It is noted however that such a measure would involve significant works in the channel.

8.1.3 Option 3 – Direct Defences and Conveyance Improvements

Option 3 (combination of direct defences and conveyance improvements) involves the construction of walls of height 1.2m through Ravensdale for the current scenario. It may be feasible for the heights of these walls to be further increased as part of a climate change adaption strategy in the future without involving a significant impact on environmental and landscape features. This measure would increases the capacity of the channel and allow it convey a greater flow through the reach.

It is noted however the walls for this option are being constructed to guarding height which is higher than the required level. It is noted therefore that the no increase in height may be required for certain lengths of the channel to address climate change.

Conveyance improvements could also be implemented as part of the climate change adaption strategy for this option. The channel could be deepened in the future without involving a significant impact on the environment. To allow the channel be widened in the future however the direct defences which form part of this option would need to be set back from the channel to allow future widening.

8.2 St. Patrick's Mills

8.2.1 Option 1 - Direct Defences

It is feasible for the walls at St. Patrick's Mills to be increased in height in the future as part of a climate change adaptation strategy. New direct defences could also be constructed on the left bank to prevent out of bank flow.

It is noted however that the proposed defences are being constructed to guarding height which is higher than the required level. It may therefore not be required to increase the height of the wall for certain lengths of the channel to address climate change.

Conveyance improvements are not feasible for this location as the primary risk of flooding is tidal.

8.3 Donnybrook Commercial Centre

The proposed culvert upgrade for Donnybrook Commercial Centre has been designed to meet with OPW Section 50 requirements. It is therefore already climate change ready as it is designed to accommodate the 1 in 100 year fluvial flood plus an allowance for climate change and freeboard.

8.4 Upstream Storage

Provision of two separate storage areas upstream of Ballybrack (Ballybrack Woods and Ardfield Estate) were considered as part of the initial screening phase of the project and are detailed in Section 3 of the report. Both of these storage areas could be considered as part of a future climate change adaptability strategy.

Figure 30 presents the Q100 MRFS hydrograph for the Ballybrack stream. It has been assumed that this future scenario is equivalent to a 20% increase in the current scenario flow. It is noted that the hydrograph shape for the current scenario has been utilised as the shape for the MRFS.

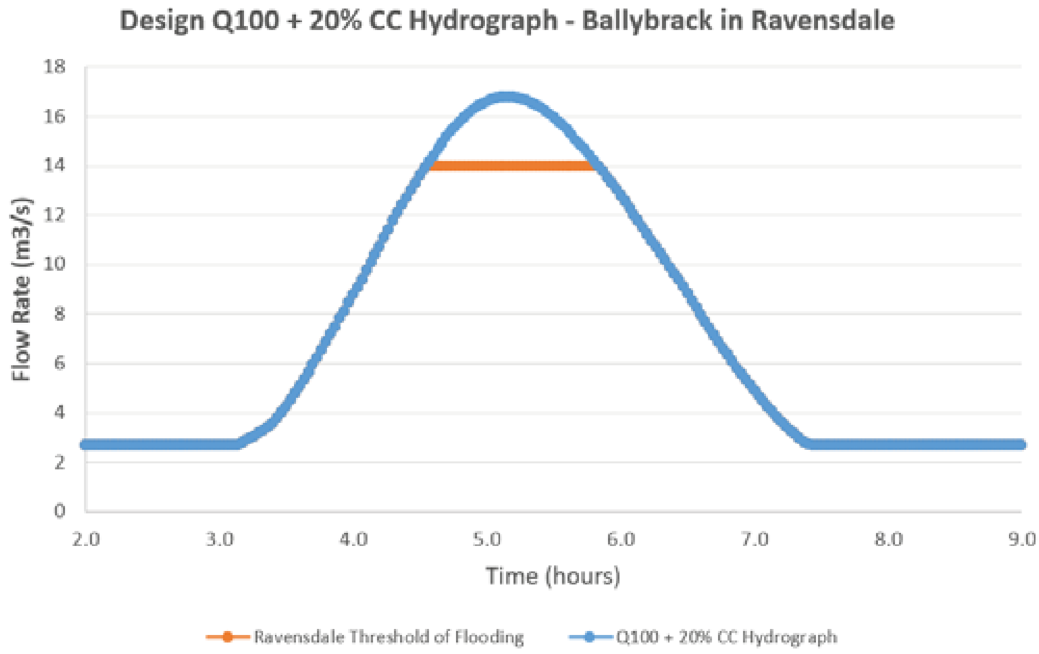
The total volume of the Q100 MRFS hydrograph is approximately 212,000m^3.

The volume of the Q100 MRFS hydrograph below an assumed threshold of flooding of 14m/s is approximately 203,000m^3. This threshold corresponds to the design flood of the scheme for the current scenario.

The difference between these volumes is approximately 9,000m^3 which equates to the minimum total volume that would need to be stored to make upstream storage a viable climate change adaption option from a technical perspective.

The viability of achieving this storage volume in Ballybrack Woods is discussed below.

Figure 30: Q100 Design Hydrograph and the threshold of flooding



8.4.1 Ballybrack Woods Storage Area

Achieving sufficient storage in a singular storage area at Ballybrack Woods would require the construction of a circa 50m length of embankment (including a control structure) at the northern end of the Park. The embankment would need to be up to 4.0m in height to achieve a storage volume of circa 9,000m3 and freeboard of 0.5m. This allows for a storage level of 15.2mOD which would also require localised defences up to 0.3m in height around the duplex apartments at Ardarrig Park.

This option can be considered as part of any future climate change adaption strategy.

8.5 Climate Change Adaptation Strategy

The various Climate Change Adaptation Strategies for the three areas considered as part of the scheme are summarised in the following tables.

Table 14: Ballybrack through Douglas

Option Considered	**CC Strategy**
Option 1 – Direct Defences	- Conveyance Improvements - Upstream storage
Option 2 – Conveyance Improvements	- Direct Defences - Further conveyance improvements

Option Considered	CC Strategy
	- Upstream storage
Option 3 - Direct Defences and Conveyance Improvements	- Increase the height of direct defences - Further conveyance improvements - Upstream storage

Table 15: St. Patrick's Mills

Option Considered	CC Strategy
Option 1 – Direct Defences	- Increase the height of direct defences - Upstream storage

Table 16: Donnybrook commercial centre

Option Considered	CC Strategy
Option 1 – Culvert upgrade	- This element of the scheme is already adaptable to climate change

9 Multi-criteria Assessment of the Shortlisted Options

9.1 Introduction

The effectiveness of each of the viable options can be measured in terms of how it achieves a set of flood risk management objectives. This section describes the detailed multi-criteria analysis (MCA) of the shortlisted options which was carried out to evaluate the performance of each option in terms of predefined objectives. As part of this process, each objective was given a global and local weighting. Each option was then scored relative to the present day situation (baseline condition), based on how well they met the objectives. The output from this stage was a total weighted score for each option. The option with the highest score is deemed to most desirable.

The analysis has been carried out in accordance with the OPW guidance document "National CFRAM Programme Guidance Note 28 – Options Appraisal and the Multi-Criteria Analysis Framework". This guidance document sets out a common approach to the undertaking of options appraisal and multi-criteria analysis.

The local weightings and scorings for each of the criteria were determined as part of a workshop help with Cork County Council and OPW.

9.2 Flood Risk Management Objectives and Weightings

The flood risk management objectives were categorised as follows:

- Technical
- Economic
- Social
- Environmental

The categories were sub-divided into objectives (Table 17). Each objective was weighted to reflect their importance and/or sensitivity, and to ensure that the objectives most relevant to the location under consideration were given priority in the decision-making process.

Two types of weighting were used:

- Global weighting (ranging between 5 and 30) which applied a weighting to each objective. There weightings are fixed by the OPW at a national level. The global weightings are presented in Table 17.

Local weighting (ranging between 0 and 5) are specific to the importance of each objective in Douglas. The local weightings are presented in Table 18.

Table 17: Flood Risk Management objectives and global weightings

Category	Objective	Global Weighting
Technical	Operationally Robust	20
Technical	Health & Safety Risk	20
Technical	Adaptability	20
Economic	Economic Return	30
Economic	Transport	10
Economic	Utility Infrastructure	10
Economic	Agriculture	10
Social	Risk to Human Health	40
Social	Community Risk	15
Social	Risk to Social Amenity	5
Environmental	Water Framework Objectives	15
Environmental	Habitats & Birds Directive	15
Environmental	Enhance Flora & Fauna	5
Environmental	Protect Fisheries	5
Environmental	Protect Landscape Character	10
Environmental	Avoid damage to Cultural Heritage	10

Table 18: Local weightings

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

9.3 Scoring

Each option was then scored relative to the present day situation (baseline condition), based on how well they met the objectives. The scores used ranged between -999 and 5 as shown in Table 19.

Table 19: Scoring system

Impact	Score
Fully Achieving aspirational target	5
Partly achieving aspirational target	3
Exceeding basic requirement	1
Meeting minimum requirement	0
Just failing minimum basic requirement	-1
Partly failing minimum basic requirement	-3

Impact	Score
Fully failing minimum basic requirement	-999

A description of the minimum targets and aspirational targets for each objective are included in Appendix B.

9.4 MCA Assessment

A total weighted score was then calculated for each objective as the sum of the weighted scores across the 15 flood risk management objectives. This MCA score reflected the performance of the option in terms of the study objectives.

The weighted score was calculate as follows:

WS = (GW * LW) * S

Where:

- WS = Weighted Score
- GW = Global Weighting
- LW = Local Weighting
- S = Score

The total MCA score was the sum of the scores for each objective.

The detailed MCA assessment is included in Appendix B.

9.5 Summary – Douglas

Table 20 presents the results of the MCA analysis for the Ballybrack Stream through Douglas. It is noted that the economic benefit used in the analysis is for entire scheme.

The analysis suggests that the three options are closely ranked in terms of MCA benefit score. Option 3 has the highest Option Selection Benefit Score of 2365. Option 1 is marginally lower at 2315. Option 2 has the lowest at 2040.

Each of the three options have strong MCA benefit/cost ratios.

Table 20: MCA Results – Area 1 Ballybrack stream

	Option 1 – Direct Defences	Option 2 – Conveyance Improvements	Option 3 – Direct Defences and Conveyance Improvements
MCA Benefit Score	2315	2040	2365
Option Selection Benefit Score	2815	1940	2665
NPV Capital Costs (€m)	€6.6	€3.2	€4.4
MCA Benefit/Cost Ratio	0.35	0.64	0.54
NPV Economic Benefit for entire scheme (€m)	€35.17	€35.17	€35.17
Economic Benefit/Cost Ratio for entire scheme	**4.37**	**9.04**	**6.5**

Full details of the individual scores for each criteria for each option, together with the rationale for same, is included in Appendix B.

It is noted that an MCA for St. Patrick's Mills and Donnybrook Commercial Centre is not presented as only a single option was deemed viable for both areas.

10 Selection of the Preferred Option

10.1 Introduction

The extent and severity of the flood risk in the study area was first established through a hydrology study and hydraulic modelling. A range of potential flood risk management measures were reviewed as part of an initial screening exercise.

A number of potentially viable flood risk management options were then developed to outline design level, including hydraulic modelling, outline design and cost estimates.

The benefits of defending to the design standard of 1 in 100years was then established to inform a detailed cost benefit analysis.

Public Consultation was carried out throughout the project and is considered to be and have been an important part in the evolution of the proposed scheme and the ultimate decision on a preferred option. This consultation consisted of 3 public consultation days as well as statutory consultation with all relevant stakeholders.

The feedback from this consultation process has been carefully considered and taken on board in finalising the scheme.

The options were also holistically reviewed by the project team as they were developed, and relevant issues were discussed with the Steering Group.

A final decision on the preferred option was made based on a holistic evaluation of the following key aspects:

- Findings of Cost Benefit Analysis
- Findings of Multi-Criteria Analysis
- Consideration of the key core messages which arose during the stakeholder consultation process
- Consideration of Key Risks
- Consideration of Climate Change Adaptability
- Combined professional judgement of the steering group members

The following sections summarise the critical issues with each potential option, along with reasons for ruling the options out where relevant.

10.2 Area 1 – Ballybrack Stream through Douglas

10.2.1 'Do-Minimum'.

This option was ruled out as the flood risk in the catchment would remain at similar levels to the existing case.

10.2.2 Option 1 – Direct Defences

This option had the lowest cost benefit ratio of the three options considered and the second highest MCA score.

There are also a number of concerns related to this option as follows:

- This option involves the construction of very high reinforced concrete walls (>3.5m) through Lower Ravendale. Walls of this height would have an extremely negative impact on the visual landscaping through this area of Douglas. Given the proximity of the river channel to the residential properties, the high walls would also have very negative social impacts.
- The adaptability of this option to climate change depends on undertaking conveyance improvements requiring significant deepening of the channel which would likely have negative environmental impacts.

Accordingly, this option was not adopted.

10.2.3 Option 2 – Conveyance Improvements

This option had the highest cost benefit ratio of the three options considered but the lowest MCA score.

There are a number of concerns with this option:

- While the option does protect to the required standard of protection, adequate freeboard is not achieved by the option in all areas. This means that further work would be needed and would therefore have eroded at least some of the cost differential between it and the next most economical option.
- Of the three options considered, this option involves the most significant impact on the channel and thus has greatest environmental option.
- This option would also have required the most extensive land take.

This option was therefore not adopted.

10.2.4 Option 3 – Direct Defences and Conveyance Improvements

This option has been selected as the preferred option for the scheme. The justification for doing so are:

- Highest MCA Benefit score;
- Visually attractive from a visual landscape perspective;
- Will not give rise to a significant negative social impact;
- Strikes the best balance in terms of visual, ecology, land take, adaptability and robustness.
- Achieves the objectives of the project and allows for adequate freeboard and climate change adaptability in the scheme.

10.3 Area 2 – St. Patrick's Mills

10.3.1 'Do-Minimum'.

This option was ruled out as the flood risk at St. Patrick's Mills would remain at similar levels to the existing case.

10.3.2 Direct Defences

Only one viable option was considered for St. Patrick's Mills. It was therefore adapted as the preferred solution.

10.4 Area 3 – Donnybrook Commercial Centre

10.4.1 'Do-Minimum'.

This option was ruled out as the flood risk at Donnybrook Commercial Centre would remain at similar levels to the existing case.

10.4.2 Option 1 – Culvert upgrade and removal of trash screens

Only one viable option was considered for Donnybrook Commercial Centre as alternative options were ruled out at the screening stage. It was therefore adapted as the preferred solution.

10.5 Conclusion

Each of the options were subject to detailed assessment as they were developed.

It was found that the standard decision support tools for options assessment (CBA and MCA) resulted in reasonably small differences between the options: all the cost benefit ratios were strong and there was little difference between some of the MCA scores.

These tools can therefore only be used as indicators on which to inform the use of professional judgement i.e. it is a decision support tool, not a decision making tool.

Therefore a decision on the preferred option was ultimately made by careful and holistic professional consideration of all the various issues, resulting in the following options being chosen for the three areas considered:

- **Ballybrack Stream through Douglas:** Combination of Direct defences and conveyance improvements;
- **St. Patrick's Mills:** Direct Defences
- **Donnybrook Commercial Centre:** Culvert upgrade and trash screen removal

11 Detailed Freeboard Analysis and Scheme Refinement

11.1 Introduction

Once the preferred option was chosen, a detailed freeboard analysis of this option was undertaken to establish its sensitivity to uncertainty in hydrological estimation, hydraulic modelling etc. and to incorporate an appropriate freeboard to ensure that the proposed solution is suitably resilient. It is noted that the outline design of the scheme in Section 5 of the report assumed a freeboard value of 0.5m.

Two separate methodologies were utilised in the study to estimate the freeboard of the scheme and both are outlined in this section of the report:

- Environment Agency's Fluvial Freeboard Guidance Note (UK Environment Agency Report W187);
- CFRAM Guidance Note 22 issued by the OPW;

For the purpose of the freeboard analysis, the area of the study has been sub-divided into four distinct areas as presented in Figure 31:

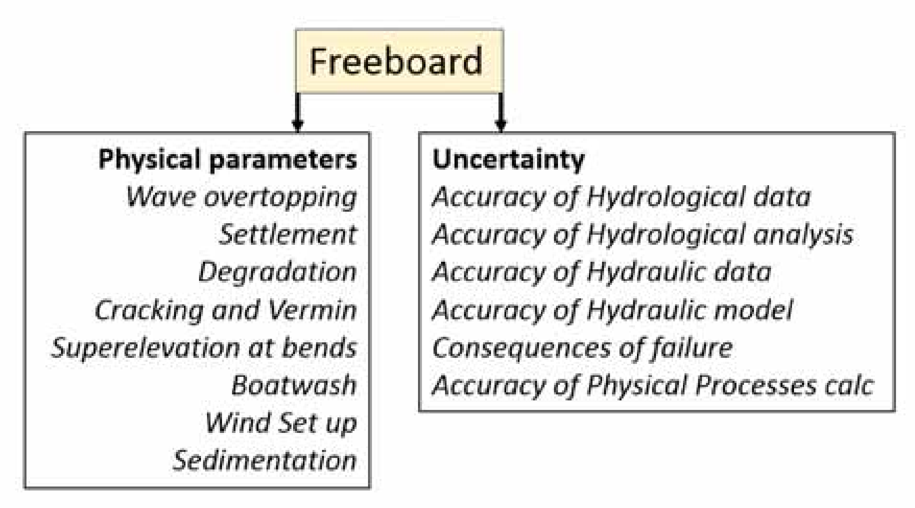
- Ballybrack Stream through Douglas Village;
- St. Patrick's Mills;
- Donnybrook commercial centre;
- All of the area outside of these three areas but within the overall study area. The purpose of including this area is twofold: to determine if works might be required in the area to defend for freeboard, and to consider climate change adaptability.

Figure 31: Study area sub-divided for freeboard purposes

11.2 Environment Agency Guidance

The analysis of freeboard was carried out in accordance with the Fluvial Freeboard Guidance Note (UK Environment Agency Report W187). The guidance is based on a qualitative approach which calculates an allowance for physical parameters and an allowance for uncertainty. The estimate of freeboard is calculated as the sum of these two allowances. A list of the relevant parameters is presented in Figure 32.

Figure 32: Schematic of Freeboard calculation.



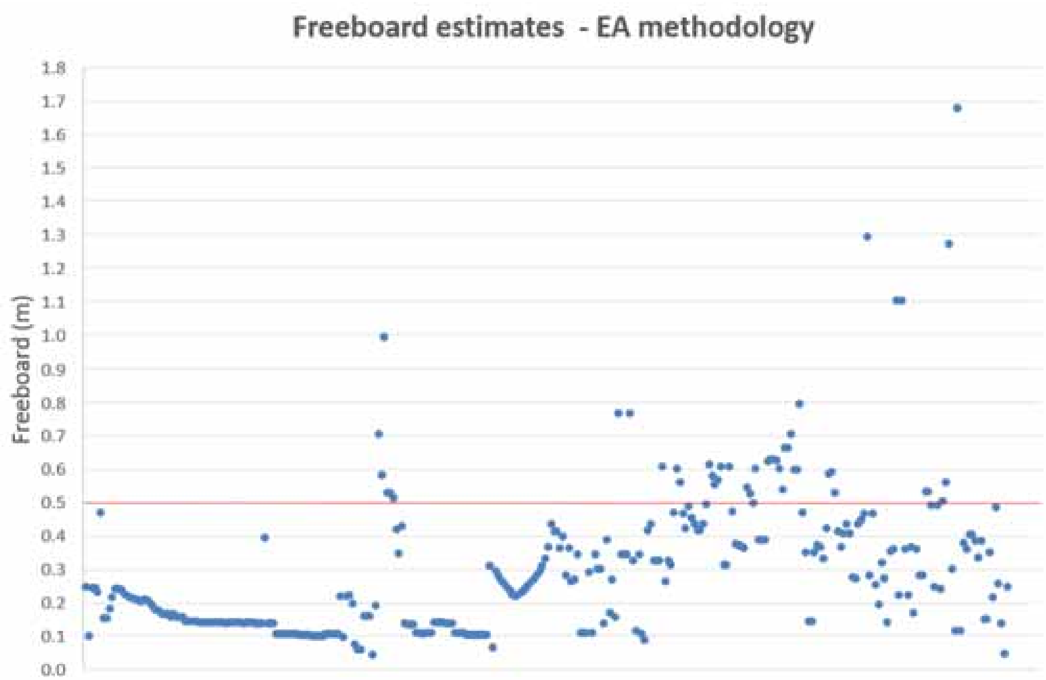
The freeboard was calculated for every cross section in the Douglas FRS model using water levels and velocities calculated by the model. A number of assumptions have been used in the analysis:

- Hard defences required on both banks;
- R.C. walls as the proposed defences;
- Wave allowance has been ignored due to the relatively narrow dimensions of the watercourse;
- Allowances for degradation, cracking, vermin, boatwash, wind set up and sedimentation have also been ignored;
- An average watercourse width of 3m has been assumed;
- The bend radius of the water courses has been determined from mapping and ranges from 5 to 10m;
- Settlement allowance has been assumed at 0.1m;
- Consequence of failure has been assumed to be worst case with a score of 5.

In general, the freeboard ranges from 0.04m to 1.68m. The average value is approximately 0.3m. The freeboard estimate at forty-four of the cross sections in the model was greater than the indicative value of 0.5m used in the Section 5 of the report.

A plot of the estimated values of freeboard are presented in Figure 33. It is noted the values are plotted against an arbitrary x axis which does not represent chainage.

Figure 33: Freeboard estimates



It can be seen from the figure that values greater than 0.8m were estimated at six cross sections each of which corresponds to a culvert conduit unit in the model. The high estimate of freeboard can therefore be attributed to a high estimate of the 'super elevation at bends' calculation[1] which utilises the equation presented in Figure 34 . It can be seen that the equation is a power function and is therefore sensitive to the cross sectional velocity. The high velocity calculated by the model within culvert conduit units therefore results in high estimates of superelevation which in turn results in high values of freeboard at those locations.

These high estimates of freeboard may not represent the likely increase in water level due to superelevation. Culvert conduit units have therefore been discounted from the analysis. It is noted however that cross sections upstream and downstream of the culverts (i.e. open channel sections in the model) have not been discounted and have been included in the analysis.

[1] As flow moves around a bend there is a rise in the water surface at the outer bank and a corresponding lowering of the water surface at the inner bank owing to centrifugal forces. This phenomenon is known as superelevation.

Figure 34: Superelevation calculation

$$\Delta h = \frac{\bar{u}^2 b}{gR}$$

where $\bar{u}$ = average velocity (m/s)
Δh = change in water surface elevation across channel width, between banks (m)
b = channel width (m)
R = distance from centre of curve to centreline of channel (m)

When culvert conduit units cross sections are discounted from the analysis the range in freeboard values is reduced to a range from 0.04m to 0.8m.

Each of the four areas considered as part of the Freeboard analysis (Figure 31) are now considered. The high estimates of freeboard calculated at cross sections of culvert conduit units have been discounted from the results.

- **Ballybrack stream through Douglas Village**

The freeboard ranges from 0.14m to 0.8m throughout the reach of the proposed works on the Ballybrack Stream through Douglas Village. The average value is 0.46m.

- **St. Patrick's Mills**

The freeboard ranges from 0.15m to 0.16m throughout the reach of the proposed works at St. Patrick's Mills. The average value is approximately 0.153m.

- **Donnybrook Commercial Centre**

The freeboard ranges from 0.11m to 0.56m throughout the reach of the proposed works at St. Patrick's Mills. The average value is approximately 0.35m.

- **Areas outside of the proposed works**

The freeboard ranges from 0.04m to 0.76m in the area outside of the proposed works. The average value is approximately 0.20m.

11.3 CFRAM Guidance Note 22

11.3.1 Introduction

CFRAM Guidance Note 22 was developed under the Western CFRAM Contract for the Office of Public Works (2014) and adopts a sensitivity analysis to determine the amount of uncertainty in the model results and provide an estimate of freeboard.

The key steps in the analysis are as follows:

- Undertake a screening assessment from knowledge of the model build and its calibration;
- Undertake sensitivity tests on hydrological parameters;

- Undertake sensitivity tests on core hydraulic modelling parameters;
- Undertake additional hydraulic testing where necessary;
- Assess which test or combination is to be used in the estimation of freeboard allowances.

11.3.2 Preliminary Screening Assessment

The primary flood risk area in Douglas is upstream of the tidally influenced areas. As a consequence, increasing the tidal boundary to the mid-range future scenario would have negligible input on the flood risk and was therefore discounted from the analysis.

Design water levels in the key flood risk areas are sensitive to the hydrological boundaries and core hydraulic parameters and are therefore assessed as part of the sensitivity testing.

11.3.3 Hydrological Analysis Undertaken as part of the study

A detailed hydrological analysis of the Tramore catchment was undertaken as part of the study which utilised a number of methods to establish a range of possible Qmed values at the various HEP points. It was considered important to use a range of methods as the catchments in the study area are small, predominantly ungauged and relatively steep. The methods used to estimate the Qmed were:

- Direct analysis of gauge data;
- Flood Studies Update method;
- Flood Studies Report Statistical Method;
- Flood Studies Report Rainfall-Runoff Method;
- Institute of Hydrology Report No. 124 Method;
- Modified Rational Method.

It was felt appropriate to adopt the FSU index flows as the design Qmed flows as they were conservative while still remaining consistent with the other methods.

A flood frequency analysis was also undertaken as part of the work. This established a study growth curve and in turn a set of design flows. The adopted growth curve was produced using the FSU pooling group methodology.

The reader is referred to the accompanying Hydrology report for a detailed description of the work.

11.3.4 Sensitivity Testing of Hydrological Boundary Conditions

As flow is typically the most critical of all the sensitivity tests it is important to consider the quality of data available in the hydrological estimation and also the approach taken in the hydrological estimation.

The overall adjustment factor is based on a combination of uncertainty in:

- The index flood (Qmed);

- The growth curve.

The following section details these estimations.

11.3.4.1 Uncertainty in the Index Flood (Qmed);

The uncertainty in Qmed is set to 1.2 as recommended by the GN for a site with a donor catchment and is considered appropriate for this study as a higher values may be overly conservative.

11.3.4.2 Uncertainty in Growth Curve

Guidance Note 22 recommends that the uncertainty in the growth curve be tested through a two-step process:

- Consideration of the "Flow Sensitivity Scoring System" which is detailed in Table 2-2 of the note.
- Estimating the "Flow Sensitivity Adjustment Factor" which is detailed in Table 2-3 of the note.

Considering both of these elements results in an adjustment factor of 1.3. However, to avoid over-conservatism in the sensitivity analysis, an adjustment factor of 1.2 is recommended to account for the uncertainty in growth curve.

11.3.4.3 Adjustment Factor Selection

Considering both the uncertainties results in an overall adjustment factor of 1.44 (i.e. Qmed uncertainty of 1.2 * Growth Curve uncertainty of 1.2) which we have taken as 1.4.

The hydraulic model for the preferred option (Option 3) was re-run with the design flows increased by 40%. The results of the analysis for the critical reach of the Ballybrack through Douglas are presented in Figure 35.

It can be seen from the plot that the 40% increase in flow, results in elevated water levels throughout the Ballybrack Stream through Douglas. The average increase is 0.26m through the reach.

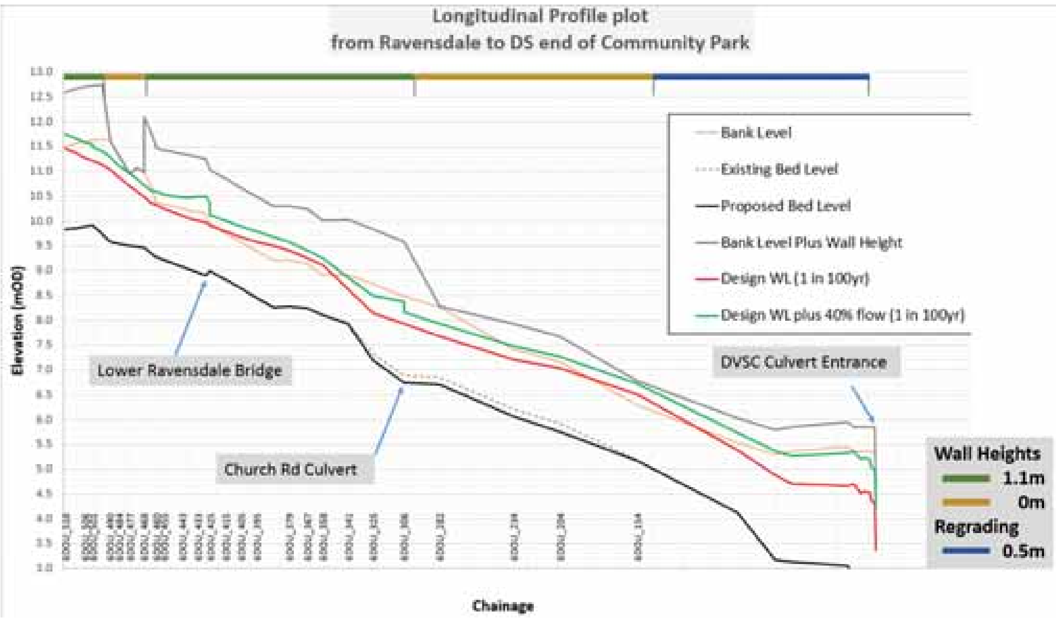
The results also indicate that there are three key throttle points in the reach:

- Upstream of Lower Ravensdale Bridge – the increase in WL is 0.53m;
- Upstream of Church Road Culvert – the increase in WL is 0.44m;
- Upstream of Church Street Culvert – the increase in WL is 0.67.

In each of the three locations however the elevated water level is below the top of the flood walls which form part of the scheme.

The results also indicate that the flow sensitivity results in water level exceeding the level of the bank in Ravensdale at the location for which no direct defences are proposed. The results also suggest that the increased flow results in peak water levels near to the top of the re-graded ground levels in the Community Park.

Figure 35: Longitudinal plot – Ballybrack Stream through Douglas



11.3.5 Sensitivity Testing of Increased Roughness

The hydraulic model was tested for a +15% increase in roughness. The results suggested that the model is relatively insensitive to hydraulic roughness as water levels are increased on average by circa 0.1m.

Through inspecting the results it was determined that the roughness sensitivity did not result in water levels greater than the water levels estimated from the hydrology sensitivity. As the guidance recommends the adoption of a worst case scenario the flow sensitivity water levels were adopted through the reach.

11.3.6 Sensitivity Testing of Structure Coefficient Sensitivity

The CFRAM guidance recommends to assess afflux at critical structures which are likely to be sensitive to changes in model coefficients. This however is unlikely to result in larger increases in water level than estimated from the flow sensitivity. It has therefore not been undertaken as the guidance recommends the adoption of a worst case scenario and is not likely to affect the freeboard allowance.

11.4 Comparison between the EA and CFRAM Methods

The results from the two separate methodologies for the four separate areas considered are compared in the following table.

Table 21: Comparison of methodologies. Values presented correspond to increases in water level as a result of the sensitivity analysis.

	EA Guidance Methodology	CFRAM GN 22
Ballybrack Stream		

	EA Guidance Methodology	CFRAM GN 22
Max	0.80	0.68
Min	0.14	0.14
Average	0.46	0.34
St. Patrick's Mills		
Max	0.16	0.34
Min	0.15	0.34
Average	0.15	0.34
Donnybrook CC		
Max	0.56	1.11
Min	0.17	0.26
Average	0.35	0.58
Areas Outside of proposed Works		
Max	0.76	0.41
Min	0.04	0
Average	0.20	0.21

11.5 Discussion

It can be seen from Table 21 that for both the Ballybrack Stream and the Areas outside of proposed works, the EA methodology predicts higher values of freeboard than the CFRAM GN.

For St. Patrick's Mills and Donnybrook Commercial centre however the reverse is true with the CFRAM GN predicting higher values than the EA methodology.

Based on the results of the freeboard analysis it is proposed to refine the scheme in Upper Ravensdale as detailed in 11.7.

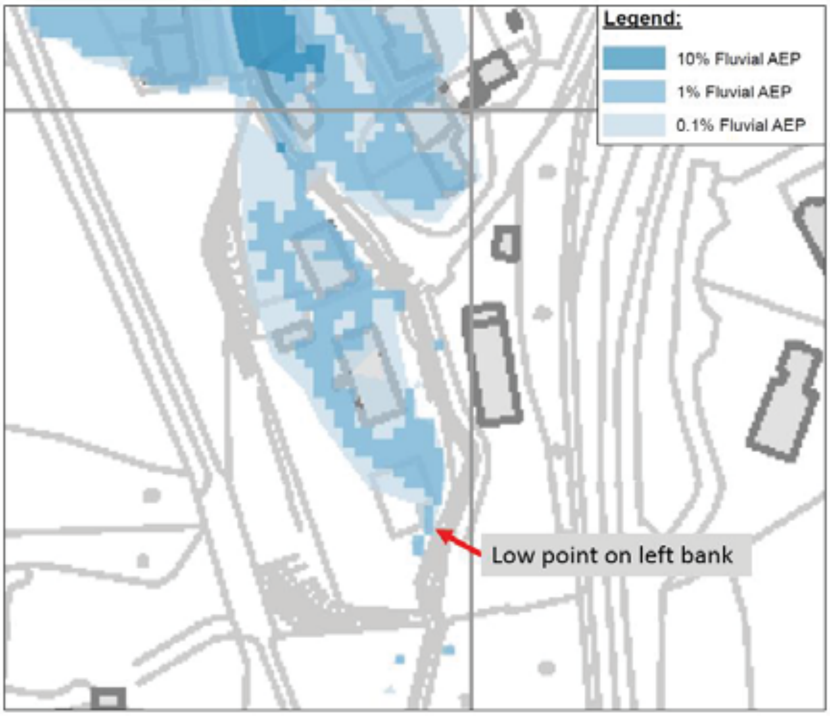
11.6 Detailed survey of Upper Ravensdale

In October 2016, Arup commissioned Amelio surveys to undertake a very detailed survey of the three areas considered as part of the scheme: along the Ballybrack Stream through Douglas, Donnybrook Commercial Centre and in St. Patrick's Mills. The survey was delivered in final format in November 2016.

The survey identified a local low point in the left bank in Upper Ravensdale in the vicinity of a residential property that was not previously considered as part of the study. The Douglas FRS hydraulic model was rerun with this low point included and it was found that the Q100 water levels exceeds the level of this low point and inundates the left hand floodplain. The modelled flood extent is presented in Figure 36.

The low point needs to be defended and is considered as part of the scheme refinement in Section 11.7.

Figure 36: Modelled flood extent in Upper Ravensdale with

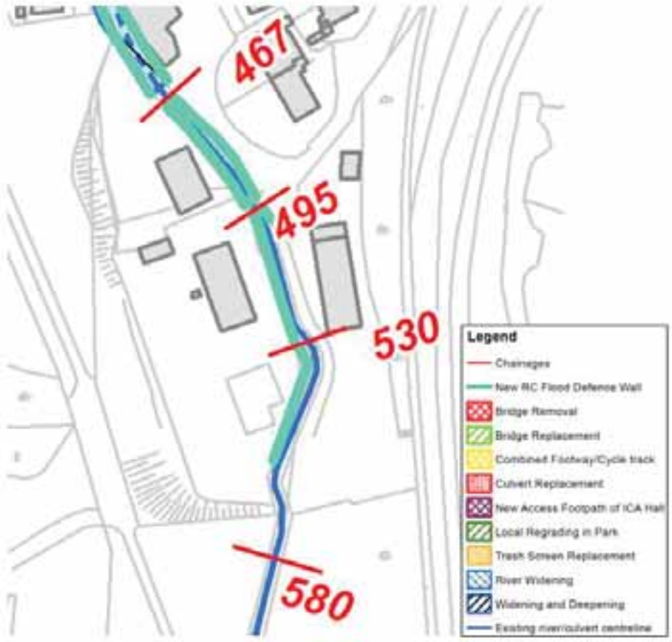


11.7 Scheme Refinement in Upper Ravensdale

The scheme was refined to account for both the freeboard analysis and the detailed survey of Upper Ravensdale which highlighted the low point on the left bank.

The refinement of the scheme is presented in Figure 37. It can be seen that additional lengths of wall in Upper Ravensdale are proposed.

Figure 37: Ravensdale refinement



12 Conclusion

The extent and severity of the flood risk in the study area was established and defined through a detailed hydrology study, hydraulic modelling, flood mapping etc.

Following a review of the potential viable measures, 3 potentially viable options that protect to the design standard of protection for the Scheme (1% AEP Fluvial/0.5% AEP Tidal) were developed for Douglas Village to outline design level and can be summarised as follows:

- Option 1 – Direct defences only;
- Option 2 – Conveyance improvements only;
- Option 3 – Combination of Direct Defences and Conveyance Improvements.

A final decision on the preferred option was made based on a holistic evaluation of the following key aspects:

- Findings of the Multi-Criteria Analysis;
- Findings of the Cost Benefit Analysis;
- Consideration of the key risks;
- Consideration of the key core messages which arose during the stakeholder consultation process;
- Consideration of Climate Change Adaptability;
- Combined professional judgement of the steering group members.

Following this evaluation, Option 3 was selected as the preferred option. The justification for doing so was:

- Highest MCA Benefit score;
- Visually attractive from a visual landscape perspective;
- Will not give rise to a significant negative social impact;
- Strikes the best balance in terms of visual, ecology, land take, adaptability and robustness.
- Achieves the objectives of the project and allows for adequate freeboard and climate change adaptability in the scheme.

Only one viable option was considered for St. Patrick's Mills and was therefore adapted as the preferred solution.

Only one viable option was considered for Donnybrook Commercial Centre as alternative options were ruled out at the screening stage. It was therefore adapted as the preferred solution.

Appendix A

Economic Assessment of Options

A1 Cost Estimates

A1.1 Option 1 – Direct Defences

Order of Magnitude of Costs			Job No:		234335-00
			Sheet No:		**1**
			Made By:		RH / DS
Project Title	**Douglas Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
	Option 1 - Direct Defences				
1	**Douglas Mills**				
1.1	New RC Wall along right bank of Tramore (extension to existing wall)	m	82	1,038.21	85,133.43
1.2	Scaffolding to the edge of bridge (2no weeks hire, signing Scafftags/GA3/handover certs, scaffolding design and TWC)	sum	1	5,000.00	5,000.00
1.3	New RC bridge parapet on Douglas West Bridge	m	12	239.13	2,869.50
1.4	Stone cladding to new RC walls (one face) - incl. in RC Wall rate	m	82		-
1.5	Local drainage measures	sum	1	10,000.00	10,000.00
1.6	Surface water pumping station	no	1	72,700.00	72,700.00
			Subtotal Douglas Mills		**175,702.93**
2	**Douglas Community Park**				
2.1	Local regrading of right bank	m	270	25.00	6,750.00
2.2	New RC wall along left bank of Ballybrack Stream	m	208	2,221.17	462,002.84
2.3	Surface water pumping stations	no	2	72,700.00	145,400.00
			Subtotal Douglas Park		**614,152.84**
3	**Ravensdale to Church Road**				
3.1	New RC Wall along both banks between Church Road to Ravensdale. Stone cladding both sides	m	522	2,221.17	1,159,449.44
3.2	New solid parapets to existing bridges	m	34	239.13	8,130.25
3.3	Surface water collector drains (225mm diameter)	m	522	85.00	44,370.00
3.4	Surface water pumping stations	no	2	72,700.00	145,400.00
3.5	Service Diversions	sum	1	50,000.00	50,000.00
	Subtotal Ravensdale to Church Road				**1,407,349.69**
4	**Ballybrack Woods**				
4.1	Removal of existing bridge	m2	33	100.00	3,255.00
4.2	Replacement of RC bridge	m2	33	2,800.00	91,140.00
4.3	Lighting, CCTV, telemetry	sum	1	50,000.00	50,000.00
4.4	Trash screen replacement	sum	1	50,000.00	50,000.00
			Subtotal Ballybrack Woods		**194,395.00**
5	**Donnybrook Commercial Centre**				
5.1	New 2.4m wide by 1.8m high culvert	m	92	2,780.50	255,806.00
5.2	Channel regrading	m	150	906.00	135,900.00
5.3	Service Diversions	sum	1	100,000.00	100,000.00
			Subtotal Donnybrook		**491,706.00**
				Total	**2,883,306.45**

A1.2 Option 2 – Conveyance Improvements

Order of Magnitude of Costs			Job No:		234335-00
			Sheet No:		**1**
			Made By:		RH / DS
Project Title	**Douglas Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
	Option 2 - Conveyance Improvements				
1	**Douglas Mills**				
1.1	New RC Wall along right bank of Tramore (extension to existing wall)	m	82	1,038.21	85,133.43
1.2	Scaffolding to the edge of bridge (2no weeks hire, signing Scafftags/GA3/handover certs, scaffolding design and TWC)	sum	1	5,000.00	5,000.00
1.3	New RC bridge parapet on Douglas West Bridge	m	12	239.13	2,869.50
1.4	Stone cladding to new RC walls (one face) - incl. in RC Wall rate	m	82		-
1.5	Local drainage measures	sum	1	10,000.00	10,000.00
1.6	Surface water pumping station	no	1	72,700.00	72,700.00
			Subtotal Douglas Mills		**175,702.93**
2	**Douglas Community Park**				
2.1	Ballybrack Channel Widening along southern half of park (incl excavation, buildup of new channel, landscaping)	m	133	326.25	43,391.15
2.2	Tree Removal circa 0-300mm diameter	no.	18	300.00	
2.3	Tree Removal circa 300-600mm diameter	no.	2	425.00	
2.4	Local regrading of right bank along northern half of park	m	155	25.00	3,875.00
			Subtotal Douglas Park		**47,266.15**
3	**Ravensdale to Church Road**				
3.1	Ballybrack Channel Widening and deepening (incl demolition of existing channel walls, excavation, buildup of new channel, landscaping)	m	149	595.40	88,714.59
3.2	Bridge Removal - ICA	m2	7	100.00	675.00
3.3	Bridge Removal - Cycle Track	m2	14	100.00	1,416.00
3.4	Removal of exisitng bridge - Lower Ravensdale	m2	45	100.00	4,500.00
3.5	Replacement of RC bridge - Lower Ravensdale	m2	45	2,800.00	126,000.00
3.6	New culvert - Church Road (excluding TM, services, drainage)	m	17	2,892.67	49,175.43
3.7	Underpinning of structures adjacent to widened channel	no	2	20,000.00	40,000.00
3.8	New two-way footway/cycle track from Church Road	m	58	133.55	7,746.13
3.9	New footpath from cycle track to ICA	m	22	73.97	1,627.26
3.10	Surface Water Drainage Diversion @ Church Road	sum	1	5,000.00	5,000.00
3.11	Foul Drainage Diversion @ Church Road	sum	1	10,000.00	10,000.00
3.12	Eircom Diversion @ Church Road	sum	1	10,000.00	10,000.00
3.13	UPC Diversion @ Church Road	sum	1	15,000.00	15,000.00
3.14	Electrical Diversions, incl relocating ESB kiosk	sum	1	50,000.00	50,000.00
3.15	Watermain Diversion @ Church Road	sum	1	10,000.00	10,000.00
3.16	Gasmain Diversion (4bar main and 75mbar main) @ Church Road	sum	1	50,000.00	50,000.00

Order of Magnitude of Costs			Job No:		234335-00
			Sheet No:		**1**
			Made By:		RH / DS
Project Title	**Douglas Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
	Subtotal Ravensdale to Church Road				**469,854.41**
4	**Ballybrack Woods**				
4.1	Removal of existing bridge	m2	33	100.00	3,255.00
4.2	Replacement of RC bridge	m2	33	2,800.00	91,140.00
4.3	Lighting, CCTV, telemetry	sum	1	50,000.00	50,000.00
4.4	Trash screen replacement	sum	1	50,000.00	50,000.00
		Subtotal Ballybrack Woods			**194,395.00**
5	**Donnybrook Commercial Centre**				
5.1	New 2.4m wide by 1.8m high culvert	m	92	2,780.50	255,806.00
5.2	Channel regrading	m	150	906.00	135,900.00
5.3	Service Diversions	sum	1	100,000.00	100,000.00
			Subtotal Donnybrook		**491,706.00**
				Total	**1,378,924.49**

A1.3 Option 3 – Direct Defences and Conveyance Improvements

Order of Magnitude of Costs			Job No:		234335-00
			Sheet No:		**1**
			Made By:		RH / DS
Project Title	**Douglas Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
	Option 3 - Combination of Direct Defences and Conveyance Improvements				
1	**Douglas Mills**				
1.1	New RC Wall along right bank of Tramore (extension to existing wall)	m	82	1,038.21	85,133.43
1.2	Scaffolding to the edge of bridge (2no weeks hire, signing Scafftags/GA3/handover certs, scaffolding design and TWC)	sum	1	5,000.00	5,000.00
1.3	New RC bridge parapet on Douglas West Bridge	m	12	239.13	2,869.50
1.4	Stone cladding to new RC walls (one face) - incl. in RC Wall rate	m	82		-
1.5	Local drainage measures	sum			10,000.00
1.6	Surface water pumping station	no	1	72,700.00	72,700.00
			Subtotal Douglas Mills		**175,702.93**
2	**Douglas Community Park**				
2.1	Ballybrack Channel Widening along southern half of park (incl excavation, buildup of new channel, landscaping)	m	133	281.25	37,406.15
2.2	Tree Removal circa 0-300mm diameter	no.	18	300.00	5,400.00
2.3	Tree Removal circa 300-600mm diameter	no.	2	425.00	850.00
2.4	Local regrading of right bank along northern half of park	m	155	25.00	3,875.00
			Subtotal Douglas Park		**47,531.15**
3	**Ravensdale to Church Road**				
3.1	Ballybrack Channel Widening (incl demolition of existing channel walls, excavation, buildup of new channel, landscaping)	m	149	494.40	73,665.59
3.2	Tree Removal circa 0-300mm diameter	no.	23	300.00	
3.3	Tree Removal circa 300-600mm diameter	no.	4	425.00	
3.4	Bridge Removal - ICA	m2	7	100.00	675.00
3.5	Bridge Removal - Cycle Track	m2	14	100.00	1,416.00
3.6	Removal of exisitng bridge - Ravensdale	m2	45	100.00	4,500.00
3.7	Replacement of RC bridge - Ravensdale	m2	45	2,800.00	126,000.00
3.8	New culvert - Church Road (excluding TM, services, drainage)	m	15	2,892.67	43,390.09
3.9	New RC Wall along left bank - 1.1m high - Church Road to Ravensdale Middle Bridge	m	156	1,038.21	161,961.15
3.10	New RC Wall along right bank - 1.1m high - Church Road to Ravensdale Middle Bridge	m	156	1,038.21	161,961.15
3.11	New RC Wall along right bank - 1.1m high (Middle Ravensdale Bridge to Ravensdale upper bridge)	m	65	1,038.21	67,483.81
3.12	Stone cladding to new RC walls (both faces) - one face alreay allowed for within RC wall rate	m	377	110.00	41,470.00
3.13	New two-way footway/cycle track from Church Road	m	58	133.55	7,746.13
3.14	New footpath from cycle track to ICA	m	22	73.97	1,627.26
3.15	Surface Water Drainage Diversion @ Church Road	sum	1	5,000.00	5,000.00
3.16	Foul Drainage Diversion @ Church Road	sum	1	10,000.00	10,000.00
3.17	Eircom Diversion @ Church Road	sum	1	10,000.00	10,000.00

Order of Magnitude of Costs			Job No:		234335-00
			Sheet No:		**1**
			Made By:		RH / DS
Project Title	**Douglas Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
3.18	UPC Diversion @ Church Road	sum	1	15,000.00	15,000.00
3.19	Electrical Diversions, incl relocating ESB kiosk	sum	1	50,000.00	50,000.00
3.20	Watermain Diversion @ Church Road	sum	1	10,000.00	10,000.00
3.21	Gasmain Diversion (4bar main and 75mbar main) @ Church Road	sum	1	50,000.00	50,000.00
3.22	Surface water collector drains (225mm diameter)	m	377	€ 85.00	32,045.00
3.23	Surface water pumping stations	no	2	€ 72,700.00	145,400.00
	Subtotal Ravensdale to Church Road				**1,019,341.18**
4.00	**Ballybrack Woods**				
4.1	Removal of existing bridge	m2	33	100.00	3,255.00
4.2	Replacement of RC bridge	m2	33	2,800.00	91,140.00
4.3	Lighting, CCTV, telemetry	sum	1	50,000.00	50,000.00
4.4	Trash screen replacement	sum	1	50,000.00	50,000.00
	Subtotal Ballybrack Woods				**194,395.00**
5	**Donnybrook Commercial Centre**				
5.1	New 2.4m wide by 1.8m high culvert	m	92	2,780.50	255,806.00
5.2	Channel regrading	m	150	906.00	135,900.00
5.3	Service Diversions	sum	1	100,000.00	100,000.00
	Subtotal Donnybrook				**491,706.00**
				Total	**1,928,676.25**

A2 Cost-Benefit Analysis

A2.1 Baseline

Douglas CBA - DRAFT
4% Discount Rate

Client/Authority		Prepared (date)	19/05/2017
Cork County Council / Office of Public Works		Printed	
Project name		Prepared by	KB/DF/AL
Douglas Flood Relief Scheme		Checked by	KL
Project reference		Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	Euro, m	(used for all costs, losses and benefits)	
Discount rate	4.0%		

Costs and benefits of options

	Costs and benefits Euro, m				
	Do Nothing	Direct Defences Only	Conveyance Improvements Only	Combination of Direct Defences and Conveyance Improvements	
PV costs PVc	0.000	8.046	3.890	5.411	
PV damage PVd	40.122	4.948	4.948	4.948	
PV damage avoided		35.17	35.17	35.17	
PV assets Pva	-	-	-	-	
PV asset protection benefits		-	-	-	
Total PV benefits PVb		35.17	35.17	35.17	
Net Present Value NPV		27.13	31.28	29.76	
Average benefit/cost ratio		4.37	9.04	6.50	

Brief description of options:

Do Nothing	Maintenance of Existing Defences
Flood Defence Options	Standard of Protection 1 in 100 year fluvial

Notes:

1) Benefits will normally be expressed either in terms of damage avoided or asset values protected. Care is needed to avoid double counting

2) PV damage avoided is calculated as PV damage (No Project) - PV damage (Option)
PV asset protection benefits are calculated as PVa (Option) - PVa (No Project)
PV benefits calculated as PV damage avoided + PV asset protection benefits

3) Incremental benefit/cost ratio is calculated as:
(PVb(current option) - PVb(previous option))/(PVc(current option) - PVc(previous option))

A2.2 Sensitivity Analysis

Douglas CBA - DRAFT
5% Discount Rate

Client/Authority		Prepared (date)	19/05/2017
Cork County Council / Office of Public Works		Printed	
Project name		Prepared by	KB/DF/AL
Douglas Flood Relief Scheme		Checked by	KL
Project reference		Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	Euro, m	(used for all costs, losses and benefits)	
Discount rate	5.0%		

Costs and benefits of options

	Costs and benefits Euro, m				
	Do Nothing	Direct Defences Only	Conveyance Improvements Only	Combination of Direct Defences and Conveyance Improvements	
PV costs PVc	0.000	8.046	3.890	5.411	
PV damage PVd	34.483	4.253	4.253	4.253	
PV damage avoided		30.23	30.23	30.23	
PV assets Pva	-	-	-	-	
PV asset protection benefits		-	-	-	
Total PV benefits PVb		30.23	30.23	30.23	
Net Present Value NPV		22.18	26.34	24.82	
Average benefit/cost ratio		3.76	7.77	5.59	

Brief description of options:

Do Nothing	Maintenance of Existing Defences
Flood Defence Options	Standard of Protection 1 in 100 year fluvial

Notes:

1) Benefits will normally be expressed either in terms of damage avoided or asset values protected. Care is needed to avoid double counting

2) PV damage avoided is calculated as PV damage (No Project) - PV damage (Option)
PV asset protection benefits are calculated as PVa (Option) - PVa (No Project)
PV benefits calculated as PV damage avoided + PV asset protection benefits

3) Incremental benefit/cost ratio is calculated as:
(PVb(current option) - PVb(previous option))/(PVc(current option) - PVc(previous option))

Douglas CBA - DRAFT
4% Discount Rate/5% Reduction in benefit

Client/Authority		Prepared (date)	19/05/2017
Cork County Council / Office of Public Works		Printed	
Project name		Prepared by	KB/DF/AL
Douglas Flood Relief Scheme		Checked by	KL
Project reference		Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	Euro, m	(used for all costs, losses and benefits)	
Discount rate	4.0%		

Costs and benefits of options

	Costs and benefits Euro, m				
	Do Nothing	Direct Defences Only	Conveyance Improvements Only	Combination of Direct Defences and Conveyance Improvements	
PV costs PVc	0.000	8.046	3.890	5.411	
PV damage PVd	40.122	4.948	4.948	4.948	
PV damage avoided		33.42	33.42	33.42	
PV assets Pva	-	-	-	-	
PV asset protection benefits		-	-	-	
Total PV benefits PVb		33.42	33.42	33.42	
Net Present Value NPV		25.37	29.53	28.01	
Average benefit/cost ratio		4.15	8.59	6.18	

Brief description of options:

Do Nothing	Maintenance of Existing Defences
Flood Defence Options	Standard of Protection 1 in 100 year fluvial

Notes:

1) Benefits will normally be expressed either in terms of damage avoided or asset values protected. Care is needed to avoid double counting

2) PV damage avoided is calculated as PV damage (No Project) - PV damage (Option)
PV asset protection benefits are calculated as PVa (Option) - PVa (No Project)
PV benefits calculated as PV damage avoided + PV asset protection benefits

3) Incremental benefit/cost ratio is calculated as:
(PVb(current option) - PVb(previous option))/(PVc(current option) - PVc(previous option))

Douglas CBA - DRAFT
3% Discount Rate

Client/Authority		Prepared (date)	19/05/2017
Cork County Council / Office of Public Works		Printed	
Project name		Prepared by	KB/DF/AL
Douglas Flood Relief Scheme		Checked by	KL
Project reference		Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	Euro, m	(used for all costs, losses and benefits)	
Discount rate	3.0%		

Costs and benefits of options

	Costs and benefits Euro, m				
	Do Nothing	Direct Defences Only	Conveyance Improvements Only	Combination of Direct Defences and Conveyance Improvements	
PV costs PVc	0.000	8.046	3.890	5.411	
PV damage PVd	47.487	5.856	5.856	5.856	
PV damage avoided		41.63	41.63	41.63	
PV assets Pva	-	-	-	-	
PV asset protection benefits		-	-	-	
Total PV benefits PVb		41.63	41.63	41.63	
Net Present Value NPV		33.58	37.74	36.22	
Average benefit/cost ratio		5.17	10.70	7.69	

Brief description of options:

Do Nothing	Maintenance of Existing Defences
Flood Defence Options	Standard of Protection 1 in 100 year fluvial

Notes:

1) Benefits will normally be expressed either in terms of damage avoided or asset values protected. Care is needed to avoid double counting

2) PV damage avoided is calculated as PV damage (No Project) - PV damage (Option)
PV asset protection benefits are calculated as PVa (Option) - PVa (No Project)
PV benefits calculated as PV damage avoided + PV asset protection benefits

3) Incremental benefit/cost ratio is calculated as:
(PVb(current option) - PVb(previous option))/(PVc(current option) - PVc(previous option))

Appendix B

Multicriteria Assessment of Options

B1 MCA Objectives and Targets

Core Criteria	Objective	Sub objective	Code	Indicator	Basic Requirement	Aspirational Target
Technical	Ensure flood risk management options are operationally robust	"	1.A.	Level of operational risk of option - Degree of reliance on mechanical, electrical or electronic systems, or on human intervention, action or decision, for the option to operate or perform successfully	Moderate to high, but manageable, degree of operational risk, i.e., an option with a high degree of reliance on mechanical, electrical or electronic systems, or on human intervention, action or decision, but which, with the allocation of adequate resources, could be operated with an acceptable degree of risk of failure	No operational risk, i.e., no reliance on mechanical, electrical or electronic systems, or on human intervention, action or decision for the option to operate or perform successfully
	Minimise health and safety risk in construction and operation of the flood risk management option	"	1.B	Degree of health and safety risk during construction and operation	Moderate to high, but acceptable and manageable, level of health and safety risk during either construction or operation	Negligible risk to health and safety during either construction or operation
	Ensure flood risk can be managed effectively and sustainably into the future	"	1.C	Sustainability and adaptability of the flood risk management measure in the face of potential future changes, including the potential impacts of climate change	Option to provide for, or be adaptable to, the MRFS in terms of maintaining the standard of protection at acceptable cost	Option to provide for, or be adaptable to, the HEFS in terms of maintaining the standard of protection at negligible cost
Economic	Reduce economic damage	"	2.A	Annual Average Damage (AAD) expressed in Euro / year, calculated in accordance with the economic risk assessment methods, but with no allowance for social / intangible benefits	AAD is not increased	100% reduction in AAD
	Minimise risk to transport infrastructure	"	2.B	Number and type of transport routes at risk from flooding	No increase in risk to transport infrastructure	Reduce risk to transport infrastructure to zero
	Minimise risk to utilities infrastructure	"	2.C	Number and type of infrastructure assets at risk from flooding	No increase in risk to utility infrastructure	Reduce risk to utility infrastructure to zero
	Minimise risk to agriculture	"	2.D	Agricultural production	No increase in the negative impact of flooding on agricultural production	Provide the potential for enhanced agricultural production
Social	Minimise risk to human health and life	(i) residents	3.A.(i)	Annual Average Number of residential properties at risk from flooding	Number of properties at risk is not increased	100% reduction in number of residential properties at risk
		(ii) high vulnerability properties	3.A.(ii)	Number and type of high vulnerability properties at risk from flooding	Number of high vulnerability properties at risk not increased	100% reduction in number of high vulnerability properties at risk
	Minimise risk to community	(i) social infrastructure	3.B.(i)	Number of social infrastructure assets at risk from flooding in a 0.1% AEP Event	Number of social infrastructure assets at risk not increased	100% reduction in number of social infrastructure assets at risk
	"	(ii) local employment	3.B.(ii)	Number of non-residential (i.e., commercial) properties at risk not increased.	Number of non-residential properties at risk not increased	100% reduction in number of non-residential properties at risk
	Minimise risk to, and where possible enhance, social amenity sites	"	3.C	Number of social amenity sites at risk from flooding in a 1% AEP Event	Number of social amenity sites at risk not increased	100% reduction in number of flood-sensitive social amenity sites at risk. Enhancement or creation of social amenity sites
Environmental	Support the objectives of the WFD	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives	4.A	-	Provide no constraint to the achievement of water body objectives.	Contribute to the achievement of water body objectives
	Support the objectives of the Habitats and Birds Directives	Avoid detrimental effects to, and where possible enhance, Natura 200 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.	4.B	-	No deterioration in the conservation status of designated sites as a result of flood risk management measures.	Improvement in the conservation status of designated sites as a result of flood risk management sites.
	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	Avoid damage to, and where possible enhance, legally protected sites / habitats and other sites / habitats of national, regional and local nature conservation importance	4.C	-	No deterioration in the condition of existing sites due to the implementation of flood risk management option	Creation of new or improvement in condition of existing sites due to the implementation of flood risk management option
	Protect and where possible enhance fisheries resource within the catchment	Maintain existing and where possible create new fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species	4.D	-	No loss of integrity of fisheries habitat. Maintenance of upstream accessibility	No loss of fisheries habitat. Improvement in habitat quality/quantity. Enhanced upstream accessibility
	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	Protect, and where possible enhance, visual amenity, landscape protection zones and views into/from designated scenic areas within the zone of influence	4.E	-	No significant impact on landscape designation (protected site, scenic route/amenity, natural landscape form) within zone of visibility of measures. No significant change in the quality of existing landscape characteristics of the receiving environment	No change to the existing landscape form. Enhancement of existing landscape or landscape feature
	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	(i) Avoid damage to or loss of features of architectural value and their setting, and improve their protection from extreme floods where this is beneficial	4.F.(i)	-	No increase in the risk to architectural features at risk from flooding. No detrimental impacts from flood risk management measures on architectural features.	Complete removal of all relevant architectural features from the risk of harm by extreme floods. Enhanced protection and value of architectural features importance arising from the implementation of the selected measures.
	"	(ii) Avoid damage to or loss of features of archaeological value and their setting, and improve their protection from extreme floods where this is beneficial	4.F.(ii)	-	No increase in the risk to archaeological features at risk from flooding. No detrimental impacts from flood risk management measures on archaeological features.	Complete removal of all relevant archaeological features from the risk of harm by extreme floods. Enhanced protection and value of archaeological features importance arising from the implementation of the selected measures.

B2 MCA Scoring Sheets

Multicriteria Analysis - Flood Risk Management Area 1 Ballybrack Stream - OPTION 1 - Direct Defences

Core Criteria	Objective	Global Weighting	Local Weighting	Local Weighting Rationale	FRS Area 1 OPTION 1 - Direct Defences		
					SCORING	Rationale	MCA SCORE
Technical	Ensure flood risk management options are operationally robust	20	5	As per GN28 guidance	3	Very low operational risk - Fixed direct defences to provide protection from fluvial flood risk. Ongoing maintenance or monitoring of head loss on trash screens may be required	300
Technical	Minimise health and safety risk in construction and operation of the flood risk management option	20	5	As per GN28 guidance	1	Risks are moderate but manageable for construction of direct defences. Deep excavations and the risk of working near water during construction and maintenance stages. H&S risk while carrying out maintenance.	100
Technical	Ensure flood risk can be managed effectively and sustainably into the future	20	5	As per GN28 guidance	1	Direct defences can be designed to account for future adaption.	100
		60				**Technical Score**	**500**
Economic	Reduce economic damage	30	5	Reducing economic damage is a key consideration. Professional judgement has therefore been applied and a high local weighting has been selected	5	Defence works to provide full protection from fluvial design flood risk	750
Economic	Minimise risk to transport infrastructure	10	5	A number of key transport routes are at risk	5	Defence works to provide full protection to all transport routes within AFA from fluvial design flood risk.	250
Economic	Minimise risk to utilities infrastructure	10	5	Considered to be an important area for utility sevices and assets	5	Defence works to provide full protection from fluvial design flood risk.	250
Economic	Minimise risk to agriculture	10	1	No agriculture in Douglas. Professional judgement applied to scoring	0	No impact on agricultural land	0
		60				**Economic Score**	**1250**
Social	Minimise risk to human health and life	30	5	Minimising risk to health and safety of residents is a key consideration. Professional judgement has been applied, therefore, a high local weighting has been selected.	5	Fixed direct defences to provide full protection from fluvial design flood risk	750
Social		10	5	A number of high risk assets are at risk from flooding within the affected area	5	Fixed direct defences to provide full protection from fluvial design flood risk	250
Social	Minimise risk to community	5	5	A health centre, school and church are at risk from flooding within the affected area. Important area of industry and social infrastructure.	5	Fixed direct defences to provide full protection from fluvial design flood risk	125
Social	"	10	5	Important area of local employment	5	Fixed direct defences to provide full protection from fluvial design flood risk	250
Social	Minimise risk to, and where possible enhance, social amenity sites	5	5	Professional judgement applied to scoring	1	Localised regrading within Douglas Park. Short term constuction impacts likely.	25
		60				**Social Score**	**1400**
Environmental	Support the objectives of the WFD	15	5	As per GN28 guidance	-1	Fixed direct defences may have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative short term impacts.	-75
Environmental	Support the objectives of the Habitats and Birds Directives	15	5	Professional judgement applied to scoring	0	As this option would not necessitate signficant in-stream works there is less probability that high silt levels will impact on designated sites downstream within Cork Harbour. However this option has the potential to spread Japanese knotweed downstream and theoretically this species could become established within Natura 2000 sites downstream of the proposed works.	0
Environmental	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	5	5	Professional judgement applied to scoring	-1	The development of high concrete walls will result in the loss of riparian vegetation. Loss of riparian vegetation can impact on feeding, roosting habitat and commuting routes for bats. Riparian vegetation can also provide feeding and nesting habitat for birds. High walls could affect the movement of otters. Loss of overhanging vegetation can result in less food resources and cover for fish populations.	-25
Environmental	Protect and where possible enhance fisheries resource within the catchment	5	5	As per GN28 Guidance	-1	Avoidance of significant in-stream works or changes in channel structure, will minimise the impact on fish populations. Loss of overhanging vegetation can result in less food resources and cover for fish populations.	-25
Environmental	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	10	5	Considered to significantly important. Views and interpretation of flood defences (high walls near Ravensdale) can lead to concern amongst residents. Professional judgement applied to	-4	High walls (greater than 2m above ground level) are likely to have a detrimental imapct on the local surroundings and visual landscape.	-200
Environmental	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	5	2	Potential effects on less than five sites listed in the RPS and recorded by NIAH	0	No effect on architectural heritage.	0
Environmental	"	5	2	Potential effects on less than five Recorded Monuments	-1	Setting of the Ballybrack River, an Area of Archaeological Potential, will be impacted by the construction of the concrete flood defence wall, concrete bridge parapets and local regrading works in the park.	-10
		60				**Environmental Score**	**-335**

MCA Benefit Score	**2315**
Option Selection Benefit Score	**2815**
NPV Capital Costs (M€)	**6.60**
MCA Benefit/Cost Ratio	**0.35**

Multicriteria Analysis - Flood Risk Management Area 1 Ballybrack Stream - OPTION 2 - Conveyance Improvements Only							
Core Criteria	Objective	Global Weighting	Local Weighting	Local Weighting Rationale	FRS Area 1 OPTION 2 - Conveyance Improvements Only		
					SCORING	Rationale	MCA SCORE
Technical	Ensure flood risk management options are operationally robust	20	5	As per GN28 guidance	2	Very low operational risk - Conveyance improvements to provide full protection from fluvial flood risk. Ongoing maintenance or monitoring of head loss on trash screens may be required	200
	Minimise health and safety risk in construction and operation of the flood risk management option	20	5	As per GN28 guidance	0	Risks are moderate but manageable for construction of direct defences. Deep excavations and the risk of working near/in water during construction and especially, during emergency maintenance to remove any potential blockage.	0
	Ensure flood risk can be managed effectively and sustainably into the future	20	5	As per GN28 guidance	-3	Sustainability of deepening of river channel is subject to the geomorphological nature of the river.	-300
		60				**Technical Score**	**-100**
Economic	Reduce economic damage	30	5	Reducing economic damage is a key consideration. Professional judgement has therefore been applied and a high local weighting has been selected	5	Defence works to provide full protection from fluvial design flood risk	750
	Minimise risk to transport infrastructure	10	5	A number of key transport routes are at risk	5	Defence works to provide full protection to all transport routes within AFA from fluvial design flood risk.	250
	Minimise risk to utilities infrastructure	10	5	Considered to be an important area for utility sevices and assets	5	Defence works to provide full protection from fluvial design flood risk.	250
	Minimise risk to agriculture	10	1	No agriculture in Douglas. Professional judgement applied to scoring	0	No impact on agricultural land	0
		60				**Economic Score**	**1250**
Social	Minimise risk to human health and life	30	5	Minimising risk to health and safety of residents is a key consideration. Professional judgement has been applied, therefore, a high local weighting has been selected.	5	Conveyance improvements to provide full protection from fluvial design flood risk	750
		10	5	A number of high risk assets are at risk from flooding within the affected area	5	Conveyance improvements to provide full protection from fluvial design flood risk	250
	Minimise risk to community	5	5	A health centre, school and church are at risk from flooding within the affected area. Important area of industry and social infrastructure.	5	Conveyance improvements to provide full protection from fluvial design flood risk	125
	"	10	5	Important area of local employment	5	Conveyance improvements to provide full protection from fluvial design flood risk	250
	Minimise risk to, and where possible enhance, social amenity sites	5	5	Professional judgement applied to scoring	1	Localised regrading within Douglas Park in addition to widening and deepening of the river channel.	25
		60				**Social Score**	**1400**
Environmental	Support the objectives of the WFD	15	5	As per GN28 guidance	-3	Improved channel conveyance may have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative short term impacts.	-225
	Support the objectives of the Habitats and Birds Directives	15	5	Professional judgement applied to scoring	-2	In-stream works could introduce high levels of silt, which although unlikely, could theoretically impact negatively on Natura 2000 sites downstream of the proposed works. Significant widening and in-stream works has the potential to spread Japanese Knotweed downstream and theoretically this species could become established within Natura 2000 sites downstream of the proposed works.	-150
	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	5	5	Professional judgement applied to scoring	-2	Loss of riparian vegetation may impact on feeding and nesting habitat for birds. Loss of riparian habitat can impact on feeding, roosting habitat and commuting routes for bats. Impacts on fish populations can reduce prey availability for otter and piscivorous birds such as heron. Increased area of riparian loss over Option 3.	-50
	Protect and where possible enhance fisheries resource within the catchment	5	5	As per GN28 Guidance	-3	Deeping and widening the channel will impact directly on fish, macro-invertebrate species and aquatic flora. If not controlled, high levels of silt may have indirect impacts. Widening of the channel will result in the loss of riparian vegetation which may have indirect impacts on fish populations. Although a compound channel will be utilised there may be difficulties in maintaining a normal flow regime during periods of low flow. Culverts and trash screens can impact of fish movement within the watercourse. The replacement of the existing concrete channel bed with a more natural gravel bed is expected to have a net beneficial impact on fish populations. Increased area affected over Option 3.	-75
	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	10	5	Considered to significantly important. Views and interpretation of flood defences (high walls near Ravensdale) can lead to concern amongst residents. Professional judgement applied to	-2	Regrading of the river corridor and banks will require removal of riverside vegetation which is an attractive and important visual feature in this area.	-100
	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	5	2	Potential effects on less than five sites listed in the RPS and recorded by NIAH	0	No effect on architectural heritage.	0
	"	5	2	Potential effects on less than five Recorded Monuments	-1	Widening and deepening the Ballybrack River, an Area of Archaeological Potential, and culvert replacement will effect the river banks and bed. The setting of the river will be impacted by the regrading works in the park, new access footpath, cycleway/ footway, bridge removal and replacement.	-10
		60				**Environmental Score**	**-610**

MCA Benefit Score	**2040**
Option Selection Benefit Score	**1940**
NPV Capital Costs (M€)	**3.20**
MCA Benefit/Cost Ratio	**0.64**

Multicriteria Analysis - Flood Risk Management Area 1 Ballybrack Stream - OPTION 3 - Combination of Direct Defences and Conveyance Improvements							
Core Criteria	Objective	Global Weighting	Local Weighting	Local Weighting Rationale	FRS Area 1 OPTION 3 - Combined		
					SCORING	Rationale	MCA SCORE
Technical	Ensure flood risk management options are operationally robust	20	5	As per GN28 guidance	3	Very low operational risk - combination of direct defences and conveyance improvements to provide full protection from fluvial flood risk.	300
	Minimise health and safety risk in construction and operation of the flood risk management option	20	5	As per GN28 guidance	1	Risks are moderate but manageable for construction of direct defences. Deep excavations and the risk of working near/in water during construction and especially, during emergency maintenance to remove any potential blockage.	100
	Ensure flood risk can be managed effectively and sustainably into the future	20	5	As per GN28 guidance	-1	Direct defences can be designed to account for future adaption however sustainability of deepening of river channel is subject to the geomorphological nature of the river.	-100
		60				Technical Score	300
Economic	Reduce economic damage	30	5	Reducing economic damage is a key consideration. Professional judgement has therefore been applied and a high local weighting has been selected	5	Defence works to provide full protection from fluvial design flood risk	750
	Minimise risk to transport infrastructure	10	5	A number of key transport routes are at risk	5	Defence works to provide full protection to all transport routes within AFA from fluvial design flood risk.	250
	Minimise risk to utilities infrastructure	10	5	Considered to be an important area for utility sevices and assets	5	Defence works to provide full protection from fluvial design flood risk.	250
	Minimise risk to agriculture	10	1	No agriculture in Douglas. Professional judgement applied to scoring	0	No impact on agricultural land	0
		60				Economic Score	1250
Social	Minimise risk to human health and life	30	5	Minimising risk to health and safety of residents is a key consideration. Professional judgement has been applied, therefore, a high local weighting has been selected.	5	Defences to provide full protection from fluvial design flood risk	750
		10	5	A number of high risk assets are at risk from flooding within the affected area	5	Defences to provide full protection from fluvial design flood risk	250
	Minimise risk to community	5	5	A health centre, school and church are at risk from flooding within the affected area. Important area of industry and social infrastructure.	5	Defences to provide full protection from fluvial design flood risk	125
	"	10	5	Important area of local employment	5	Defences to provide full protection from fluvial design flood risk	250
	Minimise risk to, and where possible enhance, social amenity sites	5	5	Professional judgement applied to scoring	4	Localised regrading within Douglas Park in addition to widening and deepening of the river channel. Positive impact of creation of a combined footway/cycle track.	100
		60				Social Score	1475
Environmental	Support the objectives of the WFD	15	5	As per GN28 guidance	-2	Improved channel conveyance may have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative short term impacts.	-150
	Support the objectives of the Habitats and Birds Directives	15	5	Professional judgement applied to scoring	-1	In-stream works could introduce high levels of silt, although unlikely, this could theoretically impact negatively on Natura 2000 sites downstream of the proposed works. Widening and in-stream works have the potential to spread Japanese knotweed downstream and theoretically this species could become established within Natura 2000 sites downstream of the proposed works.	-75
	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	5	5	Professional judgement applied to scoring	-1	Loss of riparian vegetation may impact on feeding and nesting habitat for birds. Loss of riparian habitat can impact on feeding, roosting habitat and commuting routes for bats. Impacts on fish populations can reduce prey availability for otter and piscivorous birds such as heron.	-25
	Protect and where possible enhance fisheries resource within the catchment	5	5	As per GN28 Guidance	-2	Deeping and widening the channel will impact directly on fish, macro-invertebrate species and aquatic flora. If not controlled, high levels of silt may have indirect impacts. Widening of the channel will result in the loss of riparian vegetation which may have indirect impacts on fish populations. Although a compound channel will be utilised there may be difficulties in maintaining a normal flow regime during periods of low flow and maintaining a natural substrate. Culverts and trash screens can impact of fish movement within the watercourse. The replacement of the existing concrete channel bed with a more natural gravel bed is expected to have a net beneficial impact on fish populations.	-50
	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	10	5	Considered to significantly important. Views and interpretation of flood defences (high walls near Ravensdale) can lead to concern amongst residents. Professional judgement applied to scoring	-1	Regrading of the river corridor and banks will require removal of riverside vegetation which is an attractive and important visual feature in this area. Positive impact due to creation of combined footway/cycleway. Increasing the width of the channel possesses the potential improve the amenity value of the watercourse to the local area.	-50
	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	5	2	Potential effects on less than five sites listed in the RPS and recorded by NIAH	0	No effect on architectural heritage.	0
	"	5	2	Potential effects on less than five Recorded Monuments	-1	Widening and deepening the Ballybrack River, an Area of Archaeological Potential, and culvert replacement will effect the river banks and bed. The setting of the river will be impacted by the construction of concrete flood defence wall and regrading works in the park, new access footpath, cycleway/ footway, bridge removal and replacement.	-10
		60				Environmental Score	-360

MCA Benefit Score	2365
Option Selection Benefit Score	2665
NPV Capital Costs (M€)	4.40
MCA Benefit/Cost Ratio	0.54

Multicriteria Analysis Summary Sheet

Douglas Flood Relief Scheme (including Togher Culvert)	Area 1 Ballybrack Stream OPTION 1 - Direct Defences	Area 1 Ballybrack Stream OPTION 2 - Conveyance improvements	Area 1 Ballybrack Stream OPTION 3 - Combination Direct Defences and Conveyance improvements
Technical Score	500	-100	300
Economic Score	1250	1250	1250
Social Score	1400	1400	1475
Environmental Score	-335	-610	-360
MCA Benefit Score	2315	2040	2365
Option Selection Benefit Score	2815	1940	2665
NPV Capital Costs (M€)	6.60	3.20	4.40
MCA Benefit/Cost Ratio	0.35	0.64	0.54

Appendix C

Hydraulic Modelling Output

C1

Results from the hydraulic model for the proposed option are presented in the following table.

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6TRA_2506	4.777	25.472	0.731
6TRA_2446	4.738	34.179	0.77
6TRA_2406	4.729	35.513	0.836
6TRA_2329	4.661	36.002	0.972
6TRA_2263	4.351	32.889	2.565
6TRA_2170	4.052	32.445	0.635
6TRA_2088	4.033	30.112	0.576
6TRA_2014	3.869	28.631	1.324
6TRA_1900	3.741	28.365	0.816
6TRA_1785	3.655	26.882	1.5
6TRA_1735	3.647	26.827	0.464
6TRA_1655	3.594	25.736	0.841
6TRA_1541	3.476	25.271	1.21
6TRA_1431	3.415	25.127	0.961
6TRA_1340	3.372	25.077	0.907
6TRA_1263	3.34	25.051	0.83
6TRA_1175	3.3	24.903	0.846
6TRA_1096	3.27	24.754	0.791
6TRA_1021	3.241	24.905	0.763
6TRA_938	3.249	24.891	0.703
6TRA_852	3.229	25.1	0.777
6TRA_759	3.182	25.472	0.933
6TRA_682	3.124	25.56	1.159
6TRA_619	3.084	25.611	1.22
6TRA_609U	3.078	25.62	1.233
6TRA_609D	3.033	25.62	0.048
6TRA_609Cin	3.033	25.62	1.201
6TRA_609Spu	3.033	0	1.092
6TRA_538Spd	2.994	0	1.092
6TRA_538Cout	3.026	25.684	1.217
6TRA_538spdd	2.994	25.684	0.056
6TRA_538	2.994	25.684	1.302
6TRA_532	2.994	25.689	1.238
USbridge1	2.939	25.767	1.143

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
USbridge2	2.937	25.794	1.149
USu	2.937	25.794	1.14
2d	2.931	25.806	1.103
3u	2.931	25.806	1.043
4u2	2.924	25.819	1.041
4u3	2.924	23.67	0.962
N25culv3in	2.924	2.198	0
4u4	2.922	23.677	0.962
4u5	2.922	22.168	0.905
N25culv5in	2.922	1.81	0
4u6	2.92	22.174	0.905
4u7	2.92	20.721	0.85
N25culv7in	2.92	1.903	0
N25culv3	2.906	2.198	0.523
N25culv5d	2.912	1.81	0
N25culv7d	2.911	1.903	0
4u8	2.919	20.745	0.849
4u9	2.919	19.336	0.794
N25culv8in	2.919	2.029	0
N25culv8d	2.909	2.029	0
4d	2.918	19.365	0.793
5och	2.918	2.39	0
5CUL	2.918	18.163	1.049
6CUL	2.912	18.206	1.056
6CULd	2.912	18.206	1.056
6CULdi	2.912	25.241	1.414
bal3d	2.912	13.995	2.733
ORIu	2.912	3.759	0
7CULu	2.909	25.241	1.414
7CULd	2.909	25.241	1.414
8CULU	2.791	25.282	1.416
8CULu	2.791	25.282	1.416
8CUL	2.791	26.934	1.509
8CULUu	2.791	0.927	0
8CULa	2.781	26.934	1.509
8CULb	2.781	26.325	1.475
transaup	2.781	0.348	0
transbup	2.781	0.348	0

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
8CULbb	2.774	26.326	1.475
8CULD	2.774	28.362	1.589
transcup	2.774	-0.027	0
transdup	2.774	-0.027	0
8CULDd	2.762	28.362	1.589
8CULDa	2.762	31.98	1.792
trans1up	2.762	-0.086	0
trans2up	2.762	-0.086	0
8culDD	2.762	28.362	1.589
N25culv9d	2.781	8.468	1.344
8ochD	2.781	2.747	0
COMB1	2.781	11.757	0.875
transad	2.781	0.348	0
transbd	2.781	0.348	0
9CULup2	2.749	38.052	1.83
COMB3	2.749	6.082	0.852
9CULdd	2.749	38.052	1.83
9CULOLD	2.749	38.052	1.874
9CULOLDd	2.662	38.056	1.874
9CULOLDdd	2.662	38.056	1.714
9CULstrucup	2.598	38.123	1.77
9CULoutU	2.598	38.123	1.77
9CULoutUd	2.569	38.155	1.8
9CULoutDu	2.569	38.155	1.8
9CULoutD	2.552	38.202	1.831
6TRA_20	2.537	38.202	1.784
6TRA_0s	2.541	38.3	2.135
Sedtrap_Cul1	3.356	14.003	3.856
Sedtrap_Cul2	3.388	14.002	3.053
bal1u	3.388	14.002	4.77
bal1u2	3.377	14.002	2.735
bal_new	3.377	14.002	2.735
bal1d	3.285	14.002	2.735
bal2u	3.285	14.002	2.188
bal2d	3.022	13.995	2.187
bal3u	3.022	13.995	2.733
5ochd	2.908	2.39	0.328
6och	2.904	2.394	0.361

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
ORId	2.904	3.759	0
7och	2.904	6.131	0.801
8och	2.795	6.152	0.819
N25culv9uu	2.795	0.954	0
8CULuu	2.791	0.927	0
8ochU	2.795	2.747	0
8CULUuu	2.795	0.927	0
N25culv9Uuu	2.795	0.954	0
N25culv4	2.912	2.199	0.349
N25culv5	2.912	3.728	0.592
N25culv6	2.911	3.729	0.592
N25culv7	2.911	5.231	0.83
N25culv7a	2.909	5.231	0.83
N25culv7b	2.909	6.843	1.086
N25culv8	2.905	6.843	1.086
N25culv9U	2.792	6.844	1.086
N25culv9u	2.792	6.844	1.086
N25culv9	2.792	8.468	1.344
N25culv9Uu	2.795	0.954	0
COMB1a	2.778	11.757	0.875
COMB1b	2.778	9.708	0.722
transcd	2.778	-0.027	0
transdd	2.778	-0.027	0
COMB2	2.775	9.708	0.722
COMB2a	2.775	6.082	0.453
trans1d	2.775	-0.086	0
trans2d	2.775	-0.086	0
6DOU_1370	25.383	5.941	2.508
HEP_06	44.964	7.27	1.498
6DOU_1370i1	25.142	5.941	2.437
6DOU_1370i2	24.903	5.941	2.365
6DOU_1370i3	24.665	5.941	2.298
6DOU_1370i4	24.428	5.941	2.235
6DOU_1370i5	24.192	5.941	2.179
6DOU_1370i6	23.957	5.941	2.124
6DOU_1370i7	23.724	5.94	2.065
6DOU_1276	23.488	5.94	2.035
6DOU_1370i9	23.248	5.94	2.07

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6DOU_1370i10	23.009	5.94	2.105
6DOU_1370i11	22.772	5.94	2.14
6DOU_1370i12	22.537	5.94	2.175
6DOU_1370i13	22.306	5.94	2.207
6DOU_1370i14	22.078	5.94	2.236
6DOU_1370i15	21.857	5.94	2.261
6DOU_1370i16	21.641	5.94	2.287
6DOU_1370i17	21.435	5.94	2.3
6DOU_1370i18	21.242	5.94	2.343
6DOU_1370i19	21.057	5.94	2.441
6DOU_1130	20.888	5.939	2.728
6DOU_1130Bu	20.888	5.715	2.606
6DOU_1130Spu	20.888	0.263	2.606
6DOU_1130Bd	20.749	5.715	2.606
6DOU_1130d	20.749	5.939	2.823
6DOU_1100	20.129	5.939	2.333
6DOU_1130Spd	20.749	0.263	2.606
6DOU_1059	19.377	5.939	2.316
6DOU_1009	18.506	5.939	2.229
6DOU_960	17.635	5.939	2.628
6DOU_960Bu	17.635	5.939	1.498
6DOU_960Spu	17.635	0	1.498
6DOU_960Bd	17.635	5.939	1.498
6DOU_952	17.462	5.939	2.294
6DOU_960Spd	17.635	0	1.498
6DOU_960d	17.635	5.939	2.628
6DOU_952d1	17.07	5.939	2.282
6DOU_952d2	17.07	5.939	2.282
6DOU_914	16.743	5.938	1.153
6DOU_914J	16.743	14.008	2.689
6DOU_845	16.033	14.007	1.572
6DOU_828	15.584	14.007	4.456
6DOU_828Bu	15.584	14.007	2.453
6DOU_828Spu	15.584	0	2.453
6DOU_828Bd	15.584	14.007	2.453
6DOU_828d	15.584	14.007	4.456
6DOU_803	14.812	14.007	2.519
6DOU_758	14.208	14.007	1.653

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6DOU_828Spd	15.584	0	2.453
6DOU_721	13.916	14.006	1.7
6DOU_678	13.543	14.005	1.769
6DOU_641	12.961	14.005	2.929
6DOU_628	12.719	14.005	2.942
6DOU_628Spu	12.719	0	2.254
6DOU_628Bu	12.719	14.005	2.254
6DOU_628Bd	12.719	14.005	2.254
6DOU_628d	12.719	14.005	3.774
6DOU_611	12.489	14.005	1.842
6DOU_628Spd	12.719	0	2.254
6DOU_614i1	12.342	14.005	1.914
6DOU_573	12.119	14.005	2.412
6DOU_559	11.947	14.005	2.892
6DOU_539	11.676	14.005	2.668
6DOU_524	11.532	14.005	2.363
6DOU_518	11.466	14.005	2.6
6DOU_511	11.366	14.005	3.011
6DOU_506	11.279	14.005	2.82
6DOU_501	11.22	14.005	2.677
6DOU_501Bu	11.22	14.005	2.573
6DOU_501Bd	11.22	14.005	2.573
6DOU_501d	11.22	14.005	2.677
6DOU_495	11.137	14.005	3.02
6DOU_490	11.029	14.005	3.627
6DOU_484	10.876	14.005	3.566
6DOU_477	10.716	14.005	3.511
6DOU_472	10.597	14.005	3.599
6DOU_468	10.483	14.005	3.796
6DOU_468Bu	10.483	14.005	2.167
6DOU_468Bd	10.483	14.005	2.167
6DOU_468d	10.483	14.005	3.796
6DOU_464	10.379	14.005	3.15
6DOU_460	10.313	14.005	2.576
6DOU_455	10.25	14.005	2.563
6DOU_448	10.165	14.005	2.535
6DOU_443	10.108	14.005	2.505
6DOU_438	10.055	14.005	2.463

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6DOU_433	10.009	14.005	2.405
6DOU_428	9.974	14.005	2.323
6DOU_425	9.943	14.005	2.659
6DOU_425BLU	9.943	14.005	1.899
6DOU_425BLD	9.92	14.005	1.899
6DOU_425Bd	9.92	14.005	1.899
6DOU_425d	9.92	14.005	2.726
6DOU_420	9.858	14.005	2.721
6DOU_415	9.798	14.005	2.709
6DOU_405	9.689	14.005	2.667
6DOU_395	9.595	14.005	2.598
6DOU_384r	9.514	14.004	2.467
6DOU_379	9.427	14.004	2.789
6DOU_379d	9.427	14.004	2.789
6DOU_367	9.29	14.004	2.814
6DOU_358	9.18	14.004	2.529
6DOU_358d	9.18	14.004	2.529
6DOU_341	8.557	14.004	5.255
6DOU_325	7.909	14.004	3.108
6DOU_306	7.686	14.004	2.58
6DOU_306Bu	7.686	14.004	1.797
6DOU_306Bd	7.686	14.004	1.797
6DOU_306d	7.686	14.004	2.707
6DOU_282	7.407	14.004	2.487
6DOU_219	6.682	14.004	2.47
6DOU_258	7.125	14.004	2.564
6DOU_234	6.85	14.004	2.485
6DOU_204	6.496	14.004	2.575
6DOU_179	6.201	14.004	2.392
6DOU_154	6.127	14.004	1.596
6DOU_124	5.718	14.004	2.661
6DOU_89	5.297	14.004	3.032
6DOU_65	4.888	14.004	3.294
6DOU_54	4.709	14.004	2.93
DOUFRS_18_3	4.667	14.004	2.161
DOUFRS_14_0	4.714	14.004	1.837
DOUFRS_10r	4.538	14.004	1.826
DOUFRS_14_0r	4.516	14.004	2.05

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
DOUFRS_10	4.538	14.004	1.826
DOUFRS_5_86	4.549	14.004	1.694
DOUFRS_3_36	4.524	14.004	1.777
DOUFRS_2_86	4.376	14.004	1.916
DOUFRS_00	4.308	14.004	2.184
BB_culv	3.542	14.004	3.664
BB_culv2	3.356	14.003	5.842
6TRA_470	2.963	25.752	1.259
6TRA_461	2.964	25.767	1.162
6TRA_DS	2.541	-3.092	1.258
6DO1_1177	45.009	7.27	2.157
6DO1_1129	42.955	7.27	2.571
6DO1_1076	41.55	7.269	1.746
6DO1_1045	40.571	7.269	2.331
6DO1_1014	39.559	7.269	1.844
6DO1_929	37.259	7.269	2.722
6DO1_805	34.16	7.268	1.967
6DO1_726	32.325	7.27	1.662
6DO1_581	28.864	7.267	2.235
6DO1_498	26.966	7.267	2.227
6DO1_466	26.012	7.266	2.683
6DO1_434	25.219	7.266	2.346
6DO1_402	24.908	7.264	1.351
402_rpt	24.844	7.264	0.57
397_us	24.767	7.264	1.289
397_ds	24.652	7.264	1.546
6DO1_395us	24.622	7.264	3.435
6DO1_395cul	24.43	7.264	4.821
6DO1_387_ds	24.405	7.264	2.864
6DO1_387culd	24.405	7.264	2.629
6DO1_382	24.356	7.264	1.401
6DO1_374	24.055	7.264	2.447
6DO1_374BU	24.055	7.264	0.638
6DO1_374BD	24.055	7.264	0.638
6DO1_374d	24.055	7.264	2.447
6DO1_324	23.319	7.264	2.514
6DO1_285	22.714	7.263	2.282
6DO1_277	22.678	7.263	1.705

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6DO1_277Bu	22.678	7.263	2.583
6DO1_277Spu	22.678	0	2.583
6DO1_277Bd	22.315	7.263	2.583
6DO1_277d	22.315	7.263	2.573
6DO1_277Spd	22.315	0	2.583
6DO1_262	21.967	7.263	3.279
6DO1_253	21.608	7.263	4.104
6DO1_253Spd	19.215	0	0.999
6DO1_253CUin	21.608	7.263	3.955
6DO1_253Spu	21.608	0	0.999
Culver_XS1	21.275	7.263	3.952
Culvert_XS2	20.941	7.263	3.96
Culvert_XS3	20.562	7.263	4.315
Culvert_MH1	20.033	7.263	4.9
Culvert_MH2	19.647	7.263	2.823
Culvert_MH3	19.603	7.263	2.695
Culvert_MH4	19.574	7.263	2.707
Culvert_MH4B	19.574	7.263	2.707
Culvert_MH5	19.528	7.263	2.672
Culvert_MH6	19.432	7.263	2.682
DS_MH7	19.297	7.263	2.835
6DO1_63a	19.223	7.263	1.112
Bridge_US	19.223	7.263	0.568
Culvert_DS	19.215	7.263	1.462
6DO1_63CUout	19.215	7.263	3.011
6DO1_63b	18.862	7.263	1.992
Bridge_DS	18.862	7.263	0.568
6DO1_56	18.612	7.263	2.643
6DO1_4	17.96	7.262	1.955
6DO1_4Bu	17.96	6.964	2.399
6DO1_4Spu	17.96	0.298	2.399
6DO1_4Bd	17.871	6.964	2.399
6DO1_4d	17.871	7.262	2.045
6DO1_4Spd	17.871	0.298	2.399
6DO1_0	17.837	7.262	1.743
6DO1_0S	16.833	7.262	1.906

Appendix B

Togher Options Report

Cork County Council

Douglas Flood Relief Scheme (including Togher Culvert)

Togher Options Report

234335-00

Issue | 19 May 2017

Job number 234335-00

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Appendix A

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Appendix C

Hydraulic Modelling Output

1 Introduction

1.1 Context

The Office of Public Works (OPW) in partnership with Cork City Council and Cork County Council carried out a Catchment Flood Risk Assessment and Management (CFRAM) Study for the Lee Catchment. Douglas and Togher were included as part of the study as both are located in the Tramore catchment which is a sub catchment of the Lee Catchment. The Catchment Flood Risk Management Plan (CFRMP) which was published in January 2014, identified a preferred option in Togher which involved the replacement of the existing under-capacity culvert with a new single 3.0m x 1.4m rectangular culvert extending from Lehenaghmore Industrial Estate to Greenwood Estate.

A preliminary assessment of the proposed option undertaken as part of this project indicated that the culvert should be rechecked for capacity in light of the revised hydrological assessment of the Tramore catchment which was undertaken as part of this project.

The preliminary investigation also indicated that a predominantly open channel may offer a viable alternative flood relief solution for Togher.

Arup has therefore been asked to assess the sizing of the single culvert option and also to consider the open channel option and undertake an options assessment of both. It is noted that the Lee CFRAM project only considered the single culvert option.

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 - Environmental Assessment and Planning;
- Stage III - Detailed design and Tender;
- Stage IV – Construction;
- Stage V - Handover of works.

This Draft Options report is produced as part of Stage I of the project and details how the preferred flood relief option for Togher was selected. The reader is referred to the following Stage I reports which are to be read in conjunction with this report:

- Douglas Flood Relief Scheme (Including Togher Culvert) – Final Hydrology Report;
- Douglas Flood Relief Scheme (Including Togher Culvert) – Togher Hydraulics Report;
- Douglas Flood Relief Scheme (Including Togher Culvert) – Douglas Options Report;

1.2 Scope of the Report

The purpose of this report is to assess the possible flood relief options for Togher and to outline the procedure for how the preferred option was developed and selected. The process for the selection of the preferred flood relief option is as follows:

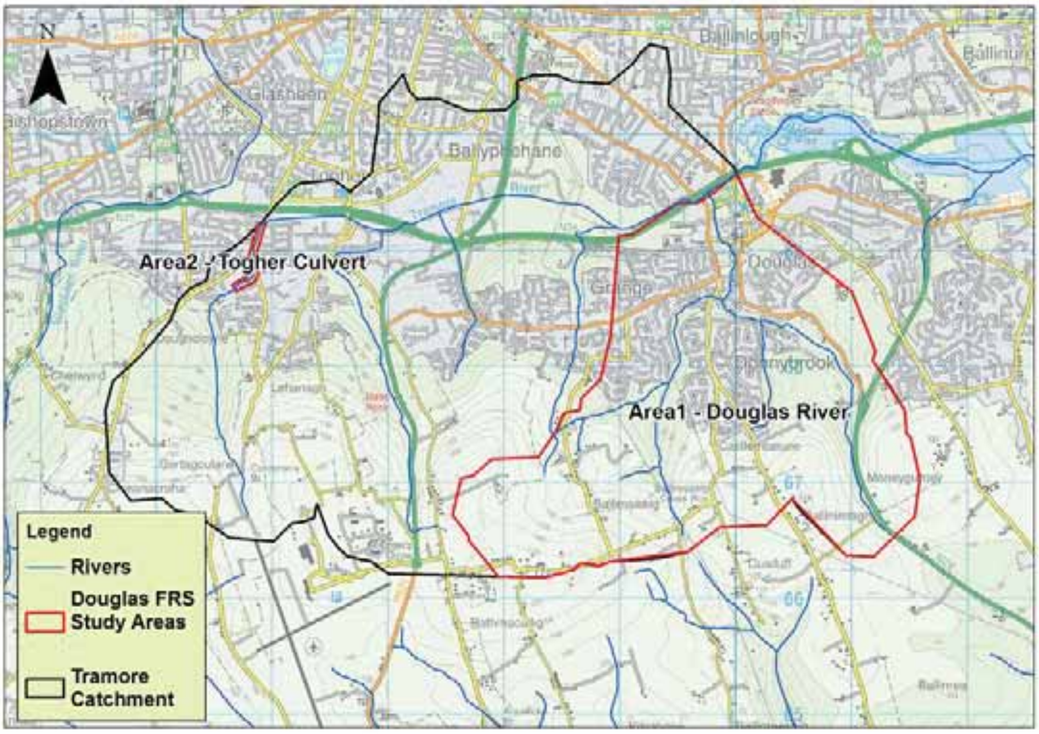
- Preliminary assessment of the Lee CFRAM preferred options (single culvert);
- Preliminary assessment of the open channel option;
- Both the single culvert and open channel options were subjected to economic, environmental and multi-criteria assessments, allowing a preferred flood relief option to be selected.

1.3 Study Area

For the purpose of this project there are two separate study areas which are both located within the Tramore River catchment (Figure 2):

- Area 1 - Douglas;
- Area 2 - Togher.

Figure 1: Douglas Flood Relief Scheme (including Togher Culvert) Study Areas



The area of Togher relevant to this study is between Lehenaghmore Industrial Estate and Greenwood Estate as indicated in Figure 2.

The Tramore River flows through Togher and is culverted over most of its length through this reach.

The river enters the culvert in Lehenaghmore Industrial Estate as shown in Figure 3 and exits it adjacent to Griffin Pianos in Greenwood Estate at the bottom of Togher Road as indicated in Figure 4.

Figure 2: Area of Togher relevant to the study. The red arrow indicates the direction of flow of the Tramore River

Figure 3: Existing trash screen at entrance to culvert in Lehenaghmore Industrial Estate

Figure 4: Exit of culvert adjacent to Griffin Pianos (red building on the left of photo). This photo is taken looking upstream.

There are two open channel sections along the reach as indicated in Figure 5. These are located:

- Upstream of the Roundabout on Togher Road (circa 40m in length) - a photograph of this reach is presented in Figure 6. The photograph is taken looking upstream. The water in the channel is not visible in the photo due to the heavy vegetation on both banks of the channel.
- Upstream of the entrance to Greenwood Estate (circa 15m in length) - a photograph of this reach is presented in Figure 7. The photograph is taken looking upstream.

The alignment of the culvert/open channel as presented in Figure 5 is indicative and does not necessarily represent the actual alignment.

Figure 5: Schematic of the existing Togher Culvert and Open Channel

Figure 6: Open channel section immediately upstream of the roundabout on Togher Road.

Figure 7: Open channel section at downstream end of the reach.

1.4 Use of Output from the Lee CFRAM Study

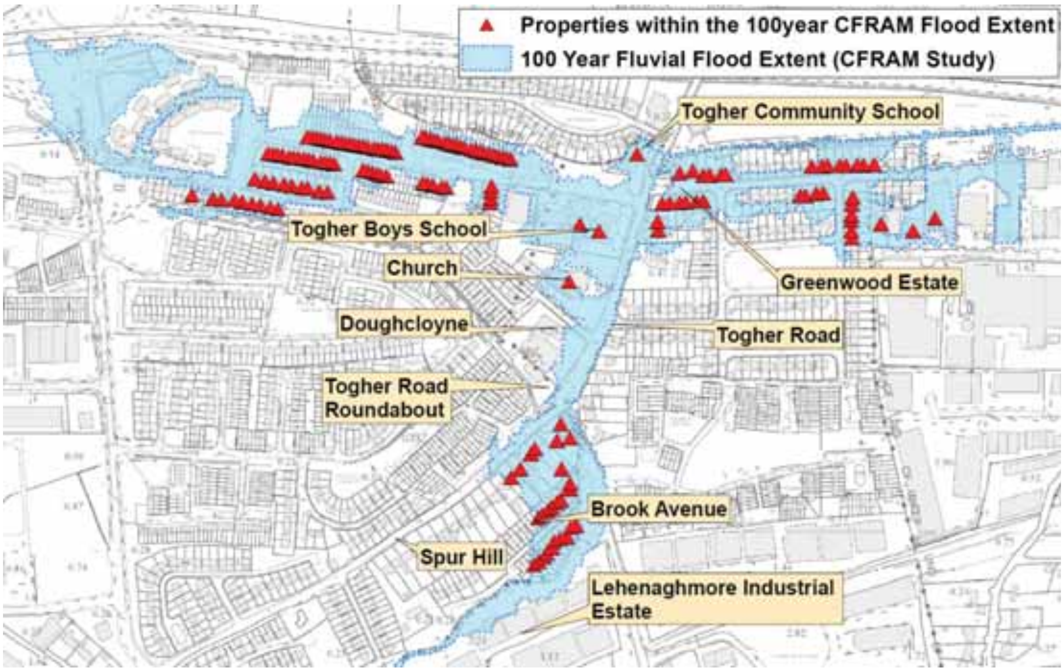
It is not within the scope of the project to consider the existing scenario in Togher. A hydraulic model of the existing scenario has therefore not been developed and flood maps of the existing scenario have not been produced.

The 1 in 100 year flood extent as estimated by the Lee CFRAM Study (Figure 8) has instead been adopted as the design flood extent for the study. It can be seen from Figure 8 that a significant number of residential and commercial properties are at risk of flooding in Togher.

It is also not within the scope of the project to estimate the economic damages associated with flooding in Togher as part of the cost benefit analysis of the study. The damages as estimated by the Lee CFRAM Study have therefore been utilised in the study as is discussed later in this report in Section 6.2.

It is noted that Togher has been considered as a single flood cell in this study.

Figure 8: Predicted 100 year flood extent in Togher for the current scenario, developed as part of the Lee CFRAM Study



2 Stakeholder Input and Constraints

2.1 Constraints Study

A Constraints Study Report was prepared as part of this project. Constraints were assessed under the following headings:

- Human Beings
- Ecology
- Water
- Soils and Geology
- Archaeology, Architectural and Cultural Heritage
- Landscape
- Noise, Air Quality and Climate
- Material Assets.

The constraints identified in the report have been taken into account in the development of the preferred option.

2.2 Public Consultation Days

Two separate public information days (PIDs) were held over the course of Phase I of the study.

The first PID was held on Wednesday 26 February 2014 in Douglas Community Centre. The purpose of the PID was to present the Study Area to the general public and to outline the process involved in the preparation of the Douglas FRS (Including Togher Culvert). A summary of the submissions received from the public is included in the project Constraints Study report.

The second PID was held on Wednesday 8 October 2014 in Nemo Rangers GAA Club. The purpose of the PID was to present the emerging preferred option for the scheme and invite comments.

The feedback received from both PIDs was taken on board and helped to inform the development of the options and selection of the preferred option.

3 Initial Screening of Potentially Viable Measures

3.1 Introduction

This section details all of the flood risk management measures considered during the initial screening stage. These measures were assessed with regard to their viability in terms of the following criteria:

- Applicability to the area;
- Economic (potential benefits, impacts, likely costs etc.);
- Environmental (potential impacts and benefits);
- Social (impacts on people, society and the likely acceptability of the measure); and
- Cultural (potential benefits and impacts upon heritage sites and resources).

The flood risk management measures which have been reviewed, as part of this initial screening process are contained in the table below.

3.2 Summary of Initial Screening

The flood risk management measures which were initially screened are outlined in Table 1 below.

Table 1: Summary of initial screening

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Initial Screening Result	Comment
Do Nothing	Y	N	Y	N	Y	Not Viable	This option provides the baseline for the study and assumes no further work or expenditure on measures to reduce flood risk in Togher. The Do Nothing scenario is defined as the option 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 sustainable option as it fails to meet the needs of the residents and business owners of Togher. Using this as the baseline scenario however allows the benefits of all existing measures to reduce the flood risk to be identified.
Do Minimum	Y	N	Y	N	Y	Not Viable	Flooding starts at high frequency events.
Non-structural Measures							
Planning Control/ Land Use Management	Y	Y	Y	Y	Y	Not Viable	Long time to implement, and would not reduce the current flood risk to an acceptable level. However, the requirement for future planning control to facilitate any potential future upstream storage to allow adaptation for climate change is important and is discussed further in this report.
Building Regulations	Y	Y	Y	Y	Y	Not Viable	
SUDS	N					Not Viable	Togher is already heavily urbanised with little space for attenuation or other SUDS features.
Flood Forecasting/Flood Warning System	N					Not Viable	The viability of a flood forecasting system has been assessed as part of this study and is reported on elsewhere. It was not found to be a viable option as the catchment is too small and flashy and the proposed scheme is likely to be a 'passive' scheme and thus would not benefit from a flood forecasting system. Tidal flood risk is not a significant issue.
Public Awareness	Y	Y	Y	Y	Y	Viable	

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Initial Screening Result	Comment
Structural Measures							
Upstream Storage	N					Not Viable	This measure is not viable in Togher as the Tramore River Catchment upstream of Togher is extremely steep with no suitable storage areas identified.
Direct Flood Defences	N	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment.
Permanent Diversion Channels or Culverts	N					Not Viable	No viable location for permanent diversion in Togher.
Flood Relief channel/culvert (including pumped option)	Y	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment of the option of a flood relief channel/culvert in Togher.
Sediment/Debris Control	Y	Y	Y	Y	Y	Viable	Undertake Further Technical Assessment of requirement for sediment/debris Control.
Conveyance Improvements	Y	Y	Y	Y	Y	Viable	Viable. Undertake Further Technical Assessment.
Property Relocation/Reconstruction	N					Not Viable	This measure involves the relocation of people and businesses from properties at risk of flooding to a less flood risk area. It is not considered feasible for Togher, due to the number of properties, and hence people and businesses, at risk.
Individual Property Protection	N					Not Viable	Large number of properties located in the Study Area.
Local SW Pumping	Y	Y	Y	Y	Y	Viable	Undertake Technical Assessment of requirement for localised pumping of surface water in the urbanised area of Togher.
Tidal Barrage	N					Not Viable	Tidal flooding is not a significant risk

4 Further Assessment of Viable Measures

4.1 Structural Measures

4.1.1 Construction of Direct Flood Defences

This measure involves the construction of direct defences to contain peak flood flows within the river channel.

In Togher the majority of the river channel is culverted and past flooding was as a result of insufficient capacity in the culvert system to convey flood flows. This caused water to bypass the culvert and flow overland resulting in flooding of residential and commercial properties along Togher Road. Direct defences would therefore be required upstream of the culvert to contain out of bank flow.

The construction of direct flood defences upstream of the culvert inlets would require significant flood water storage which is not viable due to the urbanised nature of the area.

This measure was therefore deemed not to be feasible for Togher and is not considered further in this Options Report.

4.1.2 Construction of Diversion or Flood Relief Channel or Culverts

This measure involves diverting excess flood flow away from the main river channel during the design flood event. It typically consists of the construction of a flood relief channel that remains dry in low flow conditions. When the water level rises above a certain threshold, water spills into the channel/culvert and is conveyed downstream separately to the main channel. At a suitable point downstream, the diverted flow re-joins the main river.

Excess flood flow can also be diverted away from the main river channel during the design flood event by allowing it flow overland on existing ground.

The optimum flow diversion route for Togher commences just upstream of Lehenaghmore Industrial Estate and conveys flow to a point downstream of Greenwood Estate. Due to the densely urbanised nature of Togher however, a flow diversion route is not deemed feasible as it would involve demolition of a significant number of existing properties and/or tunnelling to open up the route. An alternative flow diversion routes is not deemed technically feasible.

This option is therefore not considered further.

4.1.3 Measures to Control Debris

Blockages of hydraulic structures by water-borne debris is known to have been a mechanism of flooding during past flood events in the catchment – notably the Lehenaghmore Industrial Estate trash screen during the 2012 event, and also multiple times at the inlet to the Tramore culvert in Togher.

Measures to alleviate this risk include the construction of suitably sized structures in the channel to capture the debris at a point upstream of where it could cause major issues such as blockage of a bridge or culvert barrel.

While this measure could not alleviate flood risk by itself, the option was reviewed as a potential additional measure to minimise any residual risk following construction of the scheme.

In Togher the necessity of the trashscreen at Lehenaghmore Industrial Estate has been examined and found to be necessary for both security and blockage purposes if a culverted option is adopted.

4.1.4 Conveyance Improvements

In Togher, a lack of conveyance capacity, specifically an undersized culvert has been identified as a cause of flooding. When the culvert reaches maximum capacity and becomes surcharged, flood waters get out of bank and flow along the road resulting in significant flooding of properties. Undertaking conveyance improvement measures in Togher could result in lowering water levels at the constrictive culverts and retaining flood water in-channel leading to a considerable reduction of flood risk throughout the Study Area.

The potential conveyance improvement measures include:

- Replacement of the existing Togher culvert with a larger culvert – the alignment along Togher road can be west of the road or along the road;
- Replacement of the existing Togher culvert with an open channel that is sufficiently sized to accommodate the design flood flow;

These measures are considered to be potentially feasible for Togher and are accessed further in the detailed option selection.

4.1.5 Pumping

This measure involves pumping excess flood flow away from the main river channel during the design flood event. The works would involve the construction of a pumping station upstream of the area at risk, which would pump flood waters through a rising main before re-entering the river channel downstream of the area at risk.

The 1 in 100 year flow on the Tramore River, as estimated as part of this study, is approximately 7.6m^3/s. The results of the Lee CFRAM suggest that the threshold of flooding at the upstream end of the existing culvert in Lehenaghmore Industrial Estate is circa 2.0m^3/s. To reduce the peak flow below this threshold would require a peak pump rate of up to 5.6m^3/s assuming a small storage volume/wet well.

Whilst the above may be technically feasible, it would require the construction of a large pumping station and rising main with an estimated cost of circa €3m to €4m.

As the areas at risk cover an extended length, and given the urbanised nature of the area, finding a suitable location for such a large pumping station and rising main would prove extremely difficult.

As well as the high capital cost, this measure would generate high ongoing maintenance costs. This measure would also likely have significant negative environmental and social impacts.

Based on the above it is considered that pumping is not an economically viable option and it is therefore not considered further in the context of a primary solution for Togher.

4.2 Summary

The options for Togher which were shortlisted for further development and assessment are:

- **Option 1 -** Replacement of existing culvert with a new culvert along Togher Road;
- **Option 2 -** Replacement of existing culvert with a new culvert parallel to Togher Road (to the west);
- **Option 3 -** Replacement of existing culvert with an Open Channel with engineered banks parallel with Togher Road. This option incorporates five separate culvert crossings along the route of the open channel in order to maintain vehicular and pedestrian access to existing properties and roads from Togher Road.

These options are discussed in the following section of this report.

5 Development of Flood Relief Options

5.1 Introduction

In order to arrive at a preferred solution, three options have been developed to a sufficient level of detail to allow a detailed appraisal be undertaken.

The flood relief options taken forward for further development are:

- Option 1 – New Culvert along Togher Road;
- Option 2 – New Culvert parallel with Togher Road;
- Option 3 – Open Channel with a number of culvert crossings along its route.

5.2 Option 1 - Culvert along Togher Road

This option involves the removal of the existing undersized culverts that conveys the Tramore, from upstream of Lehenaghmore Industrial Estate to downstream of Greenwood Estate and replacing it with a single larger culvert with increased capacity. The two existing open channel sections along the existing route are to be included as part of the proposed single culvert. The Lee CFRAMS output proposed dimensions of 3m wide x 1.4m high for this replacement culvert.

The route of the proposed culvert for this option is presented in Figure 9 and described in detail in Table 1 below. It is noted that local minor conveyance improvements to the existing channel downstream of the culvert form part of this option: At the culvert exit, the existing open channel will by widened on the left bank by one meter for a length of circa 70m.

A positive aspect of this option is that the majority of the culvert route is along the main public Tramore Road ensuring little need to interfere with private lands. Compulsory purchase orders or extensive compensation packages are therefore avoided.

Culverting the two existing short reaches of open channel along the route will reduce the opportunity for blockages from illegal dumping and debris entering the river during a flood event. This will also result in a reduced number of locations to be included in CCC’s maintenance operations schedule.

A typical cross section of Option 1 (located along Togher Road at the Church of the Way Cross) is shown below in Figure 10.

A negative aspect of this option is the significant disruption to traffic that would result during the construction phase. There would also be some disruption to existing services.

Figure 9: Option 1 – Culvert along Togher Road

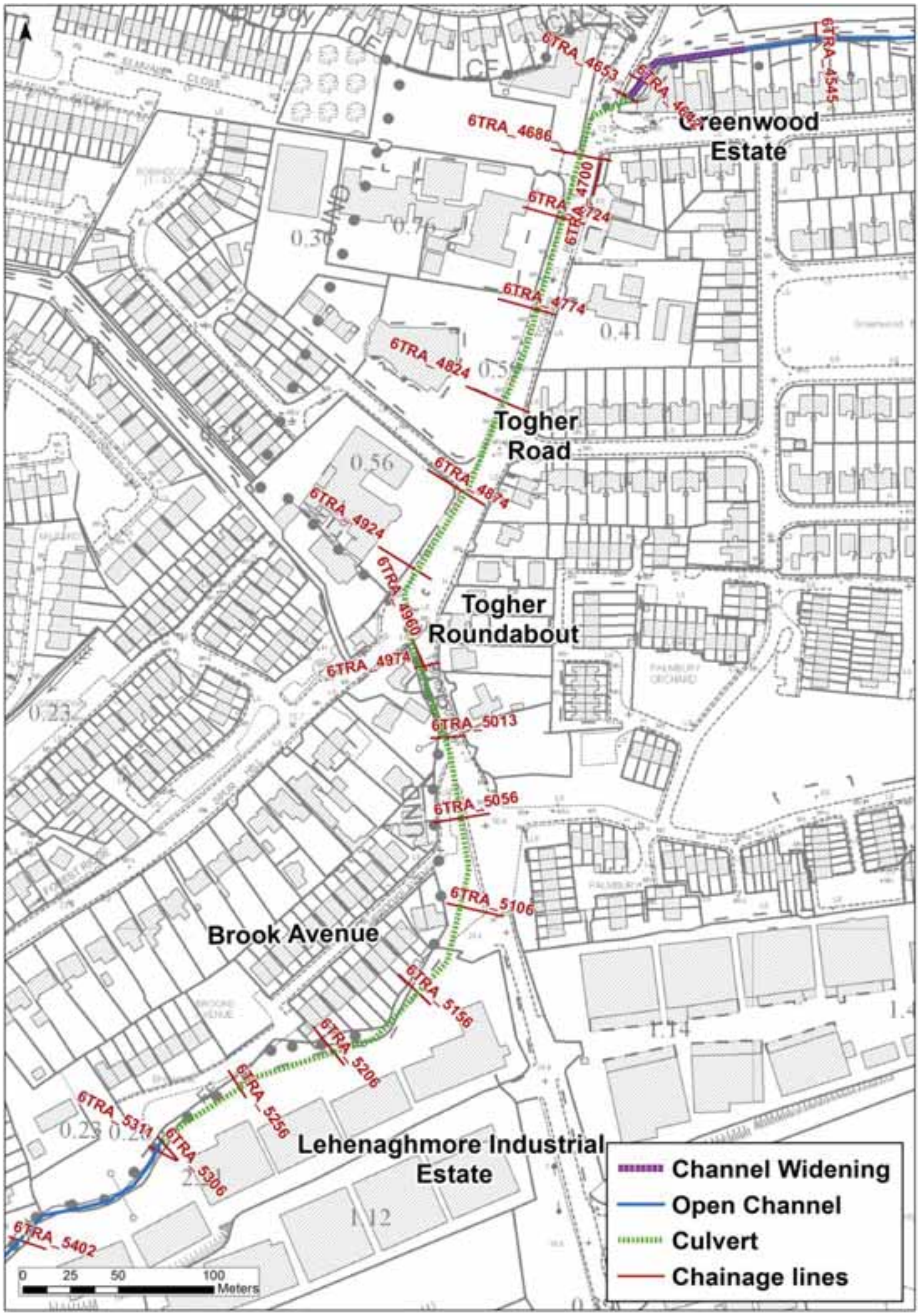


Figure 10: Option 1 – Typical Cross Section: Togher Road, at Church of the Way of the Cross

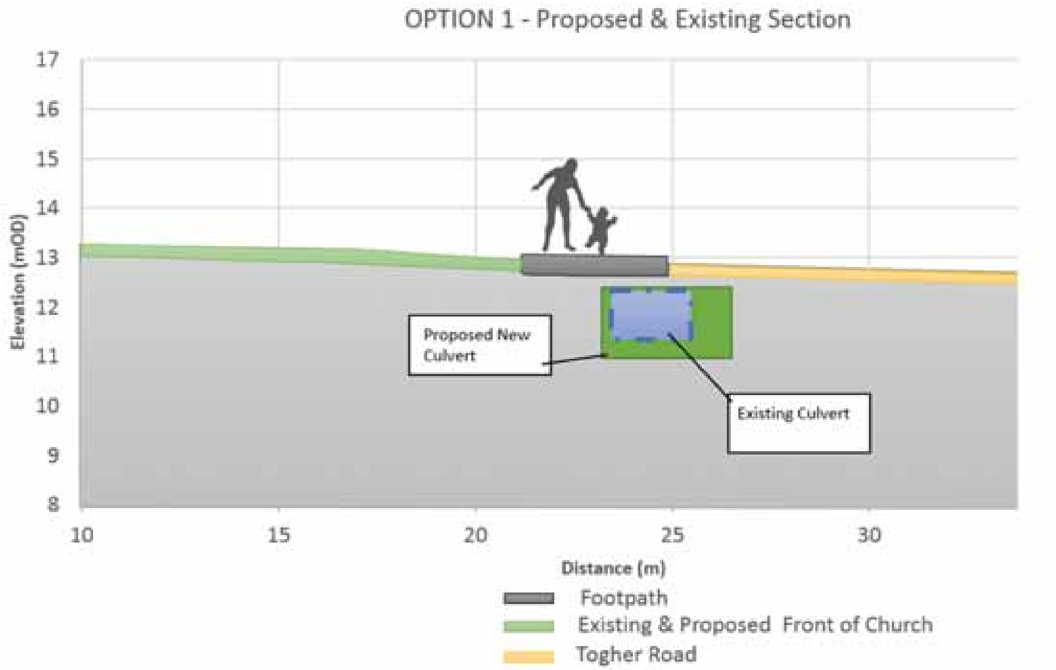


Table 2: Description of Option 1 works (Culvert along Togher Road)

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Lehenaghmore Industrial Estate Culvert Trashscreen	Tramore River	5311	Existing trash screen structure to be removed and replaced with new screen and defence walls. Screen area to be $56.4m^2$. Structure will be 6.6m wide x 12.4m long).	Refer to trashscreen report for further details
Lehenaghmore Industrial Estate Culvert	Tramore River	5306-5013	Removal of existing culvert network (twin 900mm diameter culverts at chainage 5306 and twin 600mm diameter culverts and a 900mm diameter culvert at chainage 5286 downstream) and replace with a single 3m wide x 1.4m high concrete culvert.	Construction work for the new culvert will be carried out from the southern (Industrial Estate) side of the channel. Traffic management and close liaison with industrial unit occupants will be necessary.
Existing Open channel reach upstream of Togher Road Roundabout	Tramore River	5013-4962	New 3m wide x 1.4m high concrete culvert to replace existing 2.5m wide x 0.9m high open channel reach.	The existing open channel form part of the new single culvert leading to the creation of a new pedestrian area. Construction work will be in a confined area adjacent to a busy, narrow road. Significant traffic management will be necessary.
Existing Trashscreen Structure	Tramore River	4962	Existing trash screen structure to be removed	No trashscreen required as the reach is to be culverted.
Togher Roundabout	Tramore River	4962-4934	New 3m wide x 1.4m high concrete culvert to replace existing culvert	Careful attention to detail will be required to ensure the foul drainage line at the roundabout is not interfered with as a consequence of the works.
Togher Road	Tramore River	4962-4709	Removal of existing 1.8m x 1m box culvert along northbound lane and replace with larger 3m wide x 1.4m high concrete culvert.	The existing box culvert downstream of Togher will be removed. The route will be excavated, widened and deepened to house the new larger culvert. Construction works along the length of Togher Road will require significant traffic management as the road will be reduces to one way on a phased basis. There are also a number of services running along the road parallel with the culvert which will require attention during the

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
				construction phase. Potential bypassing of services will be required at the roundabout and at the end of Togher Road where the culvert alignment crosses the road.
Togher Road	Tramore River	4709-4653	New 3m wide x 1.4m high concrete culvert to be installed	At this section the new culvert route deviates from the existing culvert route. The new culvert will continue north along Togher Road before turning northeast at chainage 4663 to join into the existing open channel downstream of the entrance to Greenwood Estate. As the culvert crosses Togher Road a number of existing services will be disrupted by the works. These include: - Eircom - Watermain - UPC Fibre Optic - Bord Gáis - ESB - Foul Drain Construction works will be carried out on a phased basis to maintain restricted traffic flow. The open channel immediately upstream of the entrance to Greenwood Estate (chainage 4700 to 4686) will be back filled and covered over leading to the creation of a public amenity space.
Existing Tramore River Channel (70m)	Tramore River	4653-4583	The existing channel will be widened by 1 metre over this 70m reach	The existing open channel will be widened along the left bank by approximately 1m.

5.3 Option 2 – Culvert Parallel with Togher Road

This option is very similar to Option 1 and only differs in the alignment of the culvert along Togher Road. Downstream of Togher Road roundabout, the alignment of the proposed culvert deviates from the route of the existing culvert as it would be orientated parallel to Togher Road and aligned through private properties to the West of the road as indicated in Figure 11. The existing culvert will be left in situ.

At Togher Community Centre, the culvert would cross under Togher Road to outfall into the Tramore River immediately downstream of the entrance to Greenwood Estate.

The existing open channel reach, upstream of Greenwood Estate will be backfilled and covered to create a small local amenity area.

At the culvert exit, the existing open channel will by widened on the left bank by one meter for a length of circa 70m.

Option 2 necessitates extensive work on private property during the construction phase but would minimise works on public roads. This would minimise traffic disruption during construction but would involve disturbance to land owners and occupiers. This option would also involve a significant amount of disruption to existing services.

Option 2 is presented in Figure 11 and a typical cross section is presented in Figure 12.

Figure 11: Option 2 – Culvert parallel with Togher Road

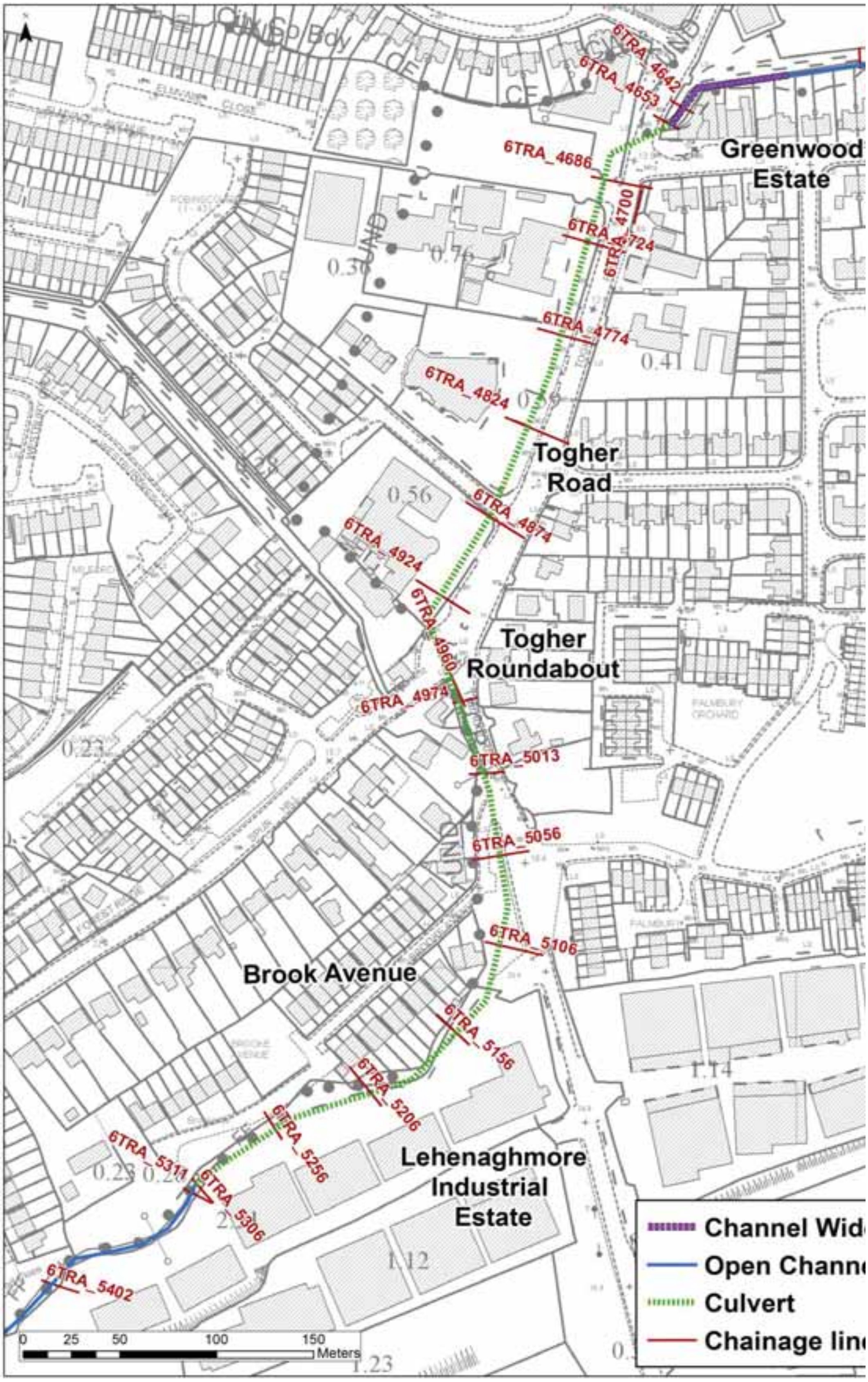


Figure 12: Option 2 – Indicative Cross Section at Church of the Way of the Cross (along Togher Road).

Table 3: Description of Option 2 Works (Culvert parallel with Togher Road)

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Lehenaghmore Industrial Estate Culvert Trashscreen	Tramore River	5323-5311	Existing trash screen structure to be removed and replaced with new screen and defence walls. Screen area to be provided: $56.4m^2$. Structure will be 6.6m wide x 12.4m long).	For further details refer to Trashscreen report
Lehenaghmore Industrial Estate Culvert	Tramore River	5306-5013	Removal of existing culvert network (twin 900mm diameter culverts at chainage 5306 and twin 600mm diameter culverts and a 900mm diameter culvert at chainage 5286 downstream) and replace with a single 3m wide x 1.4m high concrete culvert.	Construction work for the new culvert will be carried out from the southern (Industrial Estate) side of the channel. Traffic management and close liaison with industrial unit occupants will be necessary.
Existing Open channel reach upstream of Togher Road Roundabout	Tramore River	5013-4962	New 3m wide x 1.4m high concrete culvert to replace existing 2.5m wide x 0.9m high open channel reach.	The existing open channel form part of the new single culvert leading to the creation of a new pedestrian area. Construction work will be in a confined area adjacent to a busy, narrow road. Significant traffic management will be necessary.
Togher Road Existing Trashscreen Structure	Tramore River	4962	Existing trash screen structure to be removed	No trashscreen required as the reach is to be culverted.
Togher Roundabout	Tramore River	4962-4934	New 3m wide x 1.4m high concrete culvert to replace existing culvert	Careful attention to detail will be required to ensure the foul drainage line at the roundabout is not interfered with as a consequence of the works.

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Togher Road (south of the point where existing culvert crosses Togher Road)	Tramore River	4962-4709	New 3m wide x 1.4m high concrete box culvert to be installed parallel with Togher Road.	The existing box culvert along Togher Road (to chainage 4709) will be left in-situ. Land acquisition will be necessary for this reach as the new culvert will be aligned through private grounds. Construction works will be required on the Doughcloyne private premises (run by the HSE), The car park area of the Church of the Way and through Togher Boys National School and across numerous access routes. The works will require significant traffic management at the access and egress points of the properties. Considerable attention to detail will be required for existing underground services as the culvert interfere with their routing.
Togher Road (north of the point where existing culvert crosses Togher Road)	Tramore River	4709-4653	Removal of existing 1.8m x 1m box culvert along northbound lane and replace with larger 3m wide x 1.4m high concrete culvert.	At this section the new culvert route deviates from the existing culvert route. The new culvert will continue north along Togher Road before turning northeast at chainage 4663 to join into the existing open channel downstream of the entrance to Greenwood Estate. As the culvert crosses Togher Road a number of existing services will be disrupted by the works. These include: - Eircom - Watermain - UPC Fibre Optic - Bord Gáis - ESB - Foul Drain Construction works will be carried out on a phased basis to maintain restricted traffic flow. The open channel immediately upstream of the entrance to

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
				Greenwood Estate (chainage 4700 to 4686) will be back filled and covered over leading to the creation of a public amenity space.
Existing Tramore River Channel (70m)	Tramore River	4653-4583	The existing channel will be widened by 1 metre over this 70m reach	The existing open channel will be widened along the left bank by approximately 1m.

5.4 Option 3 - Open Channel

The proposed alignment of the open channel is presented in Figure 13.

The alignment is constrained through the reach by the road and existing properties and there is little scope to align it differently. An exception to this is immediately downstream of the entrance to Southern Fruits where the open green area allows the channel to be aligned along a number of routes. In order to maximise the open channel's social amenity through this area, the channel has been aligned adjacent to the footpath.

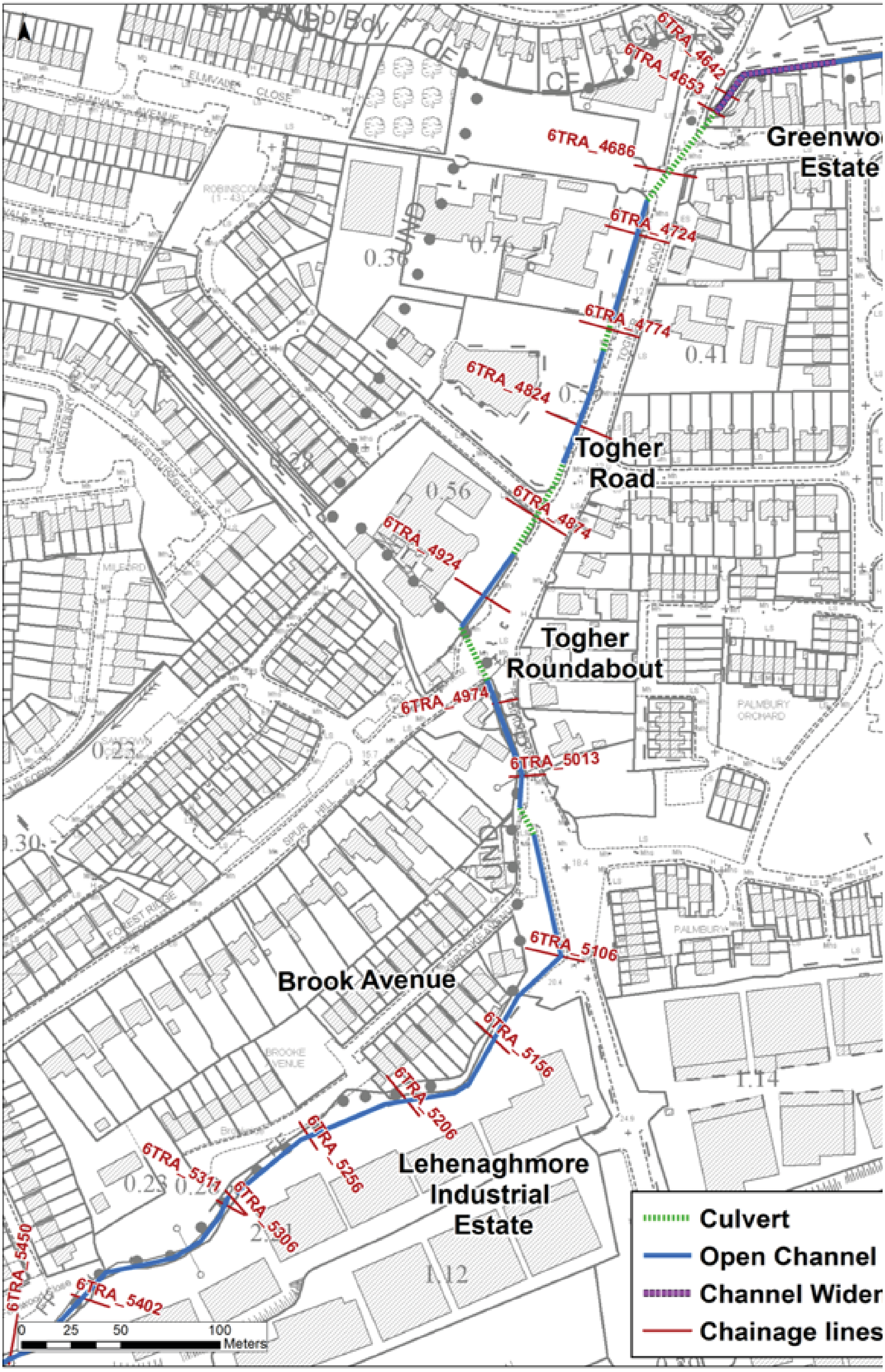
It can be seen from the figure that it will be necessary to incorporate five culverts along the route of the open channel in order to maintain vehicular and pedestrian access to existing properties and roads from Togher Road. The approximate lengths and sizes of these culverts are presented in Table 4.

The option incorporates a vertical reinforced wall for the right bank of the channel throughout the full open channel and incorporates a 60˚sloped bank for the left hand side of the channel where space allows. This approach will minimise land-take while maximising the amenity value.

It is proposed to create a meandering low flow channel within the open channel. This will ensure ecologically appropriate low flows and provide morphological diversity for habitat creation.

The overall cross sectional area of the channel is guided by flooding requirements which have been assessed using the 1D hydraulic model developed as part of the study. The reader is referred to the accompanying Draft Togher Hydraulics Report for a detailed description of the hydraulic modelling work.

Figure 13: Option 3 – Open Channel



A typical cross section of Option 3 is presented in Figure 14.

Figure 14: Option 3 - Typical Cross Section: Togher Road, at Church of the Way of the Cross.

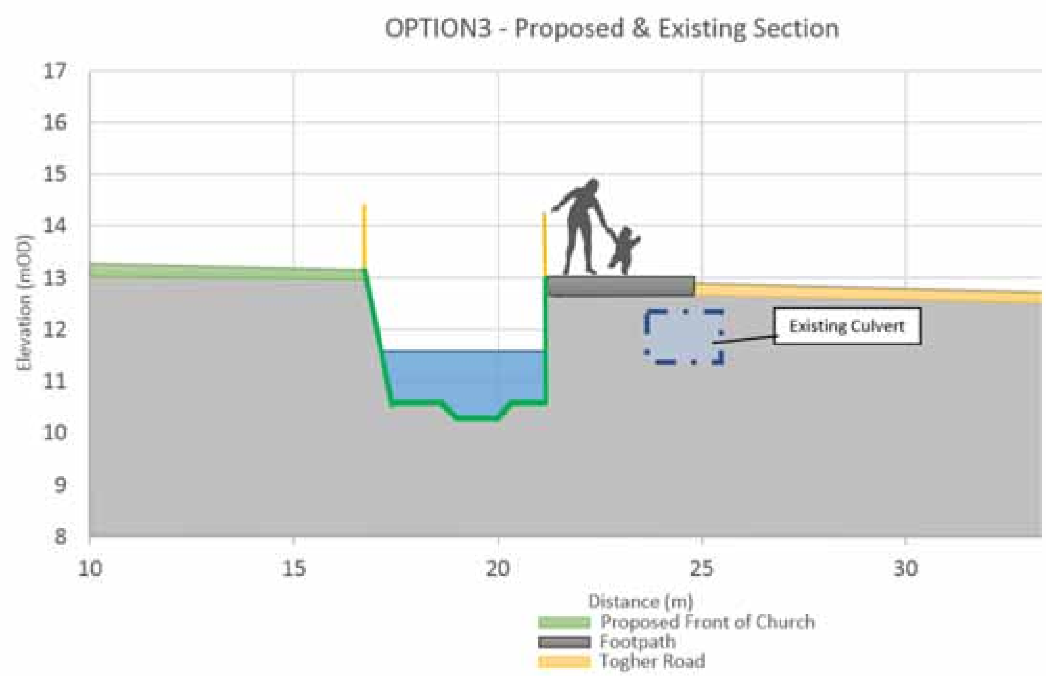


Table 4: Description of Option 3 (Open Channel)

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Lehenaghmore Industrial Estate Culvert Trashscreen	Tramore River	5311	No trash screen	Existing trash screen structure to be removed.
Lehenaghmore Industrial Estate culvert inlet to Brooke Avenue entrance (275m)	Tramore River	5306-5036	Existing culvert along the northern boundary of Lehenaghmore Industrial Estate will be removed. This involves excavation to remove the existing culvert and the construction of a new open channel. The open channel will range in depth from 1.25m to 2.34m. At ground level the culvert will be 3.3m wide. At bed level the channel will be 2.7m wide. The right bank will comprise a vertical reinforced bank while the left bank will be sloped at 60°.	The construction work for the new culvert will be carried out from the southern (Industrial Estate) side of the channel. Traffic management and close liaison with industrial unit occupants will be necessary. Efforts will be made to minimise disruption.
Brook Avenue entrance (Culvert 1) (13m)	Tramore River	5043-5028	The existing reach of culvert (approx. 13m) running under the entrance the Brooke Avenue will be removed and replaced with a larger culvert 3m wide x 0.9m high.	Traffic management will be required during the works to facilitate local access to Brook Avenue.
Brook Avenue entrance to existing open channel reach upstream of Togher Road roundabout (Grass verge) (17m)	Tramore River	5028-5013	The area adjacent to the footpath will be excavated to accommodate the open channel which will range in width from 2.7m to 3.0m at bed level and from 3.0m to 3.3m at ground level. The channel will be 1.8m deep at this location. The right bank will comprise a vertical reinforced bank, while the left bank will be sloped to 60°.	Traffic management will be required during the works to maintain traffic flow on Togher Road. The works will restrict traffic to one lane traffic. Existing road and footpath and furnishings will be reinstated upon completion of construction works.

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Existing open channel reach upstream of Togher Road roundabout (50m)	Tramore River	5013-4962	The existing open channel reach will be reconstructed – the channel will range in width from 2.7m to 3.3m at bed level and be 3.3m wide at ground level. It will range in depth from 1.85m to 2.5m. The right bank will comprise a vertical reinforced bank, while the left bank will be sloped to 60^{o}.	Traffic management will be required during the works to maintain traffic flow on Togher Road. The works will restrict traffic to one lane traffic. Existing road and footpath and furnishings will be reinstated upon completion of construction works.
Togher Road Existing Trashscreen Structure	Tramore River	4962	Existing trash screen structure to be removed	
Togher Road roundabout crossing (Culvert 2) (32m)	Tramore River	4962-4938	New 3m wide x 1.3m high culvert of approximately 32m length to be constructed.	During construction works the roundabout will be removed, to facilitate traffic flow around the works area. Significant traffic management will therefore be required during the works. Following construction the roundabout will be reinstated and all soft landscaping and street furniture replaced.
Doughcloyne Hotel (building is run by the HSE) (45m)	Tramore River	4938-4897	Open channel to be constructed on the grounds of the hotel. The width of the channel will vary from 2.7m to 3.7m at bed level and from 3.3m to 4.3m at ground level. The average depth of the channel will be 2.73m (the maximum depth will be 2.96m). The right bank will comprise a vertical reinforced bank, while the left bank will be sloped to 60^{o}.	Construction work will require diversion of local services and the removal of shrubbery & trees. Where possible removed items will be replaced and included in any soft landscaping of the area following construction.
HSE Building, Robinscourt & Church access (Culvert 3) (52m)	Tramore River	4897-4843	Ground to be excavated and a new 47m long culvert of approximate width of 4m and depth of 1.6m installed. The culvert will run under the entrances to the properties along Togher Road.	Traffic management will be required during the works to facilitate local access. Local services will be diverted. To enable construction work the removal of shrubbery, trees, paving, flagpoles and boundary walls along the route of the culvert will be required. Following construction, all possible items removed will be reinstated.

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Church (58m)	Tramore River	4843-4785	Open channel to be constructed on the grounds of the Church. The width of the channel will be approximately 3.7m at bed level and 4.3 m wide at ground level. The channel will have a depth of 2.4m. The right bank will comprise a vertical reinforced bank, while the left bank will be sloped to 60^{o}.	Construction work will require the removal of trees, grass, paving, flag poles etc. along the channel route. Where possible any such street furniture will be replaced following construction works and car park and pavement surfaces will be reinstated. Construction of the channel will also require diversion of local services. Traffic management will be required during the works to facilitate ongoing access to the church grounds.
Church access (Culvert 4) (16m)	Tramore River	4785-4769	New culvert to be constructed which will be 4m wide x 1.3m high and approximately 16m in length. The culvert will allow for 2 way vehicular and pedestrian access & egress and a parking space along the northern boundary church entrance and parking spaces along its northern entrance.	This culvert approximately 16m in length will allow the existing access and parking along the Church's northern boundary to be maintained and will include pedestrian access to the church grounds. Following construction works, ground will be reinstated to current condition. Local services including Eircom ducts will require diversion to facilitate construction of the culvert. Following construction car park and pavement surfaces will be reinstated.
Togher Boys School (63m)	Tramore River	4769-4703	Open channel to be constructed which will be approx. 2.54m deep, 3.7m wide at bed level and 4.3 m wide at ground level. The right bank will comprise a vertical reinforced bank, while the left bank will be sloped to 60^{o}.	The proposed open channel to run the length of the school yard. To facilitate construction works shrubbery, trees and fence will be removed. Following construction works the boundary fence will be reinstated and the area landscaped. Local diversions will be required for underground services. Contractors will liaise closely with school management with regard to the timing of construction works.

Location (and Total Length of Channel Affected)	Channel	Chainage (approx.)	Description	Comments
Togher Road crossing (Culvert 5) (57m)	Tramore River	4703-4653	New culvert to be installed which will be 4m wide x 1.3m high and approximately 57m long. It will run north eastwards from the northern boundary of the school to outfall directly into the existing open channel, downstream of the Greenwood Estate. The new culvert will bypass the existing open channel reach upstream of Greenwood Estate which will be filled in to create a new community amenity area.	There are a number of services running along Togher Road which cross the route of the new culvert. Based on site visits and drawings received from the utility providers, these services include: - Eircom - Watermain - UPC Fibre Optic - Bord Gáis - ESB - Foul Drain There is expected to be significant cost associated with upholding or temporarily diverting these services to facilitate the works Significant traffic management will also be required during the works.
Existing Tramore River Channel (70m)	Tramore River	4653-4583	The existing channel will be widened by 1 metre over this 70m reach	The existing open channel will be widened on the left bank to provide the channel with the necessary capacity to convey the design flow.

6 Economic Assessment of Shortlisted Options

6.1 Cost Estimate of Shortlisted Options

6.1.1 Introduction

The viable flood relief options for Togher are:

- Culvert along Togher Road
- Culvert parallel to Togher Road
- Open Channel parallel with Togher Road

This chapter details the cost of implementing each option.

6.1.2 Methodology

When building up cost estimates for a scheme of this nature, it is important that the expected whole life costs of the works and its management are developed and not just the scheme capital costs. The following list outlines the areas that were considered when developing cost estimates for this project:

- Construction costs, including the Contractor's general items and overheads.
- Design and site supervision costs.
- Site Investigation and survey costs.
- Environmental mitigation costs.
- Land purchase and compensation costs.
- Maintenance costs.
- Risk based costs.
- Allowance for Art.

The following costs were excluded:

- Value Added Tax.
- Land Remediation.
- Cost of OPW/CCC staff time on the project

6.1.3 Construction Costing Method

Base costs for construction elements of the scheme were obtained from the following sources:

- Estimates and tendered rates from similar civil engineering contracts.
- Published cost databases, including the NRA unit cost database and the draft OPW unit cost database.

The following assumptions have been made when compiling the construction cost estimates:

- Normal working week for construction personnel and plant.
- No exceptional adverse weather.

6.1.4 Environmental/Archaeological Monitoring, Mitigation Works and Improvement Works

Environmental and archaeological monitoring will be required during the construction of the works. It is also likely that some environmental mitigation and improvement works will be necessary. A provisional allowance of 10% of the base construction cost has been included in the cost estimate.

6.1.5 Site Investigation and other Surveys

A site investigation, topographic survey and archaeological survey and CCTV drainage survey will all need to be carried out for the scheme. The total cost of these investigation and surveys is estimated to be approximately €75,000 and has been included in the cost estimate.

6.1.6 Design and site Supervision Costs

An allowance of 10% of the construction cost has been made for design and site supervision costs.

6.1.7 Land Purchase and Compensation

OPW advised that 10% should generally be added to the construction cost of the scheme to allow for:

- Land purchases and compensation.
- Planning, highway and other third party costs.
- Administration and legal costs associated with land exchanges, statutory approvals, planning applications, service diversions, highway adoptions etc.
- Loss of revenue to adjacent or affected buildings

Contrary to the above, a higher allowance for land acquisition of 30% was deemed to be appropriate for the open channel option due to the large land take required.

6.1.8 Maintenance Works Costs

The maintenance regime has anticipated costs associated with the following items:

Table 5: Scheme maintenance items costed

Element	Maintenance Task
Culvert and trashscreen	Inspection (1 x year)

Element	Maintenance Task
	Clearing of silt from culvert (1 x 5 years)
	Clearing of debris from trashscreen (every 2 months)
	Full CCTV survey (1 x 10 years)
Filter drains	Inspection (1 x 5 years)
	CCTV review (1 x 10 years)
	Granular Fill Replacement (1 x 20 years)
Flap Valves	Inspection (1 x 5 years)
	Replacement (1 x 25 years)
Widened channel (d/s of culvert)	Inspection (1 x 5 years)
	Removal of excessive deposition (1 x 10 years)
Entire Scheme	Periodic inspection after major flood events greater than 1 in 25 years (say every 10 years)

Maintenance Costs were estimated in two ways as follows:

1. Building up the estimated costs using an estimated cost for each of the above items particular to the proposed scheme multiplied by the annual frequency of occurrence.
2. Assuming an annual maintenance cost of 1.5% of the Construction Cost.

The latter generally resulted in the higher figure and has therefore conservatively been used.

6.1.9 Project Contingency/Optimism Bias

There is a tendency for budget cost estimates for flood defence schemes to be overly optimistic. In a project of this nature where access for labour, plant and materials will be difficult, including a robust contingency in the cost estimate is essential.

A project contingency/optimism bias of 20% has been included in the cost estimate. This is additional to the allowance for unmeasured items.

6.1.10 Allowance for Art

The “per cent for art” scheme is compulsory for all major public works contracts. For this size of project, the required allowance for art is 1% of the capital cost up to a maximum of €38,000.

To avoid double counting we have assumed that the allowance for art for the scheme has been included as part of the cost estimate for Douglas.

6.1.11 Summary of Costs

Detailed cost build ups are contained in Appendix A. The following table shows the summary costs for each of the viable options.

Table 6 shows the summary of the total costs for each of the viable options.

Table 6: Summary of Costs

	Option T1 – Culvert on road	**Option 2 – Culvert off road**	**Option 3 – Open Channel**
	€	**€**	**€**
Gross Construction Cost Estimate	2,624,072	2,741,819	2,271,132
Prelims 15%	393,611	411,273	340,670
Unmeasured Items 20%	524,814	548,364	454,226
Subtotal	3,542,497	3,701,456	3,066,028
Archaeology & Environmental (10%)	354,250	370,146	306,603
Construction Cost Total	**3,896,747**	**4,071,602**	**3,372,631**
Contingency / Optimism Bias (20%)	779,349	814,320	674,526
Land Acquisition: (Option 1 & 2 – 10%; Option 3 – 20%)	389,675	407,160	674,526
Fees and Supervision (10%)	389,675	407,160	337,263
Allowance for Art	0	0	0
Site Investigation & Surveys	75,000	75,000	75,000
Capital Cost Total	**5,530,445**	**5,775,243**	**5,133,947**
Maintenance (NPV)	956,226	1,003,508	937,273
Project Cost Total	**€6,486,672**	**€6,778,751**	**€6,071,220**

6.2 Damages Assessment

6.2.1 Overview

The benefit to be derived from the flood protection works is the reduction in risk of flooding to land and property. This risk is quantified as the expected damage to property that would occur over the lifetime of the scheme.

It is not within the scope of the project to estimate the monetised flood damages for Togher following the same detailed methodology used for Douglas and detailed in the Douglas Options Report.

We have instead adopted the economic flood damages as calculated by the Lee CFRAM for Togher for the purpose of this report. The limitations of this approach is discussed in the following section.

6.2.2 Damages Assessment as Undertaken by the Lee CFRAM

Economic flood damages for Togher were undertaken in accordance with the OPW guidance document "Lower Lee, Douglas and Glashaboy Flood Relief Schemes: Economic Damage Assessment and Coast Benefit Analysis (Rev B)". Flood damage data for Douglas was assessed from the "The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques (2014)" published by the Flood Hazards Research Centre at Middlesex University a.k.a. the "Multicoloured Manual" (MCM).

The Lee CFRAM damages assessment methodology predates both of these guidance documents. The calculations were undertaken in accordance with guidance issued by OPW as part of the Pilot Studies of the National CFRAM Project and flood damage data was provided from the 2006 version of the MCM.

The Lee CFRAM Togher damages assessment was therefore reviewed in light of the different approaches taken in the estimation of the damages. A number of discrepancies were found as follows:

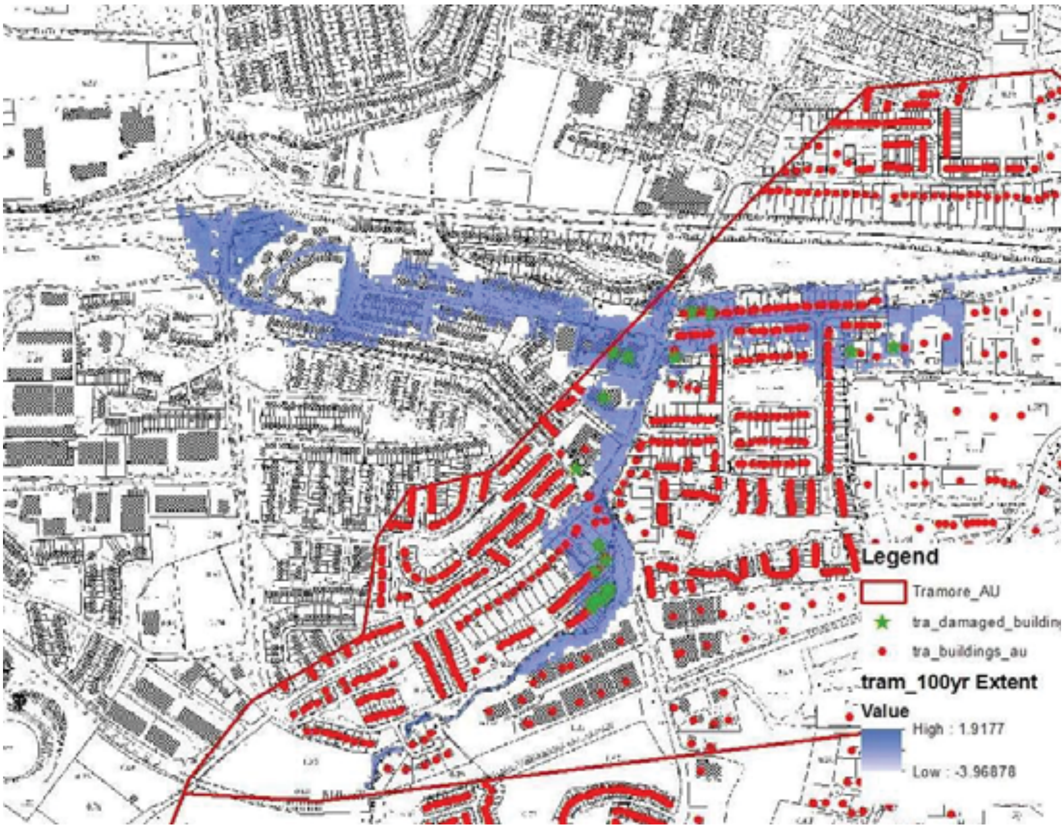
- The Lee CFRAM did not take account of any direct damage below ground floor level - current guidance states that residential damages start at 300mm below ground floor level;
- The order of the currency conversion from Sterling to Euro is incorrect in the Lee CFRAM approach - The Lee CFRAM first applied the UK CPI to bring the base 2005 damages to 2007 values, then converted with 2007 PPP;
- Utility damages were not included in the Lee CFRAM - current guidance states that utility damages is set at 20% of direct damages;
- Emergency services costs were not included in the Lee CFRAM - current guidance states that emergency services damages is set at 8.1% of direct damages;
- The Lee CFRAM damages calculation only considered the flood damage from 18 buildings in Togher. Economic flood damages incurred by properties west of Togher were ignored in the analysis. It can be seen from Figure 15 that this assumption means that approximately 80 properties at risk of flooding in Togher have been not been considered as part of the damages calculation. This omission is deemed to be very significant;
- The Lee CFRAMS cost-benefit analysis did not take account of residual damages above the 1% AEP event;
- The discount rate used in the Lee CFRAMS was 4% for costs which is in line with current OPW guidance. There is a suggestion however in one of the guidance noted produced as part of the project and made available to Arup that a 5% discount was used for the damages calculation (the reader is referred to the "*Damage Assessment_Methodology.IT.doc*" document).

The damages assessment spreadsheet developed by the Lee CFRAM project was reviewed in attempt to verify the above, but the formula for the present value calculation is not included in it.

The following aspects of the CFRAMS damages assessment are in line with current guidance,

- Intangible damages were included for residential properties;
- A 50 year project horizon was used.

Figure 15: Togher Q100 flood extent as estimated by the Lee CFRAM. The properties included in the damages assessment are indicated with the red points.



It can therefore be concluded that in light of these various discrepancies and the omission from the damage calculation of a significant number of properties at risk of flooding, the Lee CFRAM damages assessment significantly underestimates the value of damages in the context of current guidance.

The Lee CFRAMS estimated the Present Value of Damages for the Douglas/Togher APSR to be equal to €7,440,000. This figure is for Togher and Douglas combined.

PV of damages for just Togher can be estimated by filtering the results as presented in the spreadsheet and only consider properties in Togher. This is estimated as **€6,964,394**. It is noted that Togher National School at the downstream end of the reach makes the biggest contribution to the PV damages (66% of the total).

6.3 Cost Benefit Analysis of Options

Table 7: Benefit Cost Ratios

	Do Nothing Option (€m)	Option T1 – Culvert on road (€m)	Option T2 – Culvert off road (€m)	Option T3 – Open Channel (€m)
Present Value Cost (PVc) (€m)	**0**	**6.48**	**6.77**	**6.07**
Present Value Damage (PVd) (€m)	**Not calculated**	**Not calculated**	**Not calculated**	**Not calculated**
Present Value Benefit (PVb) (€m)	**-**	**6.96**	**6.96**	**6.96**
Average Benefit Cost Ratio (BCR)		**1.07**	**1.02**	**1.14**

It can be seen from the table that each of the three options considered are cost beneficial. It can also be seen that each of the three cost-benefit ratios are marginal.

As noted however in the previous section, the Lee CFRAM damages assessment represents a significant underestimation of the economic flood damages arising in Togher. Consequently, the benefit cost ratios are also significantly underestimated. Each of the three options are therefore all likely to have a much stronger cost-benefit ratio.

A sensitivity analysis has not been undertaken on the results given the uncertainty over the baseline damages figure.

These findings have been discussed with the project Steering Group and it is accepted that the scheme in Togher has, in practice, a strong cost benefit ratio and further cost benefit analysis is not warranted for the project.

7 Environmental Constraints

7.1 Summary of Constraints

This chapter details the various categories of environmental constraint associated with the design and delivery of the flood alleviation works relating to upgrading the Togher culvert, which no longer has the required capacity. It explains which receptors may be impacted upon by possible flood alleviation measures. In doing so it discusses the features which should be taken into account when designing the scheme.

7.2 Potential Impacts

7.2.1 Terrestrial Ecology

With regard to terrestrial ecology, the scheme design should take into consideration the following key constraints:

- Designated conservation sites, in particular the Cork Harbour Special Protection Area (SPA), which is protected under European legislation; and Douglas River Estuary and proposed Natural Heritage Area (pNHA), which is protected under national legislation, into which the Tramore River discharges.
- Terrestrial and riparian habitats which are considered of high value at a local level. Linear features in the landscape, such as rivers, can function as important wildlife corridors for species such as otter and bats. The location of the valley on the periphery of an urban area gives it a high amenity and recreational value.
- Bats are protected by law in the Republic of Ireland under the Wildlife Act 1976 and subsequent amendments. In addition to domestic legislation bats are also protected under the EU Habitats Directive. They are at risk through potential loss of roosting sites, loss of foraging areas and disruption of commuting roosts.
- Otter are listed on Annex II of the Habitats Directive. They can be impacted via noise and disturbance, potential impacts on prey availability if fish populations are affected, potential impacts on resting areas/holts and potential impacts on movement along watercourses. They are also affected by culverting.
- Kingfisher is listed on Annex I of the EU Birds Directive and could potentially be present, although this is considered unlikely. Impacts on this species could theoretically arise due to disturbance or loss of breeding habitat.
- A variety of plant, invertebrate, bird and mammal species occur within the habitats potentially affected. Impacts on these species could occur due to loss of habitat, habitat fragmentation and increased noise and disturbance.
- The highly invasive species Japanese Knotweed (*Fallopia japonica)* was recorded along the Ballybrack River within habitats potentially affected by this project. Japanese Knotweed is highly problematic species which successfully competes with native species and which is extremely difficult to control.

7.2.2 Aquatic Ecology

With regard to aquatic ecology, the scheme design should take into consideration the following key constraints:

- Designated sites, and in particular the Cork Harbour SPA and Douglas River Estuary pNHA into which the Tramore River discharges. Impacts on these could potentially occur if severe deteriorations in water quality were to arise due to inappropriate work practices or accidental spillage of hydrocarbons, concrete or other deleterious material.
- Riparian habitat which provides food, cover and shade and helps to stabilise river banks. Loss of riparian habitat could potentially occur due to culverting and dredging.
- Populations of Brown Trout Eel and macroinvertebrates could potentially be affected. Some suitable habitat for Brook Lamprey, which is listed on Annex II of the Habitats Directive was also recorded although this species was not recorded during an electrofishing survey that was carried out in 2014. Impacts could potentially occur on these species due to loss of habitat. In addition, high levels of silt during construction can can impact on salmonid spawning habitats. High silt levels may also impact on macro-invertebrate populations and on aquatic flora. The scheme design should take into consideration that dredging has the potential to directly impact on eggs and juvenile fish...
- Movement of fish. Notwithstanding that there has already been significant culverting of watercourses, the scheme design should take into consideration that further culverting may further restrict the movement of fish and may lead to a net loss of habitat.
- The scheme design should take into consideration that modifications of the river channel structure may result in the loss of habitat for particular age classes of fish i.e. riffle for juvenile fish or pools for adult fish. Such changes may impact on population dynamics.
- In salmonid waters, any instream works should generally be restricted to the period from July to September, inclusive.
- Due to the limited size of watercourses within the project area, relatively small volumes of polluting material during construction could have a significant impact. Inadvertent spills of hydrocarbons, poorly maintained machinery or inadequate storage should be avoided.

The construction of a replacement culvert is likely to cause negative impacts on fisheries habitats within the channel. Lack of daylighting is also likely to negatively affect fish and invertebrates. The existing condition of the waterbody could be deteriorated as a result of the defence works. Short term negative impacts are inevitable as a result of the construction works.

7.2.3 Archaeology, Architectural and Cultural Heritage

Impacts on sites of archaeological, architectural and cultural heritage interest will need to be considered, in the course of this project.

The constraint Study Area for the culvert comprises a very small area in and around the culvert.

There are no sites listed in the RMP, NIAH or County Development plan within the Study Area. Some buildings of cultural heritage interest fall within the constraint Study Area as the culvert runs through the old settlement of Togher. These are not afforded any special protection. At the junction of Spur Hill and Togher Road there is a single storey house (CHS 3) which is shown on all editions of the OS maps; the lodge (CHS 4) to the now-demolished Doughcloyne House stands opposite this and a school (CHS 5) depicted on the 1902 OS 25 inch map remains standing further to the north.

Within the Togher Culvert Study Area:

- There are no sites listed as National Monuments.
- There are no sites listed in the Register of Historic Monuments.
- There are no sites subject to Preservation Orders.
- There are no archaeological sites considered to be of international, national, local or regional importance.
- There are no structures listed in the Record of Protected Structures.
- There is one Area of Archaeological Potential - The Tramore River.
- There are three Cultural Heritage Sites not listed in any of the above, which are explained in Table 2.3 below.

Table 2.3: Cultural Heritage sites within the Togher Culvert Constraint Study Area

CHS No	Name	Location
CHS 3	Single storey house	Junction Togher Rd /Spur Hill
CHS 4	Lodge	Junction Togher Rd /Spur Hill
CHS 5	Old Schoolhouse	Togher Rd

Sites to be considered as key constraints in the Togher Culvert Study Area are:

- Three cultural heritage sites i.e. a single-storey house and a lodge at the junction of Togher Road and Spur Hill, and an old schoolhouse on Togher Road.
- The Tramore River. It is possible that remains associated with human activity from the earliest times may still survive along the banks of the river or in the river itself.

It is recommended that any proposed works to the Tramore River be archaeologically assessed in advance of works taking place. Where mitigation measures are possible these must be implemented to guarantee minimal negative impact to the integrity of these features.

7.2.4 Soils, Geology and Hydrogeology

Soils and Geology

It is recommended that a geotechnical investigation be carried out once the potential flood alleviation measures are developed in order to identify local geology and ground conditions.

Hydrogeology

The design should take into consideration the impact that any proposed flood relief scheme will have on the yields of existing groundwater abstractions from groundwater bodies in the Study Area, and take into account the vulnerability rating of the local aquifers.

The scheme design should take into consideration sensitive and protected areas identified in Appendix 3.1 of the South Western District River Basin Plan, including the protected 'Drinking Water Protected Area – Groundwater' bodies Cork City 2 and Cork City 3 to ensure that the quantity and quality of these drinking water sources are not affected.

GSI online mapping of 'Groundwater Well Data' indicates that there are groundwater wells in the Douglas River area. GSI mapping indicates that the Togher Culvert area is located approximately 60m west of two areas indicated as 'Wells Accuracy within 1km'.

GSI online data also indicates that the aquifer vulnerability in the vicinity of the Douglas River comprises 'X- Rock at or near Surface or Karst', 'E - Extreme' 'High' and 'M- Moderate', and in the vicinity of Togher Culvert, the aquifer vulnerability is similarly classified, with 'Moderate' aquifer vulnerability to the north of the Togher Culvert.

The scheme design should take into account the main objectives of the Water Framework Directive South West River Basin District Management Plan by ensuring that any works proposed do not result in the deterioration of water quality.

The scheme design should ensure that any works proposed do not result in the deterioration of water quality in Lough Mahon.

Improved channel conveyance may have the potential for negative impacts on the waterbody. Excavation, disruption and restoration of natural banks may cause negative short term impacts.

7.2.5 Socio-Economic Constraints

Socio-economic constraints relate primarily to impacts on human beings and quality of life. In designing the proposed scheme, the value (both cultural and economic) of any buildings close to watercourses, or likely to be adversely affected by the scheme should be taken into account. This includes public amenity areas, housing, commercial properties and also tourism.

Existing bridges are important for vehicular and pedestrian traffic, and any disruption to their use during construction and operation should be minimised.

Impacts on public amenity areas adjacent to the river including riverside walks and parks and playground should be considered, such as walkways through Mangala and Ballybrack, through Doman's Wood, the footpath running parallel to the Tramore River, and the Douglas Community Park. Specialist amenity areas such as any sports grounds and golf courses, should also be given consideration. The visual amenity of the area is also an important consideration.

Long-term, the replacement of the culvert at Togher will not have significant impacts on the visual amenity of the area as there will not be a major change.

Properties and businesses currently accessed by culverted sections or bridges over the Douglas and Tramore Rivers in Togher will need to have access maintained/re-established, if works in these areas are proposed. Access during construction will also need to be considered.

Impacts on sensitive receptors e.g. schools, crèches, and nursing homes should be considered during both construction and operation. Traffic disruption on sensitive receptors during construction should also be considered.

The proposed scheme should take consideration of the proposed zoning objectives and relevant specific objectives set out in the Cork County Development Plan 2009 and the Carrigaline Electoral Area Local Area Plan, and any future changes future development or changes in landuse in the Study Area. It should also note that the South West Regional Planning Guidelines 2010-2022 cite Cork as a prime location for regional tourism and Ireland and that the local tourist industry generates €1.3bn in revenue on an annual basis. Disruption to tourist facilities could therefore be extremely costly to the local economy.

7.3 Cumulative Impacts

Cumulative impacts are those resulting from a combination of two or more of the flood alleviation measures. Many of the cumulative impacts of a flood relief scheme are positive. However these are not covered in the context of the environmental constraints. The following is a list of the constraining cumulative impacts likely to arise as a result of the proposed scheme:

- Disruption to local road users and utilities as a result of the construction works. The duration of this is therefore short-term.
- The works may generate suspended solids and possibly hydrocarbon pollution depending on the design and management of the construction works.

  This can have negative short-term impacts on aquatic flora and fauna. Salmonids are particularly vulnerable to any cement solids or hydrocarbon residues that may be introduced into the waterways.
- Mechanical works alongside the river bank can may adverse, long-term impacts on in-channel flora and fauna. Works along the river can have impacts downstream, e.g. fluvial transport of knotweed remnants that may introduce the plant to areas where it was not present previously.

7.4 Conclusions and Recommendations

The provisional analysis of the environmental impacts has highlighted that the impacts can be classified on the basis of severity and duration. Many of the potential negative impacts are likely to be short-term and not significant. The upgrading of the existing culvert is not expected to cause significant disruption to any of the categories of constraint analysed. The scheme will take into account the key environmental constraints in order to reduce these negative impacts by design.

- It is recommended that the existing and proposed location of watermains and underground services in the vicinity of any proposed flood relief scheme be ascertained as part of the Engineering Study. It is recommended that Cork City and County Councils and other utility providers with services in the Study Area be consulted regarding the location and priority of existing and proposed services. It is further recommended that the services be protected as part of any proposed flood relief scheme.
- It is recommended that Cork City and County Councils and the National Roads Authority be consulted in relation to any effects on the existing and proposed roads infrastructure in the Study Area from any proposed flood relief scheme.
- It is recommended that the requirements of the Cork County Council Development Plan be observed in relation to waste management assessments.

8 Climate Change Adaptability

In considering the merits of the potential options, it is important that the short term proposals are considered in the context of a longer term strategy which is flexible and adaptive to changes in the climate and its potential impact on flood risk.

The measures considered can be categorised according to the two primary options considered as part of the project:

- Single Culvert;
- Open Channel.

The adaptability of these measures are discussed below.

8.1 Single Culvert

Once constructed, the culvert option cannot be adapted for increases in flow that may arise from changes in climate. Therefore, it is necessary to design and construct the culverts to include for a best estimate of the likely increase in flows due to climate change. The culvert has therefore been designed to meet the requirements of Section 50 of the ADA.

Our analysis confirms that the culvert is sufficiently sized to ensure that flows in excess of the design flow will not lead to pressurised flow in the culvert.

The risk of flooding from the culvert in the future in a climate change scenario is therefore limited to the potential for surcharging at the culvert entrance. Future direct defences can be constructed at the culvert inlet to ensure no out of bank flooding at the entrance.

8.2 Open Channel

The open channel option is adaptable to increases in flow in the channel that may arise from changes to the climate. Two adaptation strategies are feasible: (1) conveyance improvements, and (2) direct defences.

8.2.1 Conveyance Improvements

The bed of the channel can be deepened to increase the capacity of the channel and allow a greater flow be conveyed through the reach. The channel may also be widened on the left hand side to also increase its capacity. The five culvert along the reach would also be designed to meet Section 50 requirements.

8.2.2 Direct Defences

Direct defences can be constructed at either side of the open channel in the future to address climate change. Defences can also be constructed at the entrances to the five culverts along the reach if required. This measure would increase the capacity of the channel and allow it convey a greater flow through the reach.

It is noted however that such a measure would reduce the social amenity of the open channel by interfering with the view of the channel.

8.3 Climate Change Adaptation Strategy

The various Climate Change Adaptation Strategies considered for Togher are summarised in Table 8.

Table 8: Flood relief measures for Togher

Option Considered	**Climate Change Strategy**
Single Culvert Option	Direct Defences upstream of the entrance to the culvert
Open Channel Option	Conveyance improvements and/or direct defences throughout the reach

9 Multi Criteria Assessment of the Shortlisted Options

9.1 Introduction

The effectiveness of each of the viable options can be measured in terms of how it achieves a set of flood risk management objectives. This section describes the detailed multi-criteria analysis (MCA) of the shortlisted options which was carried out to evaluate the performance of each option in terms of predefined objectives. As part of this process, each objective was given a global and local weighting. Each option was then scored relative to the present day situation (baseline condition), based on how well they met the objectives. The output from this stage was a total weighted score for each option. The option with the highest score is deemed to most desirable.

The local weightings and scorings for each of the criteria were determined as part of a workshop help with Cork County Council and OPW.

9.2 Flood Risk Management Objectives and Weightings

The flood risk management objectives were categorised as follows:

- Technical
- Economic
- Social
- Environmental

The categories were sub-divided into objectives (see Table 9). Each objective was weighted to reflect their importance and/or sensitivity, and to ensure that the objectives most relevant to the location under consideration were given priority in the decision-making process.

Two types of weighting were used:

- Global weighting (ranging between 5 and 30) which applied a weighting, fixed by the OPW at a national level, to each objective used. The global weightings are shown in Table 9.
- Local weighting (ranging between 0 and 5) which was specific to the importance of each objective in the location where the option was being considered. The local weightings are shown in Table 10.

Table 9: Flood Risk Management Objectives and Global Weightings

Category	Objective	Global Weighting
Technical	Operationally Robust	20
Technical	Health & Safety Risk	20
Technical	Adaptability	20
Economic	Economic Return	30

Category	Objective	Global Weighting
Economic	Transport and utility Infrastructure	10
Economic	Agriculture	10
Social	Risk to Human Health	30
Social	Community Risk	10
Social	Risk to Social Amenity	5
Environmental	Ecological Status	15
Environmental	Pollution Sources	15
Environmental	Habitats	5
Environmental	Fisheries	5
Environmental	Landscape Character	10
Environmental	Cultural Heritage	10

Table 10: Local weightings

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

9.3 Scoring

Each option was then scored relative to the present day situation (baseline condition), based on how well they met the objectives. The scores used ranged between -999 and 5 as shown in Table 11.

Table 11: Scoring System

Impact	Score
Achieving aspirational target	5
Partly achieving aspirational target	3
Exceeding minimum target	1
Meeting minimum target	0
Just failing minimum target	-1
Partly failing minimum target	-3
Fully failing minimum target	-999
Uncertain	N/A

A description of the minimum targets and aspirational targets for each objective are included in Appendix B.

9.4 MCA Assessment

A total weighted score was then calculated for each objective as the sum of the weighted scores across the 15 flood risk management objectives. This MCA score reflected the performance of the option in terms of the study's objectives.

The weighted score was calculated as follows:

WS = (GW x LW) x S

Where:

- WS = Weighted Score
- GW = Global Weighting
- LW = Local Weighting
- S = Score

The total MCA score was the sum of the scores for each objective.

The detailed MCA assessment is included in Appendix B.

9.5 Summary

Table 12 shows the results of the MCA analysis. It can be seen that all three options are close in terms of MCA benefit scoring, Option Selection Benefit Scores and economic benefit cost ratio.

Full details of the individual scores for each criteria for each option, together with the rationale for same, is included in Appendix B.

Table 12: MCA results

	Option 1 – Culvert on Road	Option 2 – Culvert off Road	Option 3 – Open Channel
MCA Benefit Score	2265	2250	2300
Option Selection Benefit Score	2365	2450	2400
NPV Capital Costs (€m)	5.53	5.77	5.13
MCA Benefit/Cost Ratio	0.40	0.39	0.44
NPV Economic Benefit (€m)	6.9	6.9	6.9
Economic Benefit/Cost Ratio	1.07	1.02	1.14

10 Selection of the Preferred Option

10.1 Introduction

The extent and severity of the flood risk in the study area was first established through a hydrology study undertaken by Arup and through consultation with output from the Lee CFRAM project.

A range of potential flood risk management measures were reviewed as part of an initial screening exercise. A number of potentially viable flood risk management options were then developed to outline design level. Each of the options were costed and through use of the damages assessment from the Lee CFRAM, a cost benefit analysis was undertaken.

Public consultation was carried out throughout the project and is considered to be and have been an important part in the evolution of the proposed scheme and the ultimate decision on a preferred option. This consultation consisted of public consultation days as well as statutory consultation with all relevant stakeholders.

The feedback from this consultation process has been carefully considered and taken on board in finalising the scheme.

The options were also holistically reviewed by the project team as they were developed, and relevant issues were discussed with the Steering Group.

A final decision on the preferred option was made based on a holistic evaluation of the following key aspects:

- Findings of Cost Benefit Analysis
- Findings of Multi-Criteria Analysis
- Consideration of the key core messages which arose during the stakeholder consultation process
- Consideration of Key Risks
- Consideration of Climate Change Adaptability
- Combined professional judgement of the steering group members

The following sections summarise the critical issues with each potential option, along with reasons for ruling the options out where relevant.

It is noted that there is very little difference between Option 1 (Culvert on road) and Option 2 (Culvert off road) in terms of MCA scoring and costs. The key differences are therefore between the both culvert options and the open channel option.

10.2 ‘Do-Minimum’.

This option was ruled out as the flood risk in the catchment would remain at similar levels to the existing case.

10.3 Option 1 – Culvert on Road

This option has been selected as the preferred option for Togher. The justification for doing so is as follows:

- All three options have similar MCA benefit scores;
- The risk of people entering the Tramore River through the reach considered will be eliminated. This is one of the primary reasons as to why this option was selected over the open channel option. One of the key findings of the public consultation was that the property owners/occupiers adjacent to Togher Road had a strong desire to maintain the culvert option through Togher as they deemed the open channel option to introduce an unacceptable level of risk to the area in terms of people entering the watercourse and coming to harm. This was felt to be a valid concern by the steering group given the nature of the properties in question: a primary school, a church and residential care home for people with mental illness that is run by the HSE. It is noted that the trashscreen at the entrance to the culvert will be designed to prevent people from entering the culvert at this locations;
- The risk of illegal dumping into the Tramore River through the reach considered in the study will be eliminated;
- Achieves the objectives of the project and allows for adequate freeboard and climate change adaptability in the scheme.

10.4 Option 2 – Culvert off Road

This option scored very similar to Option 1 (culvert on road). It was originally considered as an alternative to the on-road version on the basis that there would be less traffic disruption and likely less interference with services. However, a more detailed assessment of the services confirmed that there were also significant services in the area to the west of the road and therefore no benefit arose in this regard. It was ultimately discounted as its construction would involve considerable disruption to the private properties adjacent to Tramore Road. Given the sensitive nature of these properties, this option was therefore discounted.

10.4.1 Option 3 – Open Channel

Of the three options considered, this option scored marginally the highest in terms of MCA Score. It has not however been selected as the preferred option for the scheme. The justification for not selecting it are:

- As outlined in Section 10.3, this option introduces the risk of people entering the watercourse in Togher which was deemed to be unacceptable by the property owners/occupiers along Togher Road;
- Given that all three options scored very similar MCA Benefit scores, there is no clear advantage to this option in scoring the highest MCA Benefit score;
- This option introduces the risk of illegal dumping into the Watercourse through Togher;

- There is a low risk of blockage at each of the five culvert entrances along the route of the open channel. In the event of a severe blockage occurring there is a risk of flooding of Togher;

10.5 Conclusion

Each of the options were subject to detailed assessment as they were developed.

It was found that the standard decision support tools for options assessment (CBA and MCA) resulted in very small differences between the three options and can therefore only be used as indicators on which the inform the use of professional judgement, i.e. it is a decision support tool, not a decision making tool.

The open channel option introduces the risk of people entering the watercourse. While this risk would be minimised through the provision of fencing along both sides of the channel, it was deemed to be unacceptable by the property owners/occupiers adjacent to Togher Road who expressed a strong desire to maintain a culvert option to convey the Tramore River through Togher. This was felt to be a valid concern by the steering group given the nature of the properties in question.

The culvert along Togher Road was therefore selected as the preferred flood relief option for Togher.

11 Refined Design of the Trash Screen

11.1 Introduction

Subsequent to the selection of the preferred option, Arup has undertaken a detailed assessment of the proposed trash screen at Lehenaghmore Industrial Estate. The required area of trash screen required at the entrance to the culvert was calculated as 55.6m^2.

It is proposed to locate the culvert inlet approximately 12m to the west of the existing trash screen. The benefits of locating the screen at this location are:

- It will allow the trash screen to be constructed off-line;
- It will avoid having to locate the inlet structure and screen next to the narrowest section of the industrial estate on the right bank which will avoid creating a bottleneck for the vehicular activities within the site;
- It will also improve accessibility for construction and maintenance.

It is also proposed to include a screen bypass to mitigate the residual blockage risk. A security screen at the downstream end of the culvert will also be provided to prevent unauthorised access to the culvert.

12 Section 50 Requirements

12.1 Introduction

The preferred option is to be designed in accordance with Section 50 requirements. Section 50 requirements are generally intended to ensure a conservative approach to one off culverts/bridges where the wider impacts may not necessarily be understood. In the context of a flood relief scheme, where the entire affected reach is being considered and modelled, it may be reasonable to relax the Section 50 requirements whilst still ensuring a robust solution.

12.2 OPW Guidelines

Over the course of this project, OPW has advised Arup that for culverts the following guidelines should be considered:

- Ideally the maximum net head loss over the length of the culvert is 0.1m;
- Drowning of the outlet of the culvert is permitted provided it is controlled;
- Surcharging of the inlet to the culvert is also allowed in the design flood condition provided that all head losses including entry losses are taken into account in the analysis;
- As a consequence, there is no requirement for freeboard in the culvert provided all appropriate head losses are properly accounted for;
- Velocities should not exceed 1.5m/s within the culvert except where this is unavoidable because of the natural gradient of the watercourse.

Therefore, while it is desirable to reduce the net head losses to less than 0.1m and have freeboard within the culvert, it is not an absolute requirement.

12.3 Design of the Culvert

It has been ensured that for the design Q100 Section 50 flow (11.1m3/s) a minimum freeboard of 200mm is maintained throughout the length of the culvert. There is therefore no surcharging of the culvert entrance, culvert outlet or culvert barrel for the design Section 50 flow and the culvert as a consequence strongly complies with OPW Section 50 requirements.

The preferred option for Togher is therefore suitably resilient to uncertainty in hydrological estimation, hydraulic modelling etc. and a detailed freeboard analysis is not required as part of the study.

13 Conclusion

Following a review of the potential viable measures to mitigate flood risk in Togher, 3 potentially viable options that protect to the design standard of protection for the Scheme (1% AEP Fluvial) were developed to outline design level and can be summarised as follows:

- Option 1 – New Culvert along Togher Road;
- Option 2 – New Culvert parallel with Togher Road;
- Option 3 – Open Channel with a number of culvert crossings along its route

A final decision on the preferred option was made based on a holistic evaluation of the following key aspects:

- Findings of the Multi-Criteria Analysis;
- Findings of the Cost Benefit Analysis;
- Consideration of the key risks;
- Consideration of the key core messages which arose during the stakeholder consultation process;
- Consideration of Climate Change Adaptability;
- Combined professional judgement of the steering group members.

Following this evaluation, Option 1 was selected as the preferred option. The justification for doing so was:

- It has the highest benefit cost ratio as it is the cheapest option to construct;
- The risk of illegal dumping into the Tramore river will be eliminated;
- The risk of people entering the Tramore River through the reach considered will be eliminated. One of the key findings of the public consultation was that the property owners/occupiers adjacent to Togher Road had a strong desire to maintain the culvert option through Togher as they deemed the open channel option to introduce an unacceptable level of risk to the area in terms of people entering the watercourse and coming to harm.

Appendix A

Cost Estimate of Options

A1 Cost Estimates

A1.1 Option 1

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
	Option T1 - Culvert On-Road				
1	**Greenwood Estate**				
1.1	Greenwood Estate Channel Widening with retaining wall (incl excavation, buildup of new channel)	m	70	893.94	62,576.06
1.2	Removal and replacement of existing concrete post and rail fence	m	41	75.00	3,075.00
1.3	Removal and reconstruction of existing blockwork wall	m	14	100.00	1,440.00
			Subtotal Greenwood Estate		**67,091.06**
2	**Togher Road**				
2.1	Removal and reconstruction of existing pavement road, 3.6m width	m2	1,040	96.50	100,360.00
2.2	Removal and reconstruction of existing pavement road, 5m width	m2	35	96.50	3,377.50
2.3	Removal and reconstruction of existing footpath, 1.8m width	m2	468	54.34	25,431.12
2.4	Removal and reconstruction of existing mini roundabout	no.	1	20,000.00	20,000.00
2.5	Removal and replace existing bus stop shelther incl barriers	no.	1	10,000.00	10,000.00
2.6	Kerbing	m	260	30.00	7,800.00
2.7	Fill existing open channel with 6N fill	m3	114	30.00	3,420.00
2.8	New precast 225mm dia. surface water pipe	m	19	70.00	1,330.00
2.9	Pipe connections	no.	2	500.00	1,000.00
2.10	New culvert 3m x 1.4m (excluding TM, services, drainage).	m	305	2,734.57	834,043.34
2.11	Insitu stitching at culvert bends (4m length assumed)	no.	3	12,962.43	38,887.30
2.12	Removal and replacement of gullies at 30m centres	no.	11	410.00	4,510.00
2.13	Removal and replace lighting columns/telegraph pole	no.	1	2,500.00	2,500.00
2.14	Remove, store and reinstall traffic light	no.	1	2,500.00	2,500.00
2.15	Traffic Management	no	1	40,000.00	
			Subtotal Togher Road		**1,055,159.26**

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
3	**Lehenaghmore Road**				
3.1	Removal of existing stone/blockwork wall.	m2	69	40.00	2,772.00
					-
3.2	Rebuild stone/blockwork wall	m2	69	135.00	9,315.00
3.3	Removal and reconstruction of existing pavement road, 3.2m width (widen road by 1m)	m2	214	96.50	20,689.60
3.4	Removal and reconstruction of existing pavement road, 5m width	m2	35	96.50	3,377.50
3.5	New footpath, 1.8m width	m2	121	54.34	6,553.40
3.6	Kerb Replacement (Drainage kerb with connections into culvert)	m	120	100.00	12,000.00
3.7	New culvert 3m x 1.4m (excluding TM, services, drainage)	m	153	2,734.57	418,388.95
3.8	Insitu stitching at culvert bends (4m length assumed)	no.	3	12,962.43	38,887.30
3.9	Removal and replace lighting columns/telegraph pole	no.	2	2,500.00	5,000.00
3.10	Removal and replace telegraph pole	no.	1	120.00	120.00
3.11	Removal and replace signs	no.	3	250.00	750.00
3.12	Removal of steel bar railing	m	3	40.00	112.00
3.13	Removal, store and reuse entrance stone sign	no.	1	500.00	500.00
3.14	Removal of existing trash screen structure	no.	1	5,000.00	5,000.00
3.15	Remove and replace pedestrian crossing	no	1	2,500.00	2,500.00
		Subtotal Lehenaghmore Road			**525,965.76**
4	**Southern Fruits**				
4.1	New RC Wall along industrial estate bank - 1.1m high	m	53	1,038.21	55,025.26
4.2	Removal and replace palisade fencing	m	95	85.00	8,075.00
4.3	Removal and reconstruction of existing carpark, 5m width	m2	950	67.50	64,125.00
4.4	Kerbing	m	153	30.00	4,590.00
4.5	New culvert 3m x 1.4m (excluding TM, services, drainage)	m	178	2,734.57	486,753.16

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**

Number	Item Description	Unit	Quantity	Rate €	Total €
4.6	Insitu stitching at culvert bends (4m length assumed)	no.	3	12,962.43	38,887.30
4.7	Lighting, CCTV, telemetry	sum	1	50,000.00	50,000.00
4.8	Removal of existing trash screen structure	sum	1	5,000.00	5,000.00
4.9	Trash screen replacement	sum	1	100,000.00	100,000.00
				Subtotal Southern Fruits	**812,455.72**
5	**Services Diversions**				
5.1	UPC diversions	m	250	45.00	11,250.00
5.2	Electrical diversions; ESB UG LV service connections	m	250	50.00	12,500.00
5.3	Electrical diversions connections; ESB electrical works, incl relocating ESB boxes	no.	5	1,000.00	5,000.00
5.4	Upholding UG services at culvert crossings	m	50	45.00	2,250.00
5.5	Watermain diversions; 4 inch cast iron watermain	m	100	69.00	6,900.00
5.6	Water service connections	no.	2	3,000.00	6,000.00
5.7	Gasmain service connections, 5no.	m	250	38.00	9,500.00
5.8	Gasmain diversions; 180mm diameter	m	50	200.00	10,000.00
5.9	Allowance for service provider fees	sum	1	100,000.00	100,000.00
				Subtotal Services Diversions	**163,400.00**
				Total	**2,624,071.80**

A1.2 Option 2

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
	Option T2 - Culvert Off-Road				
1	**Greenwood Estate**				
1.1	Greenwood Estate Channel Widening with retaining wall (incl excavation, buildup of new channel)	m	70	893.94	62,576.06
1.2	Removal of existing concrete post and rail fence	m	41	75.00	3,075.00
1.3	Removal and reconstruction of existing blockwork wall	m2	14	100.00	1,440.00
			Subtotal Greenwood Estate		**67,091.06**
2	**Togher Road**				
2.1	Removal and reconstruction of existing stone wall along west side of the road	m3	11	135.00	1,485.00
2.2	Removal and reconstruction of existing blockwork wall @ church	m	14	100.00	1,400.00
2.3	Removal and reconstruction of existing pavement road, 5m width	m2	185	96.50	17,852.50
2.4	Removal and reconstruction of existing carpark, 3.2m width	m2	990	67.50	66,825.00
2.5	Removal and reconstruction of existing footpath, 1.8m width	m2	72	54.34	3,912.48
2.6	Removal and reconstruction of existing mini roundabout	no.	1	20,000.00	20,000.00
2.7	Removal and replace 20mm Solid Round Bar railing fence	m	90	150.00	13,500.00
2.8	Removal and reconstruction of wall/fence (1.1m wall)	m	30	180.00	5,400.00
2.9	Removal and reconstruction of wall/fence (2.1m wall)	m	6	280.00	1,680.00
2.10	Removal and replace 20mm Solid Round Bar railing gate	no.	1	5,000.00	5,000.00
2.11	Removal and replace lighting columns/telegraph pole	no.	4	1,800.00	7,200.00
2.12	Removal and replace telegraph pole	no.	2	120.00	240.00
2.13	Removal and replace signs	no.	9	250.00	2,250.00
2.14	Removal and replace flag pole @ Church and Doughcloyne Hotel	no.	5	75.00	375.00

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
2.15	Removal and replace existing bus stop shelther	no.	1	10,000.00	10,000.00
2.16	Kerbing	m	130	30.00	3,900.00
2.17	Fill existing open channel with 6N fill	m3	114	30.00	3,420.00
2.18	New precast 225mm dia. surface water pipe	m	19	70.00	1,330.00
2.19	Pipe connections	no.	2	500.00	1,000.00
2.20	Upgrade existing 900mm dia. Circular culvert with new 300mm diameter drain	m	314	370.67	116,389.85
2.21	Removal and replace existing manholes at 25m centres	no.	13	1,800.00	22,608.00
2.22	New culvert 3m x 1.4m (excluding TM, services, drainage).	m	312	2,734.57	853,185.31
2.23	Insitu stitching at culvert bends (4m length assumed)	no.	3	12,962.43	38,887.30
2.24	Removal and replacement of gullies at 30m centres	no.	11	410.00	4,510.00
			Subtotal Togher Road		**1,202,350.45**
3	**Lehenaghmore Road**				
3.1	Removal of existing stone/blockwork wall	m2	69	40.00	2,772.00
3.2	Rebuild stone/blockwork wall	m2	76	135.00	10,246.50
3.3	Removal and reconstruction of existing pavement road, 3.2m width (widen road by 1m)	m2	214	96.50	20,689.60
3.4	Removal and reconstruction of existing pavement road, 5m width	m2	35	96.50	3,377.50
3.5	New footpath, 1.8m width	m2	121	54.34	6,553.40
3.6	Kerb Replacement (Drainage kerb with connections into culvert)	m	120	100.00	12,000.00
3.7	New culvert 3m x 1.4m (excluding TM, services, drainage)	m	153	2,734.57	418,388.95
3.8	Insitu stitching at culvert bends (4m length assumed)	no.	3	12,962.43	38,887.30
3.9	Removal and replace lighting columns/telegraph pole	no.	2	2,500.00	5,000.00
3.10	Removal and replace telegraph pole	no.	1	120.00	120.00

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
3.11	Removal and replace signs	no.	3	250.00	750.00
3.12	Removal of steel bar railing	m	3	40.00	112.00
3.13	Removal, store and reuse entrance stone sign	no.	1	500.00	500.00
3.14	Removal of existing trash screen structure	no.	1	5,000.00	5,000.00
3.15	Remove and replace pedestrian crossing	no	1	2,500.00	2,500.00
			Subtotal Lehenaghmore Road		**526,897.26**
4	**Southern Fruits**				
4.1	New RC Wall along industrial estate bank - 1.1m high	m	53	1,038.21	55,025.26
4.2	Removal and replace palisade fencing	m	95	85.00	8,075.00
4.3	Removal and reconstruction of existing carpark	m2	950	67.50	64,125.00
4.4	Kerb Replacement	m	153	30.00	4,590.00
4.5	New culvert 3m x 1.4m (excluding TM, services, drainage)	m	178	2,734.57	486,753.16
4.6	Insitu stitching at culvert bends (4m length assumed)	no.	3	12,962.43	38,887.30
4.7	Removal of existing trash screen structure	sum	1	5,000.00	5,000.00
4.8	Lighting, CCTV, telemetry	sum	1	50,000.00	50,000.00
4.9	Trash screen replacement	sum	1	100,000.00	100,000.00
			Subtotal Southern Fruits		**812,455.72**
5	**Services Diversions**				
5.1	Eircom diversions; 4 inch UG diversions x 2no.	m	325	45.00	14,625.00
5.2	UPC diversions	m	250	45.00	11,250.00
5.3	Electrical diversions	m	300	50.00	15,000.00
5.4	Electrical diversions; ESB UG LV service connections	m	250	50.00	12,500.00
5.5	Electrical diversions connections; ESB electrical works, incl relocating ESB boxes	no.	5	1,000.00	5,000.00

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
5.6	UG services at culvert/road crossings	m	50	45.00	2,250.00
5.7	Watermain diversions; 4 inch cast iron watermain	m	100	69.00	6,900.00
5.8	Water service connections	no.	2	3,000.00	6,000.00
5.9	Gasmain service connections, 5no.	m	250	38.00	9,500.00
5.10	Allowance for service provider fees	sum	1	50,000.00	50,000.00
		Subtotal Services Diversions			**133,025.00**
				Total	**2,741,819.49**

A1.3 Option 3

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
	Option T3 - Open Channel				
1	**Greenwood Estate**				
1.1	Greenwood Estate Channel Widening with retaining wall (incl excavation, buildup of new channel)	m	70	893.94	62,576.06
1.2	Removal of existing concrete post and rail fence	m	41	75.00	3,075.00
1.3	Removal and reconstruction of existing blockwork wall	m2	14	100.00	1,440.00
			Subtotal Greenwood Estate		**67,091.06**
2	**Togher Road**				
2.1	Removal and reconstruction of existing carpark, 5m width (Greenwood Estate, Church Carpark and HSE Building)	m2	725	67.50	48,937.50
2.2	Removal and reconstruction of existing pavement road, 5m width (Greenwood Estate, Robinscourt and Roundabout)	m2	370	96.50	35,705.00
2.3	Removal and reconstruction of existing footpath, 1.8m width	m2	90	54.34	4,890.60
2.4	Removal and reconstruction of existing stone wall along west side of the road	m3	11	135.00	1,485.00
2.5	Removal of existing blockwork wall @ church	m	14	100.00	1,400.00
2.6	Removal and reconstruction of existing mini roundabout	no.	1	20,000.00	20,000.00
2.7	Removal and replace 20mm Solid Round Bar railing fence	m	90	150.00	13,500.00
2.8	Removal and reconstruction of wall/fence (1.1m wall)	m	63	180.00	11,340.00
2.9	Removal and reconstruction of wall/fence (2.1m wall)	m	6	280.00	1,680.00
2.10	Removal and replace 20mm Solid Round Bar railing gate	no.	1	5,000.00	5,000.00
2.11	Removal and replace lighting columns/telegraph pole	no.	4	1,800.00	7,200.00
2.12	Removal and replace signs, telegraph pole,	no.	2	120.00	240.00
2.13	Removal and replace signs	no.	9	250.00	2,250.00

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
2.14	Removal and replace flag pole @ Church and Doughcloyne Hotel	no.	5	75.00	375.00
2.15	Removal and replace existing bus stop shelter	no.	1	10,000.00	10,000.00
2.16	Kerbing	m	272	30.00	8,160.00
2.17	Fill existing open channel with 6N fill	m3	114	30.00	3,420.00
2.18	New precast 225mm dia. surface water pipe	m	19	70.00	1,330.00
2.19	Pipe connections	no.	2	500.00	1,000.00
2.20	New open channel (average 2.45m deep)	m	58	1,048.12	60,790.96
2.21	New open channel (average 2.6m deep)	m	108	1,060.72	114,557.76
2.22	New RC retaining wall average 2.35m high	m	58	2,253.11	130,680.38
2.23	New RC retaining wall average 2.5m high	m	108	2,314.03	249,914.70
2.24	New 1.8m high decorative railings, galvanised steel and powder coated	m	332	200.00	66,400.00
2.25	New culvert 4mx1.3m (excluding TM, services, drainage)	m	73	3,033.57	221,450.49
2.26	New culvert 4mx1.6m (excluding TM, services, drainage)	m	47	3,565.57	167,581.71
2.27	Headwall structure at inlet and outlet of culvert 4m x 1m	no.	6	815.00	4,890.00
2.28	New culvert 3m x 1.3m (excluding TM, services, drainage)	m	32	2,613.03	83,617.09
2.29	Headwall structure at inlet and outlet of culvert 3m x 1m	no.	2	619.50	1,239.00
2.30	Insitu stitching at culvert bends	no.	2	12,962.43	25,924.87
			Subtotal Togher Road		**1,304,960.06**
3	**Lehenaghmore Road**				
3.1	Removal and reconstruction of existing pavement road, 2m width (roundabout to Brook Ave)	m2	138	67.50	9,315.00
3.2	Removal and reconstruction of existing stone wall - 1.1m (roundabout to Brook Ave)	m2	76	135.00	10,246.50
3.3	Kerb Replacement	m2	71	30.00	2,130.00

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
3.4	New open channel (average 2.2m deep) (existing open channe roundabout to Brook Ave)	m	65	820.57	53,337.05
3.5	New open channel (average 2.2m deep) (between Brook Avenue to entrance to Southern Fruits)	m	85	820.57	69,748.45
3.6	New 1.8m high decorative railings, galvanised steel and powder coated to one side of open channel only (Brook Avenue to Southern Fruits)	m	176.00	200.00	35,200.00
3.7	New culvert 3m x 0.9m (excluding TM, services, drainage) (under Brook Avenue)	m	13	2,245.03	29,185.44
3.8	Headwall structure at inlet and outlet of culvert 3m x 1m	no.	2	619.50	1,239.00
3.9	Removal and replace lighting columns/telegraph pole	no.	1	2,500.00	2,500.00
3.10	Removal and replace telegraph pole	no.	1	120.00	120.00
3.11	Removal and replace signs	no.	3	250.00	750.00
3.12	Removal of steel bar railing	m	3	40.00	112.00
3.13	Removal, store and reuse entrance stone sign	no.	1	500.00	500.00
3.14	Removal of existing trash screen structure	no.	1	5,000.00	5,000.00
3.15	Remove and replace pedestrian crossing	no	1	2,500.00	2,500.00
		Subtotal Lehenaghmore Road			**221,883.44**
4	**Southern Fruits**				
4.1	Removal and reconstruction of existing carpark, 2m width	m2	380	67.50	25,650.00
4.2	Removal and replace palisade fencing 1800mm high	m	95	85.00	8,075.00
4.3	Kerbing	m	153	30.00	4,590.00
4.4	New open channel (average 1.9m deep)	m	186	751.92	139,857.12
4.5	New RC retaining wall average 1.8m high	m	186	1,740.86	323,800.43
4.6	New 1.8m high decorative railings, galvanised steel and powder coated	m	186	200.00	37,200.00
4.7	Removal of existing trash screen structure	sum	1	5,000.00	5,000.00

Order of Magnitude of Costs			Job No:		234335-06
			Sheet No:		**1**
			Made By:		RH/AL/DS
Project Title	**Togher Flood Relief Option**		Date:		**19 May 2017**
Number	Item Description	Unit	Quantity	Rate €	Total €
			Subtotal Southern Fruits		**544,172.55**
5	**Services Diversions**				
5.1	Eircom diversions; 4 inch UG diversions x 2no.	m	325	45.00	14,625.00
5.2	UPC diversions	m	250	45.00	11,250.00
5.3	Electrical diversions	m	300	50.00	15,000.00
5.4	Electrical diversions; ESB UG LV service connections	m	250	50.00	12,500.00
5.5	Electrical diversions connections; ESB electrical works, incl relocating ESB boxes	no.	5	1,000.00	5,000.00
5.6	UG services at culvert/road crossings	m	50	45.00	2,250.00
5.7	Watermain diversions; 4 inch cast iron watermain	m	100	69.00	6,900.00
5.8	Watermain connections	no.	2	3,000.00	6,000.00
5.9	Gasmain service connections, 5no.	m	250	38.00	9,500.00
5.10	Allowance for service provider fees	sum	1	50,000.00	50,000.00
			Subtotal Services Diversions		**133,025.00**
				Total	**2,271,132.11**

Appendix B

Multicriteria Assessment of Options

Core Criteria	Objective	Sub objective	Code	Indicator	Basic Requirement	Aspirational Target
Technical	Ensure flood risk management options are operationally robust	"	1.A.	Level of operational risk of option - Degree of reliance on mechanical, electrical or electronic systems, or on human intervention, action or decision, for the option to operate or perform successfully	Moderate to high, but manageable, degree of operational risk, i.e., an option with a high degree of reliance on mechanical, electrical or electronic systems, or on human intervention, action or decision, but which, with the allocation of adequate resources, could be operated with an acceptable degree of risk of failure	No operational risk, i.e., no reliance on mechanical, electrical or electronic systems, or on human intervention, action or decision for the option to operate or perform successfully
	Minimise health and safety risk in construction and operation of the flood risk management option	"	1.B	Degree of health and safety risk during construction and operation	Moderate to high, but acceptable and manageable, level of health and safety risk during either construction or operation	Negligible risk to health and safety during either construction or operation
	Ensure flood risk can be managed effectively and sustainably into the future	"	1.C	Sustainability and adaptability of the flood risk management measure in the face of potential future changes, including the potential impacts of climate change	Option to provide for, or be adaptable to, the MRFS in terms of maintaining the standard of protection at acceptable cost	Option to provide for, or be adaptable to, the HEFS in terms of maintaining the standard of protection at negligible cost
Economic	Reduce economic damage	"	2.A	Annual Average Damage (AAD) expressed in Euro / year, calculated in accordance with the economic risk assessment methods, but with no allowance for social / intangible benefits	AAD is not increased	100% reduction in AAD
	Minimise risk to transport infrastructure	"	2.B	Number and type of transport routes at risk from flooding	No increase in risk to transport infrastructure	Reduce risk to transport infrastructure to zero
	Minimise risk to utilities infrastructure	"	2.C	Number and type of infrastructure assets at risk from flooding	No increase in risk to utility infrastructure	Reduce risk to utility infrastructure to zero
	Minimise risk to agriculture	"	2.D	Agricultural production	No increase in the negative impact of flooding on agricultural production	Provide the potential for enhanced agricultural production
Social	Minimise risk to human health and life	(i) residents	3.A.(i)	Annual Average Number of residential properties at risk from flooding	Number of properties at risk is not increased	100% reduction in number of residential properties at risk
		(ii) high vulnerability properties	3.A.(ii)	Number and type of high vulnerability properties at risk from flooding	Number of high vulnerability properties at risk not increased	100% reduction in number of high vulnerability properties at risk
	Minimise risk to community	(i) social infrastructure	3.B.(i)	Number of social infrastructure assets at risk from flooding in a 0.1% AEP Event	Number of social infrastructure assets at risk not increased	100% reduction in number of social infrastructure assets at risk
	"	(ii) local employment	3.B.(ii)	Number of non-residential (i.e., commercial) properties at risk not increased.	Number of non-residential properties at risk not increased	100% reduction in number of non-residential properties at risk
	Minimise risk to, and where possible enhance, social amenity sites	"	3.C	Number of social amenity sites at risk from flooding in a 1% AEP Event	Number of social amenity sites at risk not increased	100% reduction in number of flood-sensitive social amenity sites at risk. Enhancement or creation of social amenity sites
Environmental	Support the objectives of the WFD	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives	4.A	-	Provide no constraint to the achievement of water body objectives.	Contribute to the achievement of water body objectives
	Support the objectives of the Habitats and Birds Directives	Avoid detrimental effects to, and where possible enhance, Natura 200 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.	4.B	-	No deterioration in the conservation status of designated sites as a result of flood risk management measures.	Improvement in the conservation status of designated sites as a result of flood risk management sites.
	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	Avoid damage to, and where possible enhance, legally protected sites / habitats and other sites / habitats of national, regional and local nature conservation importance	4.C	-	No deterioration in the condition of existing sites due to the implementation of flood risk management option	Creation of new or improvement in condition of existing sites due to the implementation of flood risk management option
	Protect and where possible enhance fisheries resource within the catchment	Maintain existing and where possible create new fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species	4.D	-	No loss of integrity of fisheries habitat. Maintenance of upstream accessibility	No loss of fisheries habitat. Improvement in habitat quality/quantity. Enhanced upstream accessibility
	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	Protect, and where possible enhance, visual amenity, landscape protection zones and views into/from designated scenic areas within the zone of influence	4.E	-	No significant impact on landscape designation (protected site, scenic route/amenity, natural landscape form) within zone of visibility of measures. No significant change in the quality of existing landscape characteristics of the receiving environment	No change to the existing landscape form. Enhancement of existing landscape or landscape feature
	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	(i) Avoid damage to or loss of features of architectural value and their setting, and improve their protection from extreme floods where this is beneficial	4.F.(i)	-	No increase in the risk to architectural features at risk from flooding. No detrimental impacts from flood risk management measures on architectural features.	Complete removal of all relevant architectural features from the risk of harm by extreme floods. Enhanced protection and value of architectural features importance arising from the implementation of the selected measures.
	"	(ii) Avoid damage to or loss of features of archaeological value and their setting, and improve their protection from extreme floods where this is beneficial	4.F.(ii)	-	No increase in the risk to archaeological features at risk from flooding. No detrimental impacts from flood risk management measures on archaeological features.	Complete removal of all relevant archaeological features from the risk of harm by extreme floods. Enhanced protection and value of archaeological features importance arising from the implementation of the selected measures.

Multicriteria Analysis - Flood Risk Management OPTION 1 - On Road Culvert

Core Criteria	Objective	Global Weighting	Local Weighting	Local Weighting Rationale	FRS OPTION 1 - On Road Culvert SCORING	Rationale	MCA SCORE
Technical	Ensure flood risk management options are operationally robust	20	5	As per GN28 guidance	2	The culverts would require a regular inspection programme to prevent blockages. The culverts would require a regular maintenance programme to ensure they are kept in a condition to be effective flood defences. Inspection and maintenance programmes will be required to be regular to ensure culverts kept free of blockages. Meeting minimum target.	200
	Minimise health and safety risk in construction and operation of the flood risk management option	20	5	As per GN28 guidance	-1	Option would have some health and safety risk in the construction of the culverts and flood walls. Option would involve some construction works next to open water and also along urban road where traffic would create significant health and safety risk. Also medium health and safety risk to operators undertaking regular maintenance work near open water and confined spaces. Overall meeting minimum target.	-100
	Ensure flood risk can be managed effectively and sustainably into the future	20	5	As per GN28 guidance	0	Culverts designed to take 1%AEP and climate change adaptability required under Section 50	0
		60				**Technical Score**	**100**
Economic	Reduce economic damage	30	5	Local weighting = AAD for the SSA / €100000	5	Defence works to provide protection from fluvial design flood risk.	750
	Minimise risk to transport infrastructure	10	2	Low threshold of flooding on multiple local and regional routes	3	Defence works to provide protection from fluvial design flood risk	60
	Minimise risk to utilities infrastructure	10	2	Considered to be an important area for utility services and assets	4	Defence works to provide protection from fluvial design flood risk	80
	Minimise risk to agriculture	10	1	Professional judgement applied to scoring	0	No impact on affected area	0
		60				**Economic Score**	**890**
Social	Minimise risk to human health and life	30	5	Minimising risk to health and safety of residents is a key consideration. Professional judgement has been applied, therefore, a high local weighting has been selected.	5	Defence works to provide protection from fluvial design flood risk.	750
		10	5	A number of high risk assets are at risk from flooding within the affected area	5	Defence works to provide protection from fluvial design flood risk.	250
	Minimise risk to community	5	5	A health centre, school and church are at risk from flooding within the affected area. Important area of industry and social infrastructure.	5	Defence works to provide full protection from fluvial design flood risk	125
	"	10	5	Important area of local employment	5	Defence works to provide full protection from fluvial design flood risk	250
	Minimise risk to, and where possible enhance, social amenity sites	5	2	Professional judgement applied to scoring	0	No social amenities at risk	0
		60				**Social Score**	**1375**
Environmental	Support the objectives of the WFD	15	5	As per GN28 guidance	0	The Tramore River is designated as having Good Status under the WFD. Defence works unlikely to cause deterioration of the existing condition of the waterbody	0
	Support the objectives of the Habitats and Birds Directives	15	5	Professional judgement applied to scoring	0	No impact on constuction areas.	0
	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	5	3	Professional judgement applied to scoring	0	The ecological value of the watercourse within the culvert is considered to be low. Replacing the existing culvert with a larger culvert is unlikely to change the ecological value of the existing watercourse supporting flora and fauna in the catchment.	0
	Protect and where possible enhance fisheries resource within the catchment	5	5	As per GN28 Guidance	0	Construction of a replacement culvert is unlikely to cause significant negative impacts on fisheries habitats within the current culverted channel.	0
	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	10	3	Has the potential to be visually/aesthetically important for the local area. Professional judgement required.	0	Limited change in landscape character and visual amenity from existing situation.	0
	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	5	3	Professional judgement applied to scoring.	0	There are no archaeological or architectural heritage constraints in relation to the Togher culvert. There is no difference in impacts or mitigation on the above constraints if the culvert is extended or if it is removed and replaced with an open channel.	0
	"	5	1	Professional judgement applied to scoring.	0	There are no archaeological heritage constraints in relation to the Togher culvert. From an archaeological point of view, ground has probably been previously disturbed and the amount of ground in question is relatively small so there is very little difference.	0
		60				**Environmental Score**	**0**

MCA Benefit Score	**2265**
Option Selection Benefit Score	**2365**
NPV Capital Costs (M€)	**5.53**
MCA Benefit/Cost Ratio	**0.41**
Economic Benefit (M€)	**6.90**
Economic Benefit/Cost Ratio	**1.07**

Multicriteria Analysis - Flood Risk Management OPTION 2 - Off Road Culvert							
Core Criteria	Objective	Global Weighting	Local Weighting	Local Weighting Rationale	FRS OPTION 2 - Off Road Culvert		
					SCORING	Rationale	MCA SCORE
Technical	Ensure flood risk management options are operationally robust	20	5	As per GN28 guidance	2	The culverts would require a regular inspection programme to prevent blockages. The culverts would require a regular maintenance programme to ensure they are kept in a condition to be effective flood defences. Inspection and maintenance programmes will be required to be regular to ensure culverts kept free of blockages. Meeting minimum target.	200
	Minimise health and safety risk in construction and operation of the flood risk management option	20	5	As per GN28 guidance	0	Option would have some health and safety risk in the construction of the culverts and flood walls. Option would involve some construction works next to open water and off road where traffic would create significant health and safety risk. Also medium health and safety risk to operators undertaking regular maintenance work near open water and confined spaces. Overall meeting minimum target.	0
	Ensure flood risk can be managed effectively and sustainably into the future	20	5	As per GN28 guidance	0	Culverts designed to take 1%AEP and climate change adaptability required under Section 50	0
		60				**Technical Score**	**200**
Economic	Reduce economic damage	30	5	Local weighting = AAD for the SSA / €100000	5	Defence works to provide protection from fluvial design flood risk.	750
	Minimise risk to transport infrastructure	10	2	Low threshold of flooding on multiple local and regional routes	3	Defence works to provide protection from fluvial design flood risk	60
	Minimise risk to utilities infrastructure	10	2	Considered to be an important area for utility services and assets	4	Defence works to provide protection from fluvial design flood risk	80
	Minimise risk to agriculture	10	1	Professional judgement applied to scoring	0	No impact on affected area	0
		60				**Economic Score**	**890**
Social	Minimise risk to human health and life	30	5	Minimising risk to health and safety of residents is a key consideration. Professional judgement has been applied, therefore, a high local weighting has been selected.	5	Defence works to provide protection from fluvial design flood risk.	750
		10	5	A number of high risk assets are at risk from flooding within the affected area	5	Defence works to provide protection from fluvial design flood risk.	250
	Minimise risk to community	5	5	A health centre, school and church are at risk from flooding within the affected area. Important area of industry and social infrastructure.	5	Defence works to provide full protection from fluvial design flood risk	125
	"	10	5	Important area of local employment	5	Defence works to provide full protection from fluvial design flood risk	250
	Minimise risk to, and where possible enhance, social amenity sites	5	2	Professional judgement applied to scoring	0	No social amenities at risk	0
		60				**Social Score**	**1375**
Environmental	Support the objectives of the WFD	15	5	As per GN28 guidance	0	The Tramore River is designated as having Good Status under the WFD. Defence works unlikely to cause deterioration of the existing condition of the waterbody	0
	Support the objectives of the Habitats and Birds Directives	15	5	Professional judgement applied to scoring	0	No impact on constuction areas.	0
	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	5	3	Professional judgement applied to scoring	-1	The ecological value of the watercourse within the culvert is considered to be low. Replacing the existing culvert with a larger culvert off-road could impact the ecological value of the existing watercourse supporting flora and fauna in the catchment. However, the off-road area is residential and urbanised and it is unlikely that the existing habitats are of high ecological value.	-15
	Protect and where possible enhance fisheries resource within the catchment	5	5	As per GN28 Guidance	0	Construction of a replacement culvert is unlikely to cause significant negative impacts on fisheries habitats within the current culverted channel.	0
	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	10	3	Has the potential to be visually/aesthetically important for the local area. Professional judgement required.	0	Limited change in landscape character and visual amenity from existing situation.	0
	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	5	3	Professional judgement applied to scoring.	0	There are no archaeological or architectural heritage constraints in relation to the Togher culvert. There is no difference in impacts or mitigation on the above constraints if the culvert is extended or if it is removed and replaced with an open channel.	0
	"	5	1	Professional judgement applied to scoring.	0	There are no archaeological heritage constraints in relation to the Togher culvert. From an archaeological point of view, ground has probably been previously disturbed and the amount of ground in question is relatively small so there is very little difference.	0
		60				**Environmental Score**	**-15**

MCA Benefit Score	**2250**
Option Selection Benefit Score	**2450**
NPV Capital Costs (M€)	**5.77**
MCA Benefit/Cost Ratio	**0.39**
Economic Benefit (M€)	**6.90**
Economic Benefit/Cost Ratio	**1.02**

Multicriteria Analysis - Flood Risk Management OPTION 3 - Open Channel

Core Criteria	Objective	Global Weighting	Local Weighting	Local Weighting Rationale	FRS OPTION 3 - Open Channel SCORING	Rationale	MCA SCORE
Technical	Ensure flood risk management options are operationally robust	20	5	As per GN28 guidance	3	Low operational risk - regular monitoring and maintenance is likely to be required to prevent blockage.	300
	Minimise health and safety risk in construction and operation of the flood risk management option	20	5	As per GN28 guidance	-2	Construction works would likley involve deep excavations and works in/beside the river channel. Health and Safety Risk during construction and also post construction, due to vulnerbale persons residing in the area. Negative public feedback receieved during public consultation for open in channel in urban area.	-200
	Ensure flood risk can be managed effectively and sustainably into the future	20	5	As per GN28 guidance	0	Overall will cater due to height of channel - five short lengths of culverts will be designed to take 1%AEP and climate change adaptability required under Section 50	0
		60				**Technical Score**	**100**
Economic	Reduce economic damage	30	5	Local weighting = AAD for the SSA / €100000	5	Defence works to provide protection from fluvial design flood risk.	750
	Minimise risk to transport infrastructure	10	2	Low threshold of flooding on multiple local and regional routes	3	Defence works to provide protection from fluvial design flood risk	60
	Minimise risk to utilities infrastructure	10	2	Considered to be an important area for utility services and assets	4	Defence works to provide protection from fluvial design flood risk	80
	Minimise risk to agriculture	10	1	Professional judgement applied to scoring	0	No impact on affected area.	0
		60				**Economic Score**	**890**
Social	Minimise risk to human health and life	30	5	Minimising risk to health and safety of residents is a key consideration. Professional judgement has been applied, therefore, a high local weighting has been selected.	4	Defence works to provide protection from fluvial design flood risk.	600
		10	5	A number of high risk assets are at risk from flooding within the affected area	4	Defence works to provide protection from fluvial design flood risk.	200
	Minimise risk to community	5	5	A health centre, school and church are at risk from flooding within the affected area. Important area of industry and social infrastructure.	4	Defence works to provide full protection from fluvial design flood risk	100
	"	10	5	Important area of local employment	5	Defence works to provide full protection from fluvial design flood risk	250
	Minimise risk to, and where possible enhance, social amenity sites	5	2	Professional judgement applied to scoring	0	No social amenities at risk	0
		60				**Social Score**	**1150**
Environmental	Support the objectives of the WFD	15	5	As per GN28 guidance	2	The Tramore River is designated as having Good Status under the WFD. There are likely to be construction phase impacts on the river, however, opening up of culvert to introduce daylighting is likely to have a positive impact on the watercourse overall.	150
	Support the objectives of the Habitats and Birds Directives	15	5	Professional judgement applied to scoring	0	No impact post-construction on affected areas.	0
	Avoid damages to, and where possible enhance, the flora and fauna of the catchment	5	3	Professional judgement applied to scoring	2	Likely to be a marginal positive impact on the local flora and fauna within the affected area. The open channel option would encourage greater growth of macroinvertebrates which serve as food for fish populations. It is also likely to introduce riparian habitat to the river which is currently culverted. This in turn may provide feeding resources for bats and birds.	30
	Protect and where possible enhance fisheries resource within the catchment	5	5	As per GN28 Guidance	2	The Tramore River has populations of fish i.e. trout, stickleback and eel. Opening up of the existing channel and increasing daylight has the potential to create improved areas of fisheries habitat within the area and upstream. Increased fish populations may provide better feeding resources for piscivororous species such as Grey Heron or Otter.	50
	Protect and where possible enhance, landscape character and visual amenity within the zone of influence.	10	3	Has the potential to be visually/aesthetically important for the local area. Professional judgement required.	1	Opening up of the culvert has the potential to become a positive and attractive visual and landscape impact.	30
	Avoid damage to or loss of features of cultural heritage importance and their setting, and improve their protection from extreme floods.	5	3	Professional judgement applied to scoring.	0	There are no archaeological or architectural heritage constraints in relation to the Togher culvert. There is no difference in impacts or mitigation on the above constraints if the culvert is extended or if it is removed and replaced with an open channel.	0
	"	5	1	Professional judgement applied to scoring.	0	There are no archaeological heritage constraints in relation to the Togher culvert. There is no difference in impacts or mitigation on the above constraints if the culvert is extended or if it is removed and replaced with an open channel.	0
		60				**Environmental Score**	**260**

MCA Benefit Score	**2300**
Option Selection Benefit Score	**2400**
NPV Capital Costs (M€)	**5.13**
MCA Benefit/Cost Ratio	**0.45**
Economic Benefit (M€)	**6.90**
Economic Benefit/Cost Ratio	**1.14**

Multicriteria Analysis Summary Sheet for Togher

Douglas Flood Relief Scheme (including Togher Culvert)	OPTION 1 - On road Culvert	OPTION 2 - Off road Culvert	OPTION 3 - Open Channel
Technical Score	100	200	100
Economic Score	890	890	890
Social Score	1375	1375	1150
Environmental Score	0	-15	260
MCA Benefit Score	2265	2250	2300
Option Selection Benefit Score	2365	2450	2400
NPV Capital Costs (M€)	6.52	6.81	6.10
MCA Benefit/Cost Ratio	0.35	0.33	0.38

Appendix C

Hydraulic Modelling Output

C1

This section presents output from the hydraulic model for the preferred option.

C1.1 No blockage Scenario

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6TRA_5450	24.118	7.602	2.349
6TRA_5477	25.308	7.602	4.187
6TRA_5402	23.667	7.6	1.569
6TRA_5370	22.362	7.599	3.799
OLC_17.5	21.377	7.599	6.833
OLC_27.5	21.461	7.599	2.511
OLC_34.5	21.47	7.599	2.312
OLC_46.5	21.438	7.599	2.131
CULV_IN_US	21.362	7.65	2.151
OFCH_1	20.5	0.1	1.146
OFCH_2	20.357	0.137	1.28
OFCH_3	20.337	0.136	1.274
CULV_IN	21.353	7.65	5.022
CULV_3M	20.147	10.377	5.869
6TRA_4653	10.985	7.594	1.587
6TRA_4642	10.898	7.594	2.315
6TRA_4627	10.773	7.594	1.817
6TRA_4545	10.011	7.593	2.526
6TRA_4500	9.556	7.593	2.185
6TRA_4457b	9.27	7.593	1.575
6TRA_5013oa	14.627	7.598	5.933
6TRA_4956	13.338	7.598	4.708
6TRA_4906	12.602	7.597	4.21
6TRA_4856	12.067	7.597	3.843
6TRA_4806	11.743	7.596	2.837
6TRA_4756	11.566	7.595	2.621
6TRA_4706	11.405	7.595	2.652
6TRA_4656	11.19	7.594	2.558
6TRA_5286	19.927	9.369	5.548
6TRA_5256b	19.645	8.359	5.344
6TRA_5206b	19.181	7.598	4.746
6TRA_5156b	18.537	7.598	5.477

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6TRA_5106b	17.472	7.598	5.901
6TRA_5056b	16.162	7.598	5.817
6TRA_4372	8.855	7.591	1.56
6TRA_4273	8.45	7.589	1.669
6TRA_4169	7.99	7.587	1.623
6TRA_4112	7.784	7.586	1.458
6TRA_4036	7.309	7.585	1.984
6TRA_3938	6.556	7.584	2.159
6TRA_3932	6.553	7.584	1.692
6TRA_3901	6.439	7.583	1.549
6TRA_3901i1	6.387	7.583	1.659
6TRA_3884	6.312	7.583	1.845
6TRA_3870	6.365	7.582	1.167
6TRA_3884d	6.312	7.583	1.845
6TRA_3870i1	6.331	7.581	1.261
6TRA_3847	6.278	7.581	1.416
6TRA_3813	6.122	7.579	1.629
6TRA_3847d	6.278	7.581	1.416
6TRA_3847i1	6.231	7.58	1.464
6TRA_3847i2	6.18	7.579	1.531
6TRA_3732	6.025	7.57	1.053
6TRA_3732Bu	6.025	7.57	0.912
6TRA_3732Spu	6.025	0	0.912
6TRA_3732Bd	6.011	7.57	0.912
6TRA_3732d	6.011	7.57	1.056
6TRA_3732Spd	6.011	0	0.912
6TRA_3720	5.936	7.568	1.336
6TRA_3623	5.856	7.558	0.788
6TRA_3559	5.85	7.551	0.473
6TRA_3513	5.792	7.549	0.927
6TRA_3502	5.751	7.549	1.226
6TRA_3502Bu	5.751	7.549	1.377
6TRA_3502Spu	5.751	0	1.377
6TRA_3502Bd	5.711	7.549	1.377
6TRA_3502d	5.711	7.549	1.345
6TRA_3502Spd	5.711	0	1.377
6TRA_3397	5.05	7.547	2.13
6TRA_3309	4.64	7.545	1.46

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6TRA_3194	4.431	7.54	0.872
6TRA_3100	4.306	7.535	0.933
6TRA_3009	4.071	7.532	1.167
6TRA_2923	3.673	7.531	1.515
6TRA_3884Bu	6.312	7.583	0.672
6TRA_3884Spu	6.312	0	0.672
6TRA_3884Bd	6.312	7.583	0.672
6TRA_3884Spd	6.312	0	0.672
6TRA_3847Bu	6.278	7.581	0.543
6TRA_3847Spu	6.278	0	0.543
6TRA_3847Bd	6.278	7.581	0.543
6TRA_3847Spd	6.278	0	0.543

C1.2 67% Blockage Scenario

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6TRA_5450	24.13	7.602	2.252
6TRA_5477	25.309	7.602	4.185
6TRA_5402	23.755	7.6	1.422
6TRA_5370	22.337	7.6	3.965
OLC_17.5	21.504	7.6	4.392
OLC_27.5	21.44	7.6	1.353
OLC_34.5	21.45	7.6	1.247
OLC_46.5	21.489	6.86	0.974
CULV_IN_US	21.495	6.697	0.926
OFCH_1	20.808	0.1	1.168
OFCH_2	20.634	0.84	1.324
OFCH_3	20.517	1.003	2.232
CULV_IN	21.303	6.697	4.93
CULV_3M	20.091	8.231	5.11
6TRA_4653	10.921	6.694	1.524
6TRA_4642	10.83	6.694	2.275
6TRA_4627	10.7	6.694	1.756
6TRA_4545	9.935	6.693	2.415
6TRA_4500	9.478	6.693	2.125
6TRA_4457b	9.197	6.693	1.519
6TRA_5013oa	14.592	6.696	5.695
6TRA_4956	13.293	6.696	4.526
6TRA_4906	12.551	6.696	4.052

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6TRA_4856	12.001	6.696	3.713
6TRA_4806	11.662	6.695	2.748
6TRA_4756	11.484	6.695	2.524
6TRA_4706	11.324	6.695	2.554
6TRA_4656	11.109	6.694	2.454
6TRA_5286	19.872	7.411	4.713
6TRA_5256b	19.591	6.697	4.492
6TRA_5206b	19.13	6.697	4.007
6TRA_5156b	18.496	6.696	4.582
6TRA_5106b	17.433	6.696	5.151
6TRA_5056b	16.127	6.696	5.229
6TRA_4372	8.788	6.692	1.496
6TRA_4273	8.39	6.691	1.607
6TRA_4169	7.935	6.69	1.558
6TRA_4112	7.73	6.69	1.397
6TRA_4036	7.25	6.689	1.915
6TRA_3938	6.499	6.689	2.074
6TRA_3932	6.494	6.689	1.649
6TRA_3901	6.379	6.688	1.49
6TRA_3901i1	6.33	6.688	1.591
6TRA_3884	6.255	6.688	1.78
6TRA_3870	6.303	6.688	1.109
6TRA_3884d	6.255	6.688	1.78
6TRA_3870i1	6.27	6.687	1.208
6TRA_3847	6.214	6.687	1.378
6TRA_3813	6.06	6.686	1.567
6TRA_3847d	6.214	6.687	1.378
6TRA_3847i1	6.166	6.687	1.419
6TRA_3847i2	6.116	6.686	1.478
6TRA_3732	5.954	6.682	1.056
6TRA_3732Bu	5.954	6.682	0.912
6TRA_3732Spu	5.954	0	0.912
6TRA_3732Bd	5.942	6.682	0.912
6TRA_3732d	5.942	6.682	1.059
6TRA_3732Spd	5.942	0	0.912
6TRA_3720	5.873	6.681	1.3
6TRA_3623	5.794	6.677	0.743
6TRA_3559	5.789	6.674	0.444

Model Cross Section	Max Stage (mOD)	Max Flow (m^3/s)	Max Vel. (m/s)
6TRA_3513	5.735	6.673	0.89
6TRA_3502	5.693	6.673	1.226
6TRA_3502Bu	5.693	6.673	1.377
6TRA_3502Spu	5.693	0	1.377
6TRA_3502Bd	5.654	6.673	1.377
6TRA_3502d	5.654	6.673	1.34
6TRA_3502Spd	5.654	0	1.377
6TRA_3397	4.994	6.672	2.033
6TRA_3309	4.581	6.67	1.423
6TRA_3194	4.365	6.665	0.835
6TRA_3100	4.25	6.661	0.902
6TRA_3009	4.027	6.66	1.121
6TRA_2923	3.633	6.659	1.452
6TRA_3884Bu	6.255	6.688	0.672
6TRA_3884Spu	6.255	0	0.672
6TRA_3884Bd	6.255	6.688	0.672
6TRA_3884Spd	6.255	0	0.672
6TRA_3847Bu	6.214	6.687	0.543
6TRA_3847Spu	6.214	0	0.543
6TRA_3847Bd	6.214	6.687	0.543
6TRA_3847Spd	6.214	0	0.543