6. Environmental Assessment of Reasonable Alternatives

6.1 Introduction

This section provides a comparison of environmental effects of the reasonable alternatives, as outlined in Section 5.

The potential likely significant effects arising from each of the reasonable alternatives are discussed under each of the following headings:

- Population and Human Health
- Biodiversity
- Land and Soil
- Hydrogeology
- Water
- Air
- Climate
- Material Assets
- Resources and Waste
- Cultural Heritage
- Landscape
- Vulnerability to major accidents and/or disasters

The detailed environmental effects of each of the reasonable alternatives under each of the headings listed above are presented in Appendix A.

6.2 Comparison of Environmental Effects of Reasonable Alternatives

This section summarises the key environmental effects that were identified for each area, in an option-by-option comparison, with an emphasis on the critical aspects. As discussed further in Section 8, the environmental effects of any proposed intervention were assessed and scored for the multi-criteria analysis.

6.2.1 Area 1&2 – Tír Cluain to Riverside Way

Of the three reasonable alternatives identified for Area 1&2, two of the options have a similar overall level of environmental effect, and one option has a considerably reduced environmental effect in comparison.

Option 1&2A and Option 1&2C are both notably negatively impacting the objectives of the Water Framework Directive (WFD) through their interference with the natural sediment flux, through dredging, and the loss of sinusoidal meanders through river realignment for the upstream storage arrangement, respectively. Option 1&2B has a lesser impact in this regard, due in part to the limited in-channel works proposed. However, as sediment conservation would still be impacted, this option also negatively impacts the WFD objectives.

All of the options have a similar effect on the objectives of the Habitats and Birds Directives, Option 1&2A having a slightly greater impact due to the dredging and potential impacts downstream on the SPA/SAC.

When examining the effects of the options with regard to the localised loss/disturbance of flora and fauna as a whole, it was found that Options 1&2B and 1&2C had a lesser impact than Option 1&2A, due to the dredging element and also the reduced footprint of Option 1&2C. However suitable mitigation measures are technically feasible for all options.

Option 1&2C would have the least impact on air and noise, as the construction would occur further from sensitive receptors relative to the other options. The benefit of this is offset however, by the significant increase of materials required for the embankment construction and the potential decrease to soil quality by the deposition of fines in the storage area during a flood event.

All options had a similar environmental impact under the other environmental effects examined, with an overall determination that Options 1&2A and 1&2C were not significantly different in terms of their overall environmental effects. Their greater negative environmental effect on the WFD objectives however, resulted in Option 1&2B being the option with the least overall environmental effect.

6.2.2 Area 3 – Town Centre and Bailick Road

Area 3 has only a one option deemed technically viable, due to technical constraints identified by a Preliminary Technical Assessment. As such, a comparison of options is not possible.

Despite this, its standalone environmental performance has still been examined to ensure that any negative environmental effects are proportional to the objectives of the overall scheme, and that suitable mitigation measures can be considered early in the design stages.

Potential impacts to WFD objectives and indirect impacts to the downstream Special Area of Conservation were noted, as were potential impacts on fish. Mitigation measures for this option were deemed technically feasible however, reducing the overall environmental effect. Short term disruptions to the hydromorphology of the river would be likely, as some construction is likely to occur within the channel, but this would not be expected to cause long-term significant changes.

The option does not present the possibility of direct impacts at this stage on any qualifying habitat. Potential indirect impacts on SAC/SPA habitats but not on conservation objectives were considered. Suitable mitigation measures are technically feasible and the careful location of works will avoid impacts on the Conservation Objectives of the 2 adjacent European sites.

There are a number of buildings and structures of cultural heritage that would be impacted by the works; however, the flood relief works would offer protection to these buildings and structures should a flood event occur in the area.

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

Originally two options were deemed technically viable in Area 4 and were presented at the second Public Participation Day. However, as a result of further stakeholder engagement and the identification of additional technical constraints, three additional options were developed, and are detailed in Section 5.5.

None of the options assessed had a strongly negative environmental effect, due to the proposed works being offset from the Dungourney River. None of the options impacted the objectives of the Water Framework Directive or had any impact on fisheries habitat.

The loss of vegetation associated with Option 4E was considered to be greater than with the other options, as the u-shaped embankment requires significantly more land take. This increased land take would also have a potential negative effect on biodiversity. Options 4C and 4D would require significantly less land by combining with the NRRE, limiting the loss to vegetation.

The requirement for an approach embankment for integration with the proposed Greenway in the area would likely require additional tree felling, which would result in Option 4C having a slightly greater effect on local biodiversity than Option 4D which includes a demountable and does not require regarding the Greenway.

While all options would visually impact Cahermone Castle, a protected structure in the area, Options 4C and 4D would have less of an effect due to their positioning further west.

6.2.4 Area 5 – Ballinacurra

Five options have been identified as being technically feasible in Area 5, details of which have been outlined in previous sections. Upon examination of the environmental effects deemed likely by the proposed options, it was found that one option resulted in a significantly greater environmental effect, one had relatively minor overall environmental effect and the remaining three options were very similar.

The option deemed to have the most significant environmental effect is Option 5D. This is due to the nature of the option, which would see a combination of upstream storage, direct defences and overpumping combined. By combining these measures, this option resulted in the environmental effects of all of the measures.

This option therefore scored poorly with regard to its effects on the WFD objectives and the greater impact on features of cultural, architectural and archaeological significance. The larger footprint of the option also resulted in a lower score when assessing the relative impact on flora, fauna and the fisheries habitat.

This was also a feature of Options 5B and 5B-1, due to the upstream storage area both have a significantly larger footprint and would require the felling of a larger number of trees as a result. This would negatively affect bat and bird habitats, to a greater extent than the direct defence options. Conversely, the direct defences options, Options 5A and 5C, scored better when examining impacts on flora, fauna and fisheries, due to the smaller footprint.

A positive of Options 5B and 5B-1 however, is their reduced impact on the downstream areas of archaeological and cultural heritage, as the need for downstream defences is reduced. Option 5B-1 would perform better than Option 5B in these areas, due to the reduced storage area size.

While channel realignment at Kearney's Cross would result in a potential change in channel hydromorphology, and a potential impact on the biodiversity in the area, this is common to all options in the area.

Option 5A has the least negative impact on the objectives of the WFD, as the in-stream works would be temporary, and this option only requires pumping under specific circumstances while operational. The direct defence options scored less than the other options when assessed on the impacts to features of cultural, architectural and archaeological significance, as well as their relatively larger generation of carbon emissions and generation of noise pollution due to the defences being constructed in a residential area.. However, the weighting of these factors is less than that of the impacts to the WFD objectives, and for that reason Option 5A is found to have the least environmental effect of all the options considered.

6.2.5 Area 6 – Water Rock

Originally one option was deemed technically viable in Area 6 and was presented at the second Public Participation Day. However, as a result of further stakeholder engagement and the identification of additional technical constraints, three additional options were developed, and are detailed in Section 5.7.

The options all include direct defences in combination with a culvert or open channel, the purpose of which is to bypass the cave system, this removes the uncertainly associated with the cave system contributing to the flood risk in the area upstream of the caves.

The four options are similar from a construction and operation perspective and have similar environmental effects. All options would impede the WFD objectives while operational, however the extent would be limited as the flow diversions would be designed to occur only during extreme flood events, not during any other time.

However, Option 6C was found to have a greater environmental impact. This option would permanently impede the achievement of the water body objectives by changing the hydromorphology of the Water Rock stream downstream of the cave system. These changes are required due to the conveyance improvements brought about by the cave system bypass culvert/channel.

There was a minor difference in scoring between options 6A, 6B-1 and 6B-2, which was in relation to the localised loss of low value biodiversity. It was noted that Option 6B-2 would generate the potential for biodiversity opportunities through the long lengths of open channels proposed, therefore resulting in the least environmental effect, however it is noted that as the lands are currently used for agriculture, the existing value of the biodiversity in the area is low.

None of the options would result in a risk to features of cultural, architectural and archaeological significance, and most of the other objectives score similarly across the options.

The upgrading of the embankment adjacent to Dwyer's Road would require the removal of vegetation from both the Cork Harbour SPA and the Great Island Channel SAC. This would have the potential to disrupt the conservation objectives in these areas. Additionally, the removal of vegetation cover required during the construction period may lead to short term saltmarsh destabilisation, which would negatively impact the stated objectives in these areas and the flora and fauna reliant on them.

The embankment and culvert construction at the wastewater treatment plant downstream would alter the hydromorphology of the stream and may result in the removal of bat and bird habitats where tree felling would be required. However these embankments and culverts are common to all options, so do not change the relative scoring.

7. Economic Assessment of Reasonable Alternatives

7.1 Cost Estimate of Reasonable Alternatives

This section outlines the methodology and the outcome of the cost estimation of the flood relief options.

7.1.1 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 considered and not just the capital cost for this project:

- Construction costs, including the Contractor's general items and overheads
- Archaeology and environmental mitigation costs
- Contingency/Optimism Bias
- Site investigations and survey costs
- Land purchase and compensation costs
- Fees and supervision costs
- Allowance for Art
- Maintenance costs

The following costs were excluded:

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

7.1.2 Unit construction costs

The estimation of costs for each of the options developed as part of the study was completed in June 2021. Since this time there has been a dramatic increase in the price of construction materials that has manifested itself throughout 2022 and into 2023. The costing therefore needs to consider the inflation that has occurred between June 2021 and January 2023. The latest CPI index data from the Central Statistics Office has therefore been sourced in order to derive the % uplift that needs to be applied. When the period from June 2021 to December 2022 is considered, the % uplift is calculated as 11.7%.[9] This is considered later in the section.

It is noted that construction costs have increased since January 2023, however the corresponding benefit has also increased at the same rate. Therefore for the purposes of the Cost-Benefit Ratio, it was deemed not necessary to update both the costs and the benefit on an ongoing basis.

[9] https://www.cso.ie/en/interactivezone/visualisationtools/cpiinflationcalculator/

7.1.3 Construction Costing Method

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

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

These cost rates relate to June 2021.

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

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

7.1.4 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 15% has been included in the cost estimate.

7.1.5 Contingency/Optimism Bias

There is a tendency for project appraisers to be overly optimistic when preparing project cost estimates for flood risk management schemes. The aim of adding an optimism bias is to allow a contingency on cost estimates to cater for unknowns and help ensure that the project budget is robust.

An allowance for optimism bias of 20% of the estimated construction costs (including add-on costs) has been included in the total project cost estimate. This percentage was deemed reasonable following discussions with CCC/OPW and consideration of previous schemes.

7.1.6 Site Investigation and other Surveys

Significant surveys are required for the development of the scheme, including site investigations, topographic surveys, archaeological surveys, CCTV drainage surveys, etc. The total cost of these investigations and surveys is estimated to be approximately €400,000 and has been included in the cost estimate.

7.1.7 Design and Site Supervision Costs

An allowance of 10% of the baseline construction cost has been made for design and site supervision costs as per OPW guidance.

7.1.8 Land Purchase and Compensation

OPW has advised that 15% of the baseline construction costs should be added to the costs 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

For the upstream storage options in Ballinacurra, the landowner purchase and compensation costs have been increased in line with anticipated costs.

7.1.9 Maintenance Work Costs

The estimated net present value of the maintenance of the scheme has been estimated as 1% of construction costs and was calculated as €6.0 to €7.8 million dependant on the option combination selected.

7.1.10 Allowance for Art

The "per cent for art" scheme is compulsory for all major public works contracts. For this size of project, the allowance for art is 1% of the capital cost up to a maximum of €125,000. Therefore, the maximum allowance of €125,000 has been included in the cost estimate.

7.2 Summary of Costs

A summary of the total project costs for each of the reasonable alternatives set to June 2021 unit cost rates is detailed in Table 28.

Table 28 Summary of the total project costs for each of the reasonable alternatives

Option	Cost (June 2021 rates)
Area 1&2: Tír Cluain to Riverside Way	
Option 1&2A – Direct Defences and Conveyance Improvements	€10.7M
Option 1&2B – Direct Defences Only	€10.0M
Option 1&2C – Upstream Storage and Direct Defences	€8.8M
Area 3: Town Centre and Bailick Road	
Option 3A – Direct Defences Only	€14.3M
Area 4: Lauriston Estate/Rugby Club/East of IDL	
Option 4A: Groundwater cut-off and direct defences east of the current IDL site	€3.7M
Option 4B: Pumping and direct defences	€3.2M
Option 4C: Combine flood embankment with planned Northern Relief Rd Extension (NRRE) road embankment with embankment at Greenway crossing	€4.0M
Option 4D: Combine flood embankment with planned Northern Relief Rd Extension (NRRE) road embankment with flood barrier at Greenway crossing	€3.6M
Option 4E: Groundwater cut-offs and direct defences east of the current IDL site and along Greenway to mitigate impact on NRRE	€5.7M
Area 5: Ballinacurra	
Option 5A: Direct defences	€5.1M
Option 5B: Upstream storage and over pumping	€1.5M
Option 5B-1: Upstream storage – Refined storage area (smaller footprint than Option 5B) and over pumping	€1.3M
Option 5C: Optimised direct defences and over pumping	€3.5M
Option 5D: Optimised direct defences, upstream storage and over pumping	€3.1M
Area 6: Water Rock (including Dwyer's Road)	
Option 6A: Flood diversion channel / culvert (north of railway line) to the Owenacurra and direct defences	€13.0M
Option 6B-1: Flood diversion culvert (south of railway line) to the Owenacurra and direct defences	€15.9M
Option 6B-2: Flood diversion channel / culvert (south of railway line) to the Owenacurra and direct defences	€12.0M
Option 6C – Flood diversion culvert channel to Water Rock Stream and Direct Defences	€14.5M

Based on analysis of the project costs in each area, depending on the option combination selected, the total project costs are in the region of €40.6 to €51.5 million to June 2021 rates. When the % uplift due to inflation is considered, the costs in the present day are in the region of €45.4 to €57.5 million.

7.3 Benefit Assessment Methodology

7.3.1 Introduction

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

The adopted approach assesses the damages for the Midleton study by flood cell. Whilst recognised that individual properties and flood cells may have a positive or negative impact on the overall scheme based on their individual valuation of benefit and the cost, it is assumed that these differences will be aggregated across the scheme to give an overall CBR for the Scheme options. Comparison of options within each flood cell will therefore be differentiated by cost rather than CBR as all options will deliver the same SOP and thus, it is not proposed to present a CBR value per flood cell.

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 (2019)" published by the Flood Hazards Research Centre at Middlesex University. This document is often referred to as the "Multi-coloured Manual" (MCM).

7.3.2 Assumptions

7.3.2.1 Flood Damage Categories

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

7.3.2.2 Tangible Damages

These can be quantified in monetary terms, such as the reduction in flood damage costs from improvements in the standards of flood protection. Tangible damages are divided into the direct and indirect.

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.

As per OPW guidance, social class is to be excluded from the damages assessment for this project. The unit damages for residential properties therefore uses the MCM "initial appraisal" approach as the MCM 2019 "full-scale appraisal" only includes damages broken down by social class. The MCM code for each residential property has been set to the Post 1985 period. It is noted that the calculated damages are not sensitive to the selection of this time period.

The unit damages for non-residential properties used the relevant standard depth/damage curves from the MCM. 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 that are deployed during a flood event, traffic disruption associated with road closures and damage to utility assets. Each of these are now considered.

MCM 2019 estimates the cost of emergency services as between 5.6% and 10.7% of the direct tangible damages (which it is noted are referred to as the "Principal Direct Damages" (PDD) in the OPW guidance note). To account for emergency services MCM 2019 guidance proposes multiplying the direct tangible damages by 10.7% for dispersed flood incidents or 5.6% for concentrated settlements such as large towns and cities. Following consultation with OPW an uplift of 10.7% on the PDD has been selected to account for emergency services damages as Irish towns such as Midleton are smaller and less concentrated than typical urban developments in the UK.

The cost of traffic disruption is a function of the volume of traffic disrupted by a flood event, availability of alternative routes for disrupted traffic, the volume of traffic already on alternative routes as well as the duration and extent of a flood event. Previous flood events in Midleton have caused significant disruption to traffic.

During the December 2015 event a number of key routes in the town were closed to traffic: Main Street, Baby walk, Distillery Walk, Broderick Street, Bailick Road as well as the R626 in the vicinity of the Railway cottages. Bailick Road is also known to be frequently inundated during high spring tides. Damages associated with traffic disruption have therefore been included as part of the analysis. MCM 2019 notes that traffic disruption damages for previous flood events in the UK has varied between 2% and 10% of the direct tangible damages. It is proposed to account for damages due to traffic in our analysis through an allowance of 5% of the PDD.

The OPW Technical Methodology Note - Cost-Benefit Analysis (Sept 2018) advises that damage to infrastructural utility assets should be accounted for through an allowance of 20% of the PDD. Given that a number of key assets in Midleton are at risk of flooding (i.e. the WwTP, pumping stations etc) we have applied the 20% allowance to account for damage to utility assets.

A number of other loss potential sources of damage have been excluded from the analysis which we note is somewhat conservative. These include 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. Disruption to residential properties that are situated above commercial premises 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.

7.3.2.3 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 premises that are not family owned such as office spaces, retail outlets and chain stores, the intangible flood damages have been taken as zero;
- OPW guidance states that intangible damages should be applied to individually or family-owned businesses where the intangible impact would be personal and similar in nature to what might be experienced were the property residential. A significant number of local businesses in Midleton are family owned which we have identified from site visits and a virtual inspection using google street view. For these properties we have set the intangible flood damage equal to the total direct property damage.
- It is noted however that the intangible damage for family owned business has been capped at €300k which is equivalent to the residential property capping values for a detached house i.e. if the PDD of a family owned business is for example €200k then the intangible damages is also set at €200k. But if the PDD is €450k the intangible is set at €300k and not €450k as it is capped. This approach is to avoid overstating the intangible damage for these family owned properties.

7.3.2.4 Finished Floor Levels/Thresholds of Flooding

The 2D hydraulic model was used to determine the flood levels for the various return period events across the study area. The depth of flooding at each property was calculated by subtracting the finished floor level of the property from the modelled maximum water level.[10]

As part of the project, Murphy Surveys were commissioned to undertake a property threshold survey of all the properties identified in the Q100 floodplain. This data was used to set the floor levels for all the properties. For properties outside of the Q100 floodplain the ground floor level was set to 150mm above the average Lidar ground level across the footprint of the building. This data was manually checked to ensure any discrepancies in the lidar did not result in any erroneous floor levels.

7.3.2.5 Exceedance Events

In line with OPW guidance, no allowance has been made to identify any benefit of the scheme in reducing the impact of flood events greater than the 1% AEP event given that direct defences form a key component of the scheme.

7.3.2.6 Climate Change

The damages assessment has not made an allowance for increasing flood risk associated with the impact of future climate change. The damages assessment has been made for the current scenario. Damages for future timelines will however be considered as part of the climate change adaptation plan.

7.3.2.7 Discount Rate

OPW guidance and the Public Spending Code suggests that the appropriate discount rate to be applied should be 4%. The results of the cost-benefit analysis will be subjected to sensitivity testing which considers 5% and 3% discount rates.

7.3.3 Damages Assessment

7.3.3.1 Data Management

A bespoke data management and calculation tool was used to support the calculation of flood damages for the study area. The tool operates within a Geographic Information System (GIS) environment (ArcGIS).

A single dataset of all the residential and commercial properties in the study area was created, and the flood depths for the various return period at each property was automatically calculated 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 as follows:

- Geodirectory dataset – for determining the building type and use. In 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. Where discrepancies were found, the properties were inspected on site or through use of “street view” imagery freely available online, and amended accordingly;
- 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 Midleton. The OSGM15 geoid was used while conducting the hydraulic modelling. Subtraction of the property threshold level from the water level yields the depth of flooding at each property for all return period events;
- Property Threshold Survey – Defines the floor levels at each property.

[10] In line with MCM guidance, the energy grade line was not used as an estimate of the maximum water level at each property.

- Lidar data – for estimating the ground level of all the properties in Midleton for which no surveyed finished floor levels was available.

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 Midleton.

Prices (damage costs) in the data provided by MCM 2019 were converted to Euro by applying a 'PPP' multiplication factor of 1.17.

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.

7.3.4 Inflation

Since the MCM damages curves were derived in January 2019, there has been a significant period of inflation and it is necessary to account for this as part of the damages assessment.

The MCM unit damage data utilised in the damage curves needs to account for the inflation that has occurred between January 2019 (date to which the MCM data applies) and January 2023. The latest Consumer Price Index data from the Central Statistics Office (CSO) has therefore been sourced in order to derive the % uplift that needs to be applied to the MCM data. The increase in the CPI index from January 2019 to December 2022 was 15.2% and this has been utilised in the study.

It is noted that inflation has continued since January 2023, however the corresponding construction costs have also increased at the same rate. Therefore for the purposes of the Cost-Benefit Ratio, it was deemed not necessary to update both the costs and the benefit on an ongoing basis.

7.3.5 Categorisation of Damages

It is proposed to categorise the damages by watercourse and flood source. This can be summarised as:

Table 29 Damages by Watercourse and Flood Source

Watercourse	Fluvial	Tidal	Groundwater	Pluvial
Owenacurra/ Dungourney	Yes	Yes	Yes (Vicinity of Rugby Club)	Yes (centre of town)
Water Rock	Yes	Yes	Yes	n/a
Ballinacurra	Yes	n/a	n/a	n/a

7.3.6 Benefit Assessment Methodology for Pluvial Flooding

A MicroDrainage model of the Southern end of Main Street, Youghal Road and St. Mary's Road has been developed as part of the Storm Water Drainage Assessment. The results of the model have been used to develop pluvial flood risk extents for the area which in turn have been used to inform a pluvial damages assessment for this area. The BCR for the upgrade of the drainage works is then estimated.

7.3.7 Benefit Assessment Methodology for Groundwater Flooding

Different approaches to representing groundwater flood risk are proposed in the two relevant flood cells. These are both now discussed.

7.3.7.1 Midleton Rugby Club

As outlined in the hydraulics report, there are two sources of flood risk to the properties in the vicinity of Midleton Rugby Club:

- Fluvial flooding from the Dungourney River that flows overland via North of the IDL site and inundates the Rugby Pitch and its surrounding area. The threshold of flooding for the properties from this mechanism is the Q100 event;

- Groundwater flooding which comes to surface in the vicinity of the Rugby Pitch.

The damages associated with the fluvial flood risk are calculated as part of the fluvial flood damage calculations. This section of the report describes how the groundwater damages were calculated.

We have used the 2015 groundwater flood extent to assess the groundwater flood risk (and associated damages) in the vicinity of the Midleton Rugby Club and Lauriston Estate. It has not been possible to quantify the magnitude of the return period of the 2015 groundwater event due to lack of data.

Given the magnitude of the event we have assumed it is equivalent to the required groundwater design standard of the scheme in the area and is therefore deemed to approximate to the 1% AEP groundwater event.[11] The probability of a ground water event of similar magnitude reoccurring in any given year is therefore 0.01.

The maximum groundwater flood level of the 2015 event has been calculated as 6.45mOD and is based on our analysis of photographic evidence, observed flood extents and the Lidar dataset. By subtracting the floor levels of the affected properties from this maximum water level, a proxy GW100 flood depth has been calculated at each property. This data has then been used as part of the damages calculation associated with the event which is deemed equivalent to the GW100 damages which allows for the AAD to be calculated. A number of other assumptions have also been made:

MCM Depth-Damage curve for extra-long duration flood events have been utilised for the calculation given that the duration of groundwater flooding experienced during the 2015 event was a few days.

The threshold of groundwater flooding to the properties at risk is assumed equal to the 2015 flooding event i.e. there is no flooding for groundwater return period event less than the 1% AEP event. Smaller magnitude groundwater events are likely to cause flooding but as there is no way to accurately define this, the damages associated with lower return period event have been ignored. This is therefore a conservative approach and that will likely underestimate damages.

7.3.7.2 Water Rock Cave System

The hydraulic complexity of the Cave system in Water Rock and its impact on flood risk in the area is detailed in the hydraulics report. In order to estimate both the fluvial and ground water damages for the catchment the following approach has been adopted:

Fluvial flood risk for the damages calculation upstream of the cave system has been estimated assuming that neither the groundwater regime nor the cave system impacts flows in the Water rock stream.

Fluvial damages downstream of the cave system have been calculated on the basis that the hydrologically derived flows can pass through the cave system unimpeded, i.e. any storage or attenuation offered by the cave system is ignored.

Groundwater flood risk for the damages calculation upstream of the Cave system has been calculated based on the assumption that both high groundwater levels within the Cave system associated with a groundwater flood event and the Cave's internal geometry will significantly restrict the flow in the Water Rock stream. In this case water in the stream is prevented from entering the Cave System which causes very significant backwatering upstream of the entrance to the Cave.

Due to the topography of the surrounding land, the backwatering will cause the water level to exceed the crest level of the local access road which in turn will lead to a very significant volume of water spilling across the road and flowing in an Easterly direction and flooding a large number of commercial premises.

It is assumed that there is no Groundwater flood risk downstream of the Cave system for the damages calculation.

[11] It is noted that the assumed return period for the groundwater flooding experienced in 2015 is larger than the estimated circa 30-year return period of the fluvial flood for the same event.

7.3.8 Results

The baseline benefit (4%DR) associated with the various sources of flooding for the three primary flood cells is presented in Table 30 below. The results account for the 15.2% uplift due to inflation.

Table 30 Damages Avoided/ Benefit Results

Watercourse	Fluvial	Tidal	Groundwater	Pluvial
Owenacurra/ Dungourney	€37.92M	€5.36M	€1.84M	€0.81M*
Water Rock	€0.40M	€0M**	€6.12M	n/a
Ballinacurra	€5.12M	n/a***	n/a	n/a
Total per source	€43.45M	€5.36M	€7.79M	€0.81M
TOTAL				**€57.58M**

* Calculated pluvial benefit is provisional.

** Benefit associated with defending the WwTP is accounted for in the utilities % uplift.

*** Tidal flap gate at Ballinacurra is assumed to function as part of damages calculation. Tidal benefit is therefore n/a.

It is noted that the benefit in the main area of the town is based on the same fluvial/tidal joint probability used to derive the flood maps.

7.4 Conclusion of Benefit Cost Analysis

As discussed in Section 7.2, the total project costs, depending on the option combination selected, are in the region of €40.6 to €51.5 million (€45.4 to €57.5 million in December 2022 costs).

The June 2021 costs were as presented at the Public Participation Day No. 2 and as estimated for the subsequent additional assessments in Areas 4, 5 and 6. They have been estimated before a detailed freeboard assessment, and updated water level assessment, including wave overtopping and seiche analysis, have been carried out. It was also subsequently assessed that quay wall remediation works will likely be required in Area 3 which have not been accounted for in the costs presented above.

Details of the subsequent refinement of the preferred option, including the impact on the heights and extents of the defences following the freeboard and revised water level assessment, inflation and associated changes in cost are presented in Section 13.

However from inspection of the initial cost estimate, it is considered that the final Benefit Cost Ratio (BCR) will be positive. This is confirmed and discussed in Section 13.9.

8. Multi-Criteria Assessment of Reasonable Alternatives

8.1 Introduction

Multi Criteria Analysis is a decision-making support tool, developed for complex multi-criteria problems that include quantitative and/or qualitative aspects of the problem in the decision-making process.

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 reasonable alternatives which was carried out to evaluate the performance of each option in terms of predefined objectives.

The analysis has been carried out using the OPW guidance document "National CFRAM Programme Guidance Note 28 – Options Appraisal and the Multi-Criteria Analysis Framework, September 2018" as a basis. The framework has been modified in sections to link the MCA objectives to the "Environmental factors" that require impact assessment in an EIAR and ensure that these are all adequately considered at Options stage. Early consideration of these environmental factors means that likely significant effects on the environment could potentially be identified sooner, could inform the decision-making process at Options stage and likely significant effects potentially be designed out/avoided. The framework has also been modified to specifically include local feedback from the public and landowners as gleaned to date.

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 meet the objectives. The output from this stage was a total weighted score for each option. The option with the highest score is deemed to be most desirable, taking into the account the objectives considered in the modified MCA Framework.

8.2 Flood Risk Management Objectives and Weightings

The flood risk management objectives were categorised as follows:

- Social
- Economic
- Environmental
- Technical

The categories were sub-divided into objectives (refer to Table 31). Each objective has been 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 1 and 24), most of which have been fixed by the OPW at a national level. The global weightings are shown in Table 31.
- Local weighting (ranging between 0 and 5), which is specific to the importance of each objective in the location where the option was being considered. The local weightings are shown in Table 32.

Table 31 Flood Risk Management objectives and global weightings

No.	Category	Objective	Global Weighting
1A(i)	Social	Risk to Residents	0*
1A(ii)	Social	Risk to High Vulnerability Properties	0*
1B(i)	Social	Social Infrastructure	10
1B(ii)	Social	Local Employment	10
1C	Social	Social Acceptability	15
1D	Social	Proportionality on Impacted Community	15
1E	Social	Wider Benefit of Option	10
2A	Economic	Reduce Economic Damage	24
2B	Economic	Transport Infrastructure	10
2C	Economic	Utility Infrastructure	14
2D	Economic	Agriculture	12
3A	Environmental	WFD Objectives	15
3B	Environmental	Habitats and Birds Directives	9
3C	Environmental	Flora and Fauna	4
3D	Environmental	Fisheries	10
3E	Environmental	Landscape Character	7
3F(i)	Environmental	Cultural Heritage – Architectural	4
3F(ii)	Environmental	Cultural Heritage – Archaeology	4
3G	Environmental	Land, Soil and Bedrock	1
3H	Environmental	Hydrogeology	1
3I	Environmental	Air	1
3J	Environmental	Impact on Climate Change	2
3K	Environmental	Waste Generation	1
3L	Environmental	Major Accidents and Disaster	1
4A	Technical	Operationally Robust	20
4B	Technical	Risk of Failure	15
4C	Technical	Climate Change Adaptability	15
4D	Technical	Scheme Design Exceedance Events	5

No.	Category	Objective	Global Weighting
4E	Technical	Impact on Critical Infrastructure	5

* All options assessed in this MCA appraisal achieve the Standard of Protection as required in the Project Brief. The scoring system for Objectives 1A(i) and 1A(ii) is based on the number of properties (residential and high vulnerability properties respectively) potentially affected by flooding and the highest probability of flood event that causes flooding of each property.

As all options provide the same Standard of Protection for the same number of properties, there will be no difference between the scores using this scoring system. Therefore, these objectives are not considered to be differentiators for the Midleton Options Appraisal and it was agreed that the weighting be reduced to zero for the purposes of the appraisal process.

Table 32 Local Weighting

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

8.3 Scoring

Each option was then scored relative to the present-day situation (baseline condition) and each other, based on how well they met the objective. The scores used ranged between 5 and -999, as shown in Table 33 below.

Table 33 MCA Scoring

Impact	Score
Fully Achieving Aspirational Target	5
Partially Achieving Aspirational Target	3
Exceeding Basic Requirement	1
Meeting Basic Requirement (No Change)	0
Just failing minimum target	-1
Partly failing minimum target	-3
Fully failing minimum target	-999

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

8.4 MCA Process

A total weighted score was then calculated for each objective as the sum of the weighted scores across the 29 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.

8.5 Stakeholder Engagement Workshops

As part of the MCA assessment, a comprehensive engagement process was undertaken with relevant stakeholders. A number of workshops were held between the project team, project specialists, CCC, OPW and relevant stakeholders as outlined below. At each workshop, the reasonable alternatives for each area were reviewed holistically, and MCA weightings and scores for the objectives under review were discussed. Feedback from the various stakeholders was considered and was applied to inform the scoring of the MCA.

1. Review of Technical Objectives
2. Review of Heritage, Landscape and Visual Objectives
3. Review of Environmental/Biodiversity Objectives
4. Summary Review of All Objectives

8.5.1 Review of Technical Objectives Workshop

The purpose of the workshop was to agree local weightings and scores of the technical criteria. Attendees included Midleton based CCC staff, including the Senior Executive Engineer, Roads & Transportation, Executive Engineer, Roads Operations and Senior Executive Engineer, Water Services – Waste Water, a CCC Senior Resident Engineer with experience on other flood schemes and OPW staff from South West region maintenance and construction division.

Feedback on the operational robustness of the options, in particular options with proposed storage and options with pumping stations, resulted in some of the scores being adjusted.

8.5.2 Review of Heritage, Landscape and Visual Objectives Workshop

The purpose of the workshop was to agree local weightings and scores of the Landscape and Visual, and Heritage criteria. Attendees included staff from CCC - Planning Department including County Archaeologist and Conservation Officer, Senior Architect from CCC - Capital Projects Implementation Unit, County Engineer Directorate, the project landscape and visual specialist and the project archaeology specialists.

Feedback included that unregistered cultural heritage features should also be considered in the options assessment. Some of the scores were subsequently adjusted to take into account those features that have been identified to date.

8.5.3 Review of Environmental/Biodiversity Objectives Workshop

The purpose of the workshop was to agree local weightings and scores of the environmental criteria. Attendees included staff from CCC, an Ecologist from Water Services/County Engineers Dept, an Ecologist from Forward Planning & Strategic Development Dept, Senior Executive Scientist from Environment Directorate and Executive Engineer from Climate Action Regional Office, Environment Directorate, OPW environmental staff and the project ecologist.

In general, it was noted that the key objectives to consider, in terms of biodiversity and water quality protection, are Objectives 3A and 3B. It was suggested that, due to the very high weighting of Objective 3A relative to the other objectives, sensitivity analysis on the relative option marking should be undertaken. This was undertaken however it did not have an impact on the final outcome.

It was suggested further justification should be given to option scoring and narrative to consider direct and indirect effects on the European sites and their targets for conservation. It was also suggested that scores should consider Objective 3A and the potential connection between these objectives. Some of the scores were subsequently adjusted to take into account these comments.

It was also noted that consideration should be given to where opportunities might present for positive impact or enhancement, and which might mitigate loss/environmental impact in other areas.

8.6 Environmental Assessment of Reasonable Alternatives

In addition to the MCA, a comparison of environmental effects of the reasonable alternatives was undertaken.

The potential likely significant effects arising from each of the reasonable alternatives are discussed under each of the following headings:

- Population and Human Health
- Biodiversity
- Land and Soil
- Hydrogeology
- Water
- Air
- Climate
- Material Assets
- Resources and Waste
- Cultural Heritage
- Landscape
- Vulnerability to major accidents and/or disasters

This is included in Appendix A and the findings inputted into the MCA process and the selection of the preferred option.

8.7 MCA Outcomes

Once the MCA was applied, each option had a weighted score for each category (i.e. Social, Economic, Environmental and Technical). **MCA Benefit Score** was calculated by summing the economic, social and environmental category scores. This score represents the net benefits of the option and does not include the Technical score.

For each option, the scores for each of the four categories were summed to provide the **Option Selection Benefit Score**. This score compliments the MCA Benefit Score with the Technical Criteria Score, and hence includes all of the aspects that should be taken into account in considering the preferred option for a given area.

The MCA Benefit Score was divided by the cost of the option to provide a numerical, but non-monetised, **MCA Benefit - Cost Ratio** that provided an indication of the overall benefits that may be delivered per Euro invested.

8.8 MCA Summary

Findings for Option 3A are presented for information purposes only as there were no comparative reasonable alternatives available. The remaining areas had multiple reasonable alternatives and therefore allowed for a comparative assessment. The following sections outline the key differentiators between the options.

8.8.1 Area 1&2: Tír Cluain to Riverside Way

The total MCA Score for Option 1C&2C, the upstream storage option, is the lowest score of the three options. This is due to the potential operational risk and the maintenance requirements with an upstream storage solution of this scale. This option also scores lowest in the environmental and economic categories, due to the potentially negative impact of river realignment, impact on fisheries and the flow control structure within the river channel, and the loss of agricultural land during flood events.

Public perception of this option was initially positive. However, after the PPD2, a number of submissions were received which were strongly in opposition. Thus, a notable risk to project delivery was identified.

The total MCA Scores for Option 1A&2A and 1B&2B are closer, however Option 1A&2A, which includes dredging and bridges removal/replacement, scores lower due to the potentially significant negative environmental impact of dredging, and the operational risk and the maintenance requirements associated with dredging. This option also includes removal and replacement of the Carrigogna bridge. Although not protected, this bridge is of cultural heritage importance. From a social perspective, local opposition to Option 1A&2A was also noted, due to the removal of Moore's Bridge.

Therefore Option 1B&2B, the direct defences only option, was found to be the most favourable.

Table 34 MCA Summary Results – Area 1&2

Option	1A&2A	1B&2B	1C&2C
Description	**Direct Defences and Conveyance improvements**	**Direct defences only**	**Upstream Storage and Direct Defences**
MCA Benefit Score	1789	2083	1163
Option Selection Benefit Score	2639	2933	1463
Total Project Costs (€m)	10.7	10	8.8
MCA Benefit/ Cost Ratio	0.17	0.21	0.13

8.8.2 Area 3: Town Centre and Bailick Road

There is only one reasonable alternative identified in Area 3, due to the constraints identified in the Preliminary Technical Assessment. An MCA was still conducted to ensure that a reasonable MCA Benefit/Cost Ratio could be achieved and that any additional constraints could be identified and mitigated against early in the design if necessary.

This option received positive feedback during and post the PPD2. The option would facilitate and enhance other projects within the area, including regeneration of the Baby Walk / People's Park area.

Conversely, it was identified that the in-stream works would likely have a negative impact on biodiversity and sediment transport to the Special Area of Conservation (SAC), although it was noted some mitigation measures would be technically feasible to reduce the extents. A direct impact on Lewis Bridge would be required, which is a protected structure. Indirect impacts on other protected sites such as Midleton House and Charleston Maltings were also noted. This resulted in a reduction in the environmental scoring.

From a technical perspective, it was found that this option was operationally robust, with a limited number (3-4No) of rapidly deployed in-situ flood defences, i.e., flood gates at Baby Walk and Bailick Rd. It was also found to be adaptable to the MRFS at moderate to significant cost. However, it was noted that the option may not be adaptable to the HEFS, as the heights of the direct defences would likely become socially unacceptable in public areas.

Table 35 MCA Summary Results – Area 3

Option	3A
Description	**Direct Defences**
MCA Benefit Score	2179
Option Selection Benefit Score	2779
Total Project Costs (€m)	14.28

Option	3A
Description	**Direct Defences**
MCA Benefit/ Cost Ratio	0.15

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

In Area 4, originally there were five options identified as being technically feasible. However further to stakeholder consultation with IDL and CCC (other departments), and receipt of additional information, it was considered that Option 4B has some technical limitations. It is considered that the proposed embankment located east of the railway bridge, which would hold water on the east of the defence, could induce groundwater flooding within the IDL site as the existing IDL embankments are not designed as flood defence embankments. Furthermore, this option does not take the interaction of the scheme with the other ongoing and proposed CCC projects into consideration. Therefore, this option will not be progressed.

It was found that Options 4A and 4C scored similarly when examining their respective Option Selection Benefit Scores. Option 4D scored lowest of all options, with Option 4E emerging as the option with the highest score. All of the options scored similarly in the MCA Benefit Score which examines the Social, Environmental and Economic effects of the proposed schemes, this was expected as the options mainly differ under the technical criteria.

From a social perspective, Option 4E scored the highest. Although it was not presented at the PPD, its design is a derivative of Option 4A, which received a favourable public response. Option 4E is the only option deemed not to negatively impact other projects currently proposed for the area, namely the NRRE and Midleton to Youghal Greenway. While Option 4D was not deemed to impact on the delivery of the other proposed projects, the requirement for flood barriers to be erected during a flood event would result in considerable operational risk and maintenance requirements.

Due to the relatively larger scale of Options 4A and 4E, it was found that these options had the greater environmental effects, although the scores across all of the options were found to be similar. Options 4A and 4E would require a comparatively greater land take and potential tree removal, which would have potential impacts on bat and bird habitats in the area.

There were substantial differences noted across the technical scores. Option 4D received the worst score due to the operational risk with inclusion of the demountable flood barrier within the option and the poor adaptability of the option. Option 4C scored poorly due to potential project delivery risks with the Greenway, NRRE and FRS embankment all crossing at the same location.

Options 4A and 4E both scored positively in the technical criteria, however Option 4E eliminated a noted constraint identified in relation to the impact of the design on the proposed NRRE. By moving a portion of the flood defence embankment further east prior to crossing the Greenway, the option facilitated enough room to regrade the Greenway on its approach to the crossing without impacting on the proposed NRRE to the west.

Given the factors outlined above, Option 4E was found to be the most favourable reasonable alternative.

Table 36 MCA Summary Results – Area 4

Option	4A	4C	4D	4E
Description	**Groundwater Cut-offs and Direct Defences**	**Combined NRRE/FRS Design with Embankment at Greenway Crossing**	**Combined NRRE/FRS Design with Flood Barrier at Greenway Crossing**	**Groundwater Cut-offs and Direct Defences along Greenway**
MCA Benefit Score	1281	1263	1313	1445
Option Selection Benefit Score	1826	1733	783	2150
Total Project Costs (€m)	3.7	4.0	3.6	5.7
MCA Benefit/ Cost Ratio	0.35	0.32	0.36	0.25

8.8.4 Area 5: Ballinacurra

In Area 5, there were five options identified as being technically feasible.

It was found that Options 5A, 5B and 5C scored similarly when examining their respective Option Selection Benefit Scores. Option 5D scored lowest of all options, with Option 5B-1 emerging as the option with the highest score. This was also true for the MCA Benefit Score.

Option 5D, being a combination of direct defences and upstream storage, was found to have the worst environmental impact. This was due to the reoccurring impediment to the Water Framework Directive (WFD) objectives, as a result of channel realignment, in-stream works and pumping requirements. Furthermore, this option would directly impact four features of architectural/cultural heritage and a burial site. This option also received the lowest technical score in the MCA, due to the increased operational risk of reliance on both the flow control at the embankment and the pumping station

In the Social category, Option 5A scored lowest, with a clear public preference instead for an upstream storage solution which would minimise works near the residential areas. Option 5B-1 scored highest under this category, due to the reduced landowner impact. There was no significant difference in the Economic category identified between the options, with only a minor difference noted with regard to the use of agricultural land during flood events for the upstream storage options.

When assessed on their environmental criteria, Option 5A scored the highest, with the remaining three options all scoring similarly. Option 5A achieved the higher score through the lesser impacts on the WFD objectives and the relatively lesser impacts expected for fish and fisheries. It should be noted that both Option 5B and Option 5B-1 were found to have a lesser impact on features of architectural, archaeological and cultural importance, thus reducing the difference in the environmental score between the option types.

The final criteria on which options were assessed was technical. Under this criteria, Option 5C scored less than Options 5A, 5B and 5B-1, despite its low operational risk. This option scored poorly with regard to its adaptability to future interventions to address future flood risk. This was also noted in Option 5A, as it is a notable drawback for direct defence options.

Where Options 5B and 5B-1 were found to significantly outperform the other options was their adaptability to the impacts of climate change and future, more extreme, flood events. This is due to the ability to take the assumptive approach and design for these flood events in the present day and minimise the need for future work. The very nature of these options also lends them to provide a significantly greater level of protection for properties downstream under exceedance events.

Given the factors outlined above, Option 5B-1 was found to be the most favourable.

Table 37 MCA Summary Results – Area 5

Option	5A	5B	5B-1	5C	5D
Description	**Direct Defences only**	**Upstream Storage**	**Upstream Storage – Refined Storage Area and Overpumping**	**Optimised Direct Defences and Overpumping**	**Optimised Direct Defences, Upstream Storage and Overpumping**
MCA Benefit Score	1092	1016	1212	1092	905
Option Selection Benefit Score	1627	1576	1772	1402	1215
Total Project Costs (€m)	5.1	1.5	1.3	3.5	3.1
MCA Benefit/ Cost Ratio	0.21	0.68	0.93	0.31	0.29

8.8.5 Area 6: Water Rock

In Area 6, there were four options identified as being technically feasible. The options all include direct defences in combination with a culvert or open channel, the purpose of which is to bypass the cave system, this removes the uncertainly associated with the cave system contributing to the flood risk in the area upstream of the caves.

It was found that Options 6A, 6B-1 and 6B-2 scored similarly when examining their respective Option Selection Benefit Scores. Option 6C scored lowest of all options, with Option 6B-2 emerging as the option with the highest score. This was also true for the MCA Benefit Score.

Option 6C scored lowest under the social criteria due to the potential delivery risk of interaction with existing Irish Rail and TII infrastructure, and the impact of the option on landowners not currently at flood risk. The option has significant interaction and potential clashes with a number of planned critical infrastructure projects, including Irish Water Wastewater Load Diversion project, the Water Rock Lihaf infrastructure and the Ballinacurra to Midleton Cycleway Scheme..

As all options offer the same level of protection without increases to the impact of flooding on agricultural lands, all options scored identically under the economic core criteria.

Under the environmental core criteria, a minor difference was observed between options 6A, 6B-1 and 6B-2, which was in relation to the localised loss of low value biodiversity. It was noted that Option 6B-2 would generate the potential for biodiversity opportunities through the long lengths of open channels proposed. As the construction, operation and maintenance requirements were the same between the options, no further differences in the environmental effects were noted. However, Option 6C was found to have a greater environmental impact. This option would permanently impede the achievement of the water body objectives by changing the hydromorphology of the Water Rock stream downstream of the cave system. These changes are required due to the conveyance improvements brought about by the cave system bypass culvert/channel.

Under the technical core criteria, Option 6C scores lowest as it is considered that there is an increased operational risk due to the greater number of culverts and channels which may become blocked without regular maintenance works.

While all options would involve works close to existing and proposed critical infrastructure, the alignment of Option 6B-1 and 6B-2 mitigates the potential clashes and project delivery risks. Options 6B-1, 6B-2 and 6C also noted a risk to project delivery due to the underground railway crossing required. However, this was deemed to be manageable on the basis of the initial consultation with Irish Rail. Irish Rail are planning a shutdown of the line in 2023/2024 to facilitate widening of the route, which would provide an opportunity for the works in these options to proceed.

Overall, Option 6B-2 had the highest overall MCA Benefit and Option Selection Benefit Score. Given the factors outlined above, Option 6B-2 was found to be the most favourable.

Table 38 MCA Summary Results – Area 6

Option	6A	6B-1	6B-2	6C
Description	**Flood Diversion Channel/Culvert and Direct Defences**	**Flood Diversion Culvert South of Railway and Direct Defences**	**Flood Diversion Channel/Culvert South of Railway and Direct Defences**	**Option 6C: Flood Diversion Channel (bypassing Cave System) and Direct Defences**
MCA Benefit Score	1102	1152	1164	778
Option Selection Benefit Score	1742	1832	1844	1318
Total Project Costs (€m)	13.0	16.0	12.0	14.5
MCA Benefit/ Cost Ratio	0.08	0.07	0.10	0.05

8.9 MCA Conclusion

MCA scores for Area 3 is presented for information purposes only as no comparative reasonable alternatives were available.

The remaining areas allowed for a comparative assessment. The MCA process was therefore used to aid identification of a preferred option for these areas, which is outlined in detail in Section 9.

The option selection benefit score of Option 1B & 2B was found to the highest due to the better scores in comparison to the other options for the social and environmental objectives, and the similar scoring in the technical and economic objectives. The key differentiators are the operational robustness of the option as a "passive" option, the perceived lesser project delivery risk and the lesser impact on the environment with the direct defence only option.

The option selection benefit score of options for Area 4 varied significantly across the options. Option 4E was found to have the highest score due to the better scores in comparison to the other options for the social and technical objectives, and the similar scoring in the environmental and economic objectives. The key differentiators between Option 4E and the other options are the perceived lesser project delivery risk due to the consideration of the interaction with other infrastructure projects, and consideration that it is more operationally robust and more adaptable solution than the other options.

The option selection benefit score of the five options for Area 5 were found to be similar, with Option 5B-1 scoring the highest. This was due to the better scores in comparison to the other options for the social and technical objectives, and the similar scoring in the environmental and economic objectives. The key differentiators between Option 5B-1 and the other options are the perceived lesser project delivery risk due to the lesser impact on number of landowners, and consideration that it is a more adaptable solution than the other options.

The option selection benefit score of the four options for Area 6 were found to be similar, with the exception of Option 6C which had a much lower score than the other options. Option 6B-2 was found to have the highest option selection benefit score. This was due to the better scores in comparison to the other options for the social, environmental and technical objectives, all options scored the same for the economic objective. The key differentiators between Option 6B-2 and the other options is the potential for biodiversity opportunities through the long lengths of open channels proposed and the perceived lesser project delivery risk by designing out known clashes with existing and planned infrastructure.

9. Selection of Emerging Preferred Option

Having assessed the various options in each area, conclusions can be drawn to inform the development of the emerging preferred option. The merits of the alternative options will be summarised on the basis of cost, MCA score, environmental and ecological impact, process and programme and climate change adaptability.

It is important that the current 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.

Also taken into account in the selection of the preferred option was the combined professional judgement of the steering group members and consideration of the feedback which arose during the public and stakeholder consultation process.

9.1 Area 1&2: Tír Cluain to Riverside Way

As outlined in detail in Section 8.8.1, the option selection benefit score of Option 1B & 2B was found to be the highest due to the better scores in comparison to the other options for the social and environmental objectives, and the similar scoring in the technical and economic objectives. The key differentiators are the operational robustness of the option as a “passive” option, the perceived lesser project delivery risk and the lesser impact on the environment with the direct defence only option.

Option 1B & 2B was found to be readily adaptable to future flood risk with limited difficulty, cost and impact. The option does not provide impediment to future interventions to address future risk.

Furthermore there was significant opposition to the other options, upstream storage and conveyance improvements, from various stakeholders and landowners. It is also noted that this option facilitates other planned infrastructure in the area.

Although the project capital cost of Option 1B&2B is the second least expensive of the three options, the Economic Benefit/Cost Ratio of the option is positive.

Given the factors outlined above, Option 1B&2B, the direct defences only option, was found to be substantially more favourable than the other options, and it is recommended as the preferred option.

9.2 Area 3: Town Centre and Bailick Road

The MCA scores for Area 3 are presented for information purposes only as no comparative reasonable alternatives were available.

The only option considered viable in Area 3 is adaptable for the Mid- Range Future Scenario (MRFS) at moderate to significant cost, difficulty and impact.

It is noted that this option facilitates other planned infrastructure in the area, and allows for the upgrade of the Baby Walk and People’s Park which will benefit the local community..

It is also noted that the Economic Benefit/Cost Ratio of the option is positive.

Given the factors outlined above, Option 3A, the direct defences only option, is recommended as the preferred option.

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

As outlined in detail in Section 8.8.3, the option selection benefit score of Option 4E was found to be the highest due to the better scores in comparison to the other options for the social and technical objectives, and the similar scoring in the environmental and economic objectives. The key differentiators between Option 4E and the other options are the perceived lesser project delivery risk due to the consideration of the interaction with other infrastructure projects – the Greenway and the Northern Relief Rd Extension, and consideration that it is more operationally robust than the other options.

It is proposed that the assumptive approach be adopted for Option 4E in the present day and that the embankment be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal further cost or intervention, however there will be a minimum increase in present day capital costs. The assumptive approach for the groundwater cut-off is also applicable to accommodate the MRFS and HEFS required standard of protection.

Significant consultation was undertaken with the other infrastructure project teams in the area and it is considered that this is the preferred option to facilitate the other planned infrastructure in the area which have wider societal value.

Although the project capital cost of Option 4E is the most expensive of the four options, if the costs are taken in combination with the NRRE project costs, it is considered that there would be saving across both projects.

Given the factors outlined above, Option 4E - Groundwater Cut-offs and Direct Defences along Greenway option, was found to be substantially more favourable than the other options, and it is recommended as the preferred option.

9.4 Area 5: Ballinacurra

As outlined in detail in Section 8.8.4, the option selection benefit score of Option 5B-1 was found to be the highest due to the better scores in comparison to the other options for the social and technical objectives, and the similar scoring in the environmental and economic objectives. The key differentiators between Option 5B-1 and the other options are the perceived lesser project delivery risk due to the lesser impact on number of landowners, and consideration that it is a more adaptable solution than the other options.

It is proposed that the assumptive approach be adopted for Option 5B-1 in the present day and that the embankments and flow control structure be designed to accommodate the MRFS and HEFS required standard of protection. This approach will have minimal further cost or intervention, however there will be a minimum increase in present day capital costs.

There is opposition to the option from a landowner within the storage area which needs to be addressed. However, there may be an opportunity for additional social infrastructure and amenity /social value within the storage area. There is also some opposition to realignment of watercourse at Kearney's Cross, this will be considered through the design process.

The project capital cost of Option 5B-1 is the least expensive of the five options and the Economic Benefit/Cost Ratio of the option is positive.

Given the factors outlined above, Option 5B-1 - Upstream Storage - Refined Storage Area and Overpumping option, was found to be substantially more favourable than the other options, and it is recommended as the preferred option.

9.5 Area 6: Water Rock

9.5.1 Upstream of the cave system

A number of technically feasible options have been developed for Area 6. In order to achieve the target standard of protection upstream of the cave system, all of the options include a significant length of culvert and/or open channel, the purpose of which is to bypass the cave system. This would remove the uncertainty associated with the cave system contributing to the flood risk in the area upstream of the caves.

However a large portion of the total scheme costs is associated with the construction of this flood relief culvert and /or open channel and the costs of the culvert crossing under various significant infrastructure, such as the Midleton to Cork railway line and/or the N25. The benefit associated with the protection of the area upstream in Water Rock is in the order of €6 million. This results in a significantly negative benefit cost ratio (BCR) of between 0.31- 0.42 depending on the option selected. It also puts the overall scheme BCR at risk of being negative.

Due to high costs/ low benefit associated with the options presented in Area 6 and the technical complexity of delivering any of these options, at this stage it is not proposed to progress with the flood relief culvert option in the area upstream of the cave system.

It is proposed to carry out further investigations into potential flood risk management measures that may provide flood mitigation (albeit not to the target standard of flood protection) in the Water Rock area upstream of the cave system. Measures that are under consideration include but are not limited to:

- Individual Property Protection (IPP) upgrades
- Direct defences
- Flood relief culvert under Water Rock Rd
- Upstream storage
- Conveyance improvements downstream of the cave system

Further consultation with the impacted landowners will be undertaken.

9.5.2 Downstream of the cave system

Immediately downstream of the cave system, it is proposed to upgrade the drainage in area just south of the N25 to allow the springs discharge back into the Water Rock stream. However due to the potential of unknown springs in the area, it may not be possible to achieve the target standard of protection in this area.

Further downstream, in the tidally dominated reach, it is proposed to provide direct defences and culvert upgrades to provide protection to the wastewater treatment plant and the Dwyer's Rd area. These interventions will be included in the Area 3 description of the Refinement of Preferred Option due to the tidal nature of the flooding.

9.6 Emerging Preferred Option

On the basis of the information outlined in this report, the emerging preferred options in each area are as follows:

Table 39 Emerging Preferred Scheme

Area	Option
Area 1&2: Tír Cluain to Riverside Way	Option 1B&2B – Direct Defences only
Area 3: Town Centre and Bailick Road	Option 3 – Direct Defences only
Area 4: Lauriston Estate / Rugby Club / East of IDL	Option 4E – Groundwater Cut-offs and Direct Defences along Greenway
Area 5: Ballinacurra	Option 5B-1 – Upstream Storage - Refined Storage Area and Overpumping
Area 6: Water Rock	Flood relief culvert option will not be progressed upstream of the cave system. Flood risk mitigation measures to a lower standard of flood protection to be investigated. Direct defences option downstream of the cave system will be included in Area 3 of the refined option.

10. Tidal Water Level Update

10.1 Introduction

As discussed in Section 1.7, the design tidal water levels were updated over the course of the study as a consequence of the findings of a very detailed study of tidal levels in Cork Harbour undertaken by Arup as part of the Lower Lee (Cork City) Flood Relief Scheme. This section provides an overview of analysis undertaken as part of that work and how it relates to Midleton.

10.2 Overview

The tidal water level in the Owenacurra Estuary acts as the downstream boundary condition of the hydraulic model developed as part of the study. As detailed in the Hydraulics report two different types of model runs have been considered as part of the study:

- calibration model runs;
- design model runs used to inform both the existing scenario flood risk and the optioneering.

Both of these are now discussed.

10.2.1 Calibration model runs

The calibration hydraulic model utilised actual recorded tidal water levels from the Port of Cork Gauge at Cobh as the basis of the downstream boundary in the Owenacurra estuary. As the tidal water levels at Cobh are not however equivalent to the levels in the Owenacurra estuary due to tidal amplification between the two locations, the recorded data at Cobh was adjusted based on the water level relationship between the two points.

10.2.2 Design runs (hydraulics report and optioneering)

The tidal boundary for the existing scenario design model runs were first derived for the outer harbour area using two separate datasets: (a) extreme value tidal water levels for the outer harbour as estimated by the Lee CFRAM study, and (b) recorded tidal water levels from the Cobh tidal gauge which was used to define the shape of the tidal curve in the outer harbour. A two-dimensional MIKE 21 model of Cork Harbour was then used to propagate the tide from the outer harbour up into the Owenacurra estuary in order to derive design water levels at this point. These results were then used to define the downstream boundary condition for both the existing scenario design simulations (as presented in Section 6 of the Hydraulics report) and the optioneering model runs (as presented in Section 5 of this options report).

The peak water levels for each AEP event are presented in the following table. It is noted that the peak levels do not include any allowance for seiche.

Table 40 Peak Tidal Water Levels

Design Event (AEP)	Peak Tidal Levels in Owenacurra Estuary - Hydraulics Report and options selection (mOD Malin)
50%	2.37
20%	2.48
10%	2.55
4%	2.64
2%	2.71
1%	2.78

Design Event (AEP)	Peak Tidal Levels in Owenacurra Estuary - Hydraulics Report and options selection (mOD Malin)
0.5%	2.84
0.1%	3.00

10.2.3 Updates to the design water levels

As part of the Lower Lee (Cork City) Flood Relief Scheme (LLFRS), Arup was commissioned by the OPW to undertake a very detailed assessment of tidal water levels throughout Cork Harbour which includes the full extent of the Owenacurra estuary. The scope of the study can be summarised as:

- Collection and review all the datasets relevant to the study such as tide gauge data, bathymetric and topographic data, meteorological forcing data, river flow data, historical flood event data and all other relevant data;
- Assess and review all previous tidal water level studies for Cork Harbour with particular emphasis on the Lee CFRAM and ICPSS studies;
- Estimate design tidal water levels at each of the primary gauge locations in the Harbour by undertaking an Extreme Value Analysis (EVA) on the recorded water levels;
- Development of a high-resolution MIKE 21 hydrodynamic model of Cork Harbour to allow accurate modelling of the movement of the tide throughout the harbour and subsequently, undertake a series of simulations in order to assess the impact of storm surge events on water levels in Cork Harbour.
- Provide an estimate of the design water levels across the harbour by considering the findings of different studies and assessments:
  - The Arup hydrodynamic model of the harbour (as noted above);
  - The Arup EVA of the gauged data (as noted above);
  - The previous Lee CFRAM and ICPSS studies (as noted above);
- Undertake an uncertainty analysis of the design tidal water levels estimated by the study for use as part of the wider freeboard assessment of the LLFRS;
- Undertake a detailed assessment of seiche in the harbour and determine a suitable allowance for seiche in the design of the scheme.

The primary output from the study was a set of design tidal water levels for the whole area of the harbour which supersede the previously derived set of design water levels for the harbour which used to inform earlier stages of the LLFRS.

10.2.4 Updates to the design water levels in the Owenacurra estuary

As the Owenacurra estuary forms part of Cork Harbour, an updated set of design water levels were produced for the estuary as part of the LLFRS study. Its findings are deemed to be more accurate than the findings of our previous estimate of the design water levels as described in Section 10.2.2 above for the following reasons:

- the methodology adopted as part of the LLFRS study was considerably more robust than that used by the Lee CFRAM such that the results have a much greater level of confidence associated with them;
- The LLFRS study takes account of the most up to date water level datasets from the harbour which includes a number of tidal flood events from 2014, 2016 and 2018. As the EVA of tidal water levels used to inform the Lee CFRAM study was undertaken in circa 2008, none of the recent flood event data was considered as part of that study.

A substantial volume of work had been undertaken as part of the Midleton FRS by the time at which the LLFRS water level assessment had been finalised. This work is listed as:

- Existing scenario hydraulic modelling and flood mapping (detailed in the Hydraulics Report);
- Development of options (Section 5 of Options Report)
- Damages assessment (Section 7.3 of Options Report)
- SCCAP study

It was decided by the Steering Group that this work would not be revised in light of the updated tidal water levels as part of the Options Report. The updated tidal levels are instead to be utilised from the point in time at which they were made available to the study. The following items of work have therefore been undertaken with the updated water levels:

- Freeboard assessment (Section 11 of Options Report)
- Confirmation and refinement of the emerging preferred option (Section 13 of Options Report)

The justification for this approach is given as:

- The updated design water levels do not impact on the conclusions of the work undertaken using the older set of tidal levels (i.e. existing scenario flood mapping or optioneering). Utilising the updated levels will therefore not impact on the selection of the emerging preferred option.
- Revisiting all of the work undertaken to date with the updated tidal water levels would have entailed a very significant delay to the project programme.
- It is acknowledged that the updated tidal levels will however impact on the damage assessment as the higher water levels will entail higher total direct damages at the relevant properties. The damages for the scheme are however to be revised at a later stage in the project in order to take account of the revised damages/benefit guidance note issued by the OPW. The updated water levels can therefore be used to inform the updated damage assessment when it is being undertaken at that future point in the project.

Given that the assessment and refining of the emerging preferred option has taken account of the revised tidal water levels, the finalised defence heights and freeboard allowance (as presented in Sections 11 and 13) are confirmed and will not subject to revision at a later stage of the project.

Both the superseded and revised peak water levels for the Owenacurra estuary are presented in the following table. It is noted that the revised levels do include an allowance for seiche which is discussed further in Section 10.3.

Table 41 Peak Tidal Water Levels

Design Event (AEP)	Peak Tidal Levels in Owenacurra Estuary - hydraulics report and options selection (mOD Malin)	Revised Peak Tidal Levels in Owenacurra Estuary – emerging preferred option and freeboard assessment (mOD Malin OSGM15)	
	No seiche	No seiche	150mm seiche allowance included
50%	2.37	2.49	2.64
20%	2.48	2.59	2.74
10%	2.55	2.66	2.81
4%	2.64	2.73	2.88
2%	2.71	2.85	3.00

Design Event (AEP)	Peak Tidal Levels in Owenacurra Estuary - hydraulics report and options selection (mOD Malin)	Revised Peak Tidal Levels in Owenacurra Estuary – emerging preferred option and freeboard assessment (mOD Malin OSGM15)	
	No seiche	No seiche	150mm seiche allowance included
1%	2.78	2.92	3.07
0.5%	2.84	2.94	3.09
0.1%	3.00	3.15	3.30

10.3 Seiche Allowance

A seiche is defined as a standing wave in an enclosed body of water. In macro-tidal estuaries such as Cork Harbour, a seiche can be generated by a number of different mechanisms:

- Wind forcing: gusts acting on the sea surface and/or sudden changes in the direction of the wind;
- Atmospheric pressure: Sudden and sharp changes in the atmospheric pressure;
- Local amplification: Wave reflection and/or tidal resonance can generate standing waves in an estuary such as Cork Harbour.

In both cases the external forcing induces a standing wave (i.e. a vertical oscillatory motion of the water surface) which leads to the actual water level to exceed the still tidal water level. Seiche therefore needs to be considered as part of flood relief scheme design.

The LLFRS study undertook a detailed assessment of seiche in Cork Harbour by assessing two separate high-temporal resolution 1 minute water level datasets from the inner harbour area and also by reviewing the findings of the ICPSS study which analysed seiche in the harbour. Based on this work the LLFRS adopted a seiche allowance of 150mm for the whole harbour area. This allowance was added to the still water level estimates for all AEP events in order to derive the total design tidal water levels.

Given that seiche generation can be sensitive to local conditions the suitability of adopting a harbour wide allowance for the Owenacurra estuary was investigated by undertaking a detailed inspection of the 1 minute temporal resolution water level data collected by the two tidal gauges in the Owenacurra estuary over a six month period from the 1st of January to the end of June 2022. The location of the gauges is presented in Figure 38.

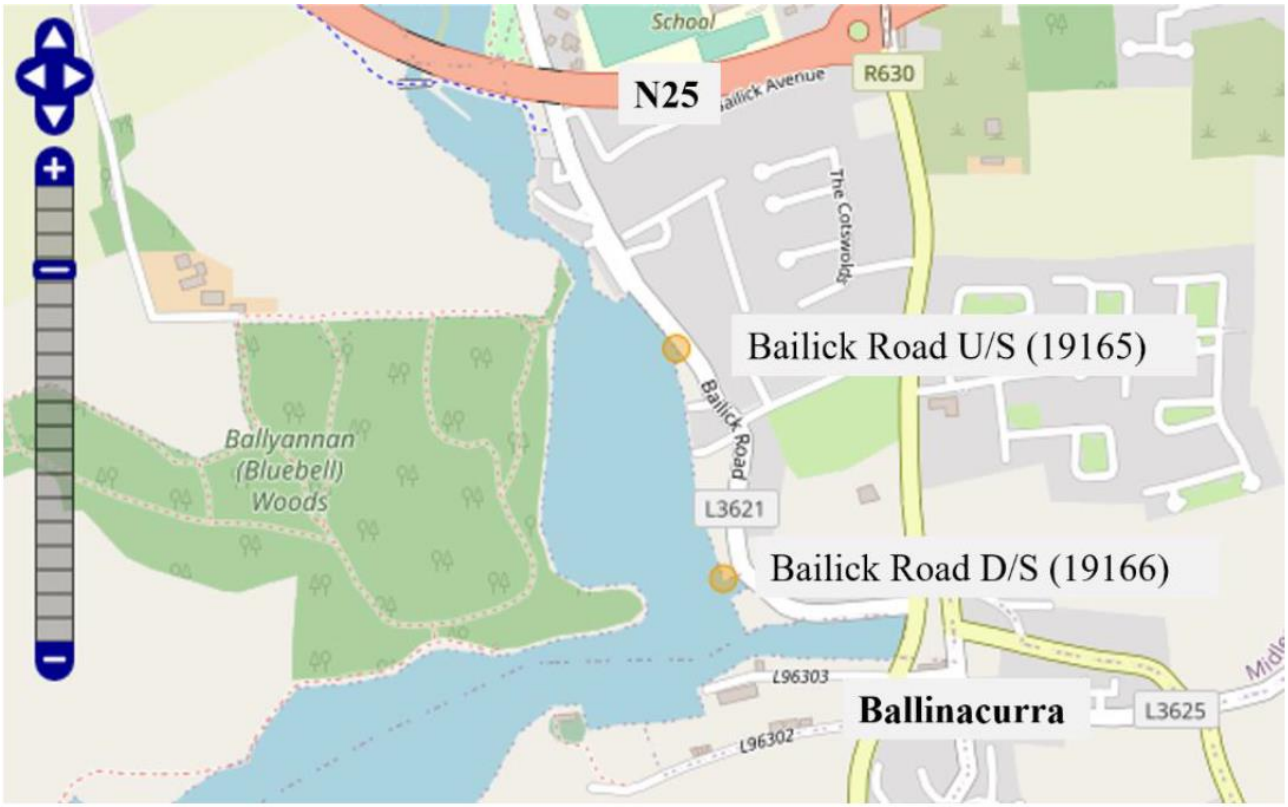


Figure 38 Location of the tidal gauges in the Owenacurra estuary

The following conclusions were derived from the detailed assessment of the data:

- No local wind generated seiche events occurred over the six month period in the Ballinacurra estuary;
- Locally generated seiche resulting from wave reflection/resonance forcings occurred on multiple occasions over the six month period. These events adopt a sinusoidal wave form and typically last from between 30 minutes and 3 hours and generally occur at low tide during neap tidal conditions. An example of such an event is presented in the figure below. It can be seen from the plot that seiche is observed on both the low tides that occur on the 23rd and 24th of April. The seiche is not evident on at other stages of the tide.

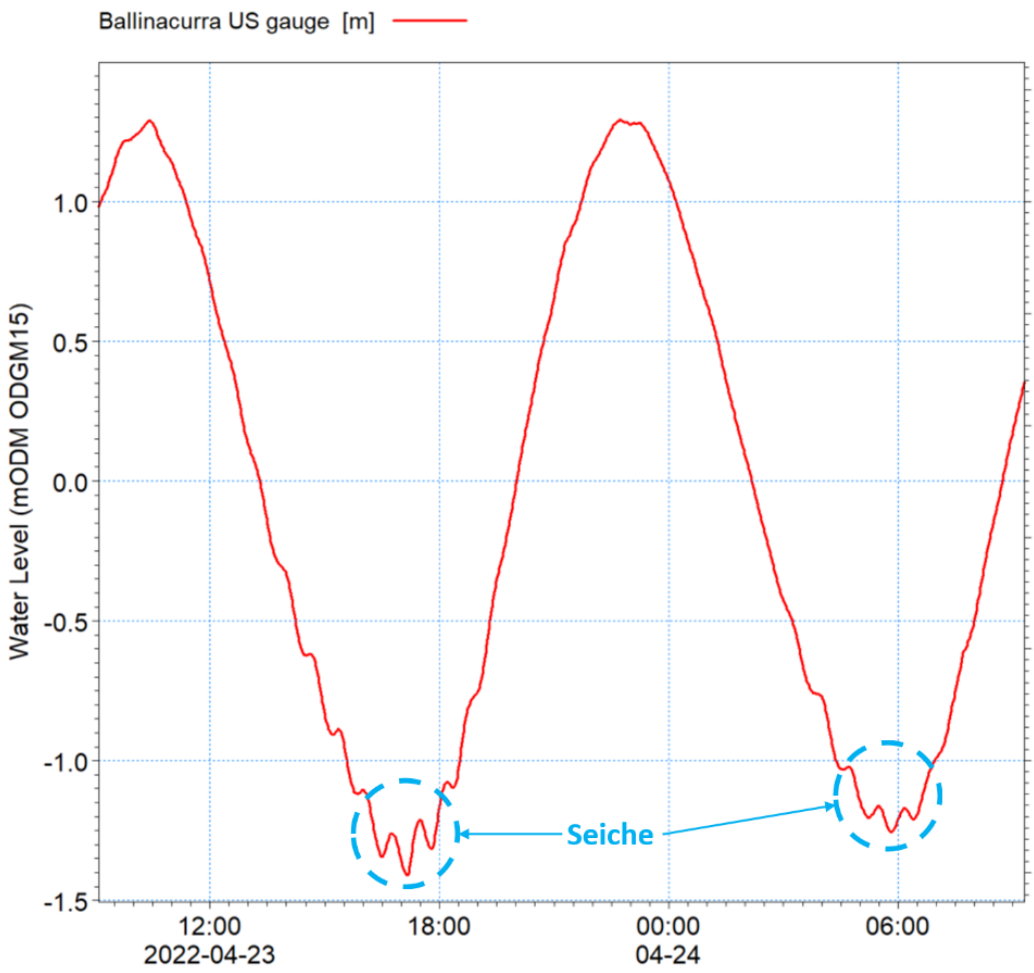


Figure 39 Location of the tidal gauges in the Owenacurra estuary

- Harbour wide generated seiche events resulting from sudden and sharp changes in the atmospheric pressure occurred on circa 3 occasions over the six month period. These events adopt a sinusoidal wave form and lead to seiche being generated across the entire inner area of Cork Harbour. An example of such an event happened on the 11th of April and is presented in the figure below. It can be seen from the plot that the seiche occurred in both the Ballinacurra estuary and the North Channel of Cork City at St. Patricks Quay during this event.

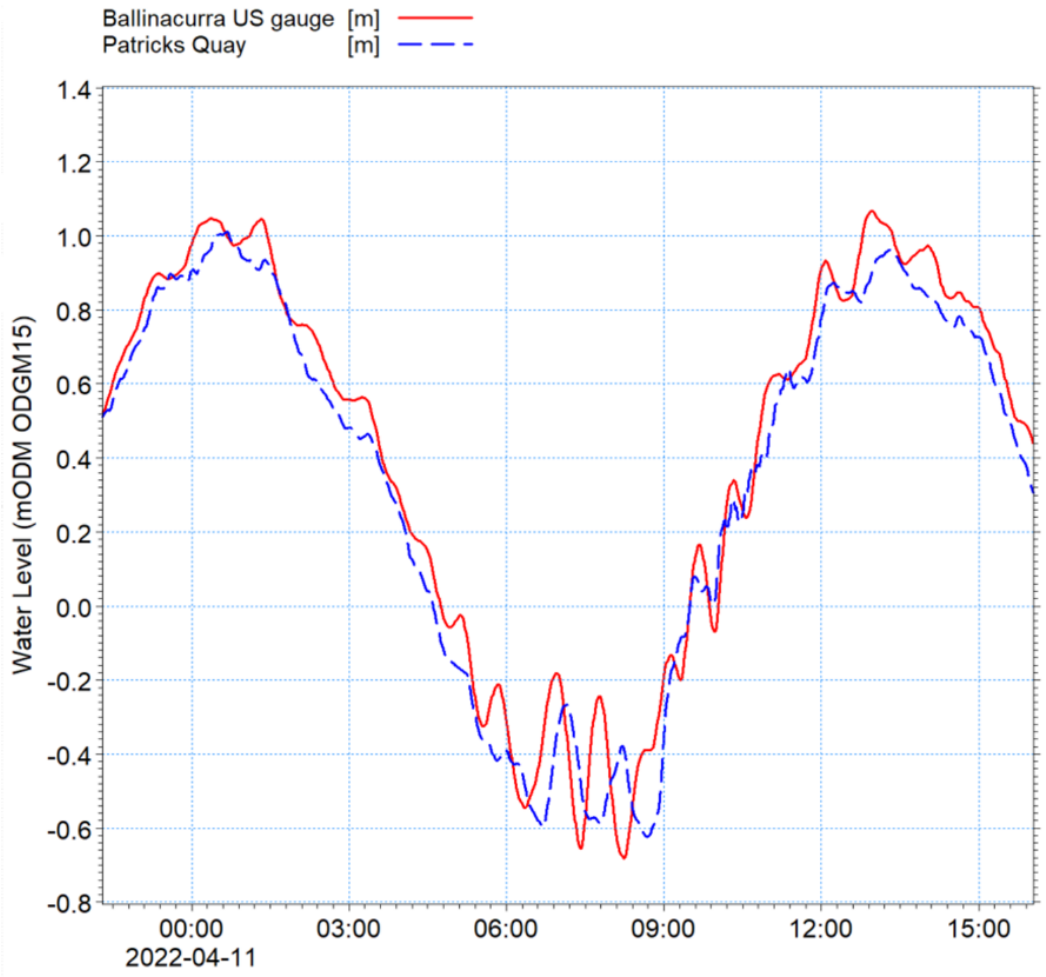


Figure 40 Location of the tidal gauges in the Owenacurra estuary

Based on the assessment of the recorded data it was concluded that adopting the Lower Lee FRS harbour wide seiche allowance of 150mm for the Midleton FRS was both prudent and justified given that the Owenacurra estuary is clearly subject to seiche. The reader is referred to the Lower Lee FRA Tidal Water Level Analysis report for a detailed discussion of seiche behaviour in Cork Harbour.

11. Detailed Freeboard Analysis

11.1 Introduction

Once the emerging preferred option was selected, a detailed freeboard assessment was undertaken in order to determine an appropriate allowance for the scheme. The project brief does not specify a freeboard methodology. Two separate methodologies have therefore been selected by Arup to inform the project:

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

This approach was also adopted as part of the Douglas FRS. Both of these methods are described in the following sections of the report.

11.2 Reaches of the scheme area assessed

For the purpose of the freeboard analysis, the study area has been divided into nine distinct reaches as presented in Figure 2:

- Owenacurra Reach
- Glenathonacash Reach
- Elfordstown Reach
- Dungourney Reach
- Ballinacurra Reach
- Owenacurra Millrace
- Water Rock Reach
- IDL Millrace
- Owenacurra Estuary

11.3 Minimum Freeboard Requirements

The project brief states that for fluvial reaches a minimum freeboard of 300mm must be adopted for hard defences, and 500mm for soft defences. The brief also states that these allowances are "generally increased by 0.2m for Coastal defences".

The coastal defence region of the scheme area has been defined as the area downstream of the confluence of the Owenacurra and Dungourney rivers where a sufficient fetch length exists in order to generate surface waves at high tide and hence a risk of wave overtopping of the defences. As all the defences in this reach are hard defences, the minimum freeboard allowance for these defences is therefore calculated as 500mm.

There is scope to adopt a freeboard of 300mm for the hard defences in the fluvial reach. It is however desirable to ensure a consistent approach within the same flood cell. A minimum allowance of 0.5m for all defences (i.e. both soft and hard) has therefore been adopted.[12]

11.4 Environment Agency Guidance W187

11.4.1 Overview

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 a freeboard allowance for three separate items as indicated in Figure 41. The total freeboard is then calculated as the sum of these three separate freeboard allowances.

[12] It is noted that should the defence present a landscaping constraint there is scope to reduce the heights of the hard defences in the fluvial dominated reach by up to 200mm in light of these freeboard allowances.

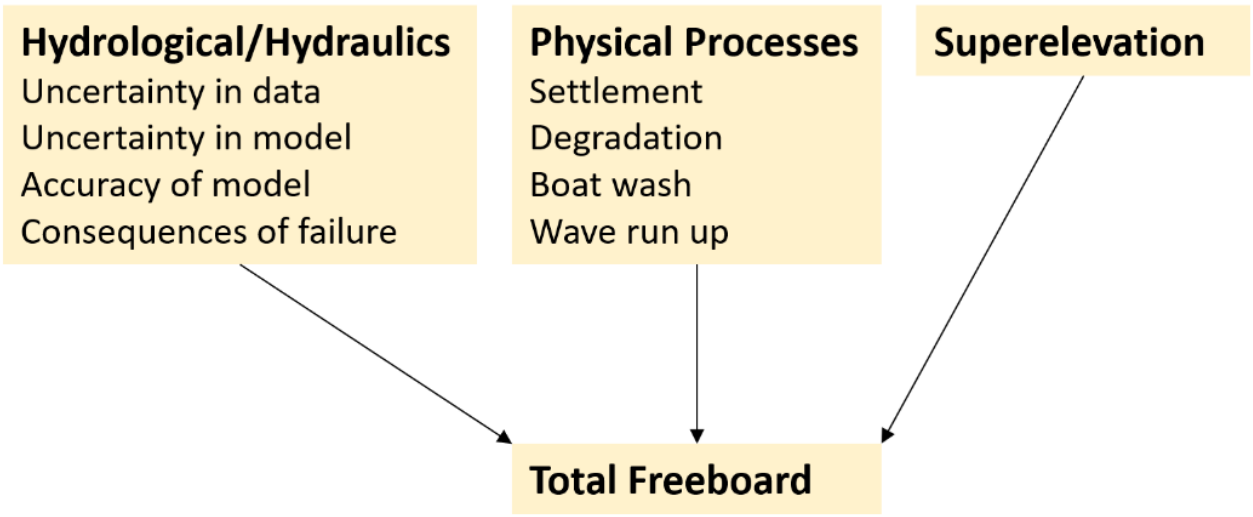


Figure 41 Schematic of Freeboard calculation

A number of assumptions have been adopted as part of the W187 assessment for Midleton:

- No allowance has been made for seiche as it is included in the design water levels;
- Allowances for degradation, cracking, vermin impact and sedimentation have been ignored as they are not deemed to be significant;
- Settlement allowance for embankments has been assumed at 0.2m;
- The consequence of failure has been assumed to be worst case with a score of 5.

Superelevation[13] was calculated using the free vortex method from channel conditions in the defenced scenario. The following formula was used to determine the change in water surface elevation:

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

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)

It is noted that the dimensions of the watercourses were calculated using the geometry tool in Flood Modeller Pro and the bend radius has been determined from aerial imagery.

11.4.2 EA W187 method results

The results from the W187 method are presented in Figure 42 for both the left and right banks. The Y axis presents the estimates of total freeboard i.e. the sum of the hydrological/hydraulics freeboard, superelevation and physical processes.

[13] Superelevation is the effective increase in water levels as the river flows around a bend. There is an increase in the water level at the outer bank and a decrease water level on the inner bank because of the centrifugal force that is been exerted on the river body. Given than superelevation is not captured by the hydraulic model (which assumes a horizontal water level surface at each individual cross section) it needs to be considered as part of the freeboard assessment.

The X axis presents model chainage with each of the nine reaches presented sequentially on the axis. It can be seen from the plot that the freeboard allowance across the study ranges from 0.04m to 0.96m. The average value is circa 0.3m.

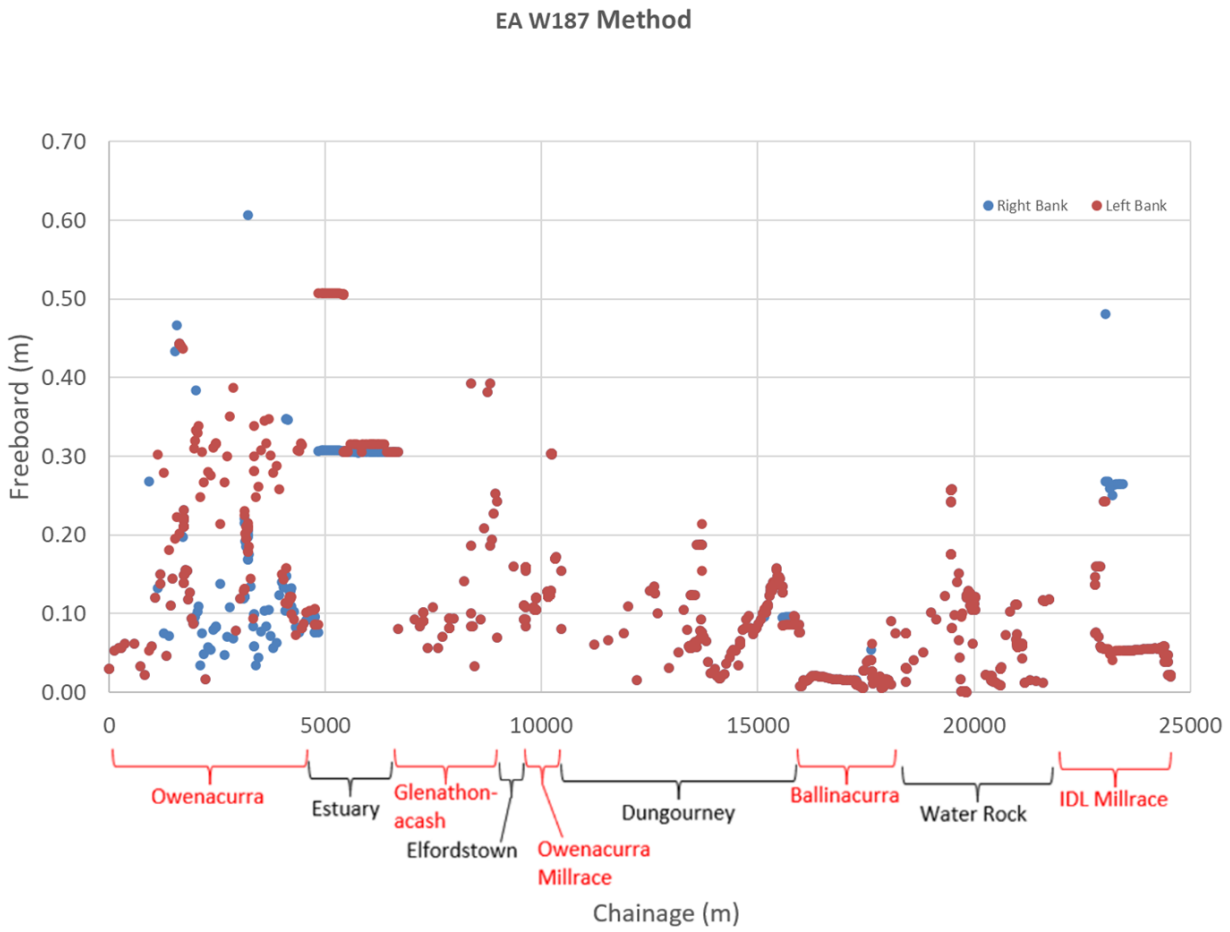


Figure 42 Freeboard estimates

Freeboard values greater than the proposed minimum requirement of 0.5m were estimated at one location:

- An allowance of 0.60m was estimated at the right bank of the Owenacurra at cross section **3OWE_3521** which is located on the bend immediately downstream of the Northern Relief Road;

At this location the relatively high freeboard allowance is driven by superelevation due to the bend in the river. The superelevation is however very localised given that the required freeboard upstream and downstream of cross section **3OWE_3521** is estimated as 0.21m (**3OWE_3531**) and 0.18m (**3OWE_3510**) respectively. The relatively high freeboard requirement is therefore not applicable to any significant length of the river and is only relevant to the exact location of the bend in the river.

11.5 CFRAM Guidance Note 22

11.5.1 Introduction

CFRAM Guidance Note 22 was developed under the Western CFRAM Contract for the Office of Public Works (2014) and adopts a sensitivity analysis approach in determining the hydrological/hydraulic uncertainty.

As with the EA method, the total freeboard is estimated as the sum of three separate freeboard allowances for hydrological/hydraulics, superelevation and physical processes. The allowances for superelevation and physical processes are calculated in exactly the same way as per the EA W187 method – the differences between the methods therefore relate to the hydrological/hydraulics uncertainty allowance only.

The steps in the CFRAM GN 22 method are listed as:

- 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;
- Calculate the hydrological/hydraulic uncertainty allowance at every cross section of the model using a least squares approach;
- Assess the allowances for physical processes and superelevation (as per EA W187);
- Sum the hydrological/hydraulic, superelevation and physical processes allowances to derive the total freeboard.

The various steps in estimating the hydrological/hydraulic freeboard allowance are described in detail in the following sections.

11.5.2 Preliminary Screening Assessment

Midleton is at risk of fluvial and tidal flooding. Design water levels upstream of the tidal reach are sensitive to the hydrological boundaries and core hydraulic parameters and are therefore assessed as part of the sensitivity testing.

11.5.3 Hydrological Analysis Sensitivity Testing

A detailed hydrological analysis of the Owenacurra and Dungourney catchments was undertaken as part of the study and the reader is referred to the accompanying Scheme Hydrology report for a detailed description of the work.

The uncertainty in the design hydrological flows (i.e. in the calculation of Qmed, Growth Curve etc.) was assessed as part of the CFRAM GN 22 assessment by considering a 20% increase in the peak flow rates. The hydraulic model was therefore re-run with all the hydrological inputs increased by 20%. The downstream tidal boundary and all other model parameters were left unchanged.

The results suggest that the maximum water levels are quite sensitive to a 20% increase in the design flow as water levels are increased throughout the reach. Water levels are particularly sensitive upstream of bridges which are surcharged (or very close to being surcharged) in the Q100 event such as upstream of the Lewis Bridge at the Baby Walk and upstream of the bridge adjacent to Clohessy's Yard on the Glenathonacash stream.

Figure 43 presents a longitudinal plot of the modelled reaches showing model chainage vs max water levels for the design Q100 and design Q100 +20% events. The difference between the water levels (i.e. Q100 +20% max water level – Q100 max water level) is plotted on the secondary axis and is referred to as "delta" in the figure.

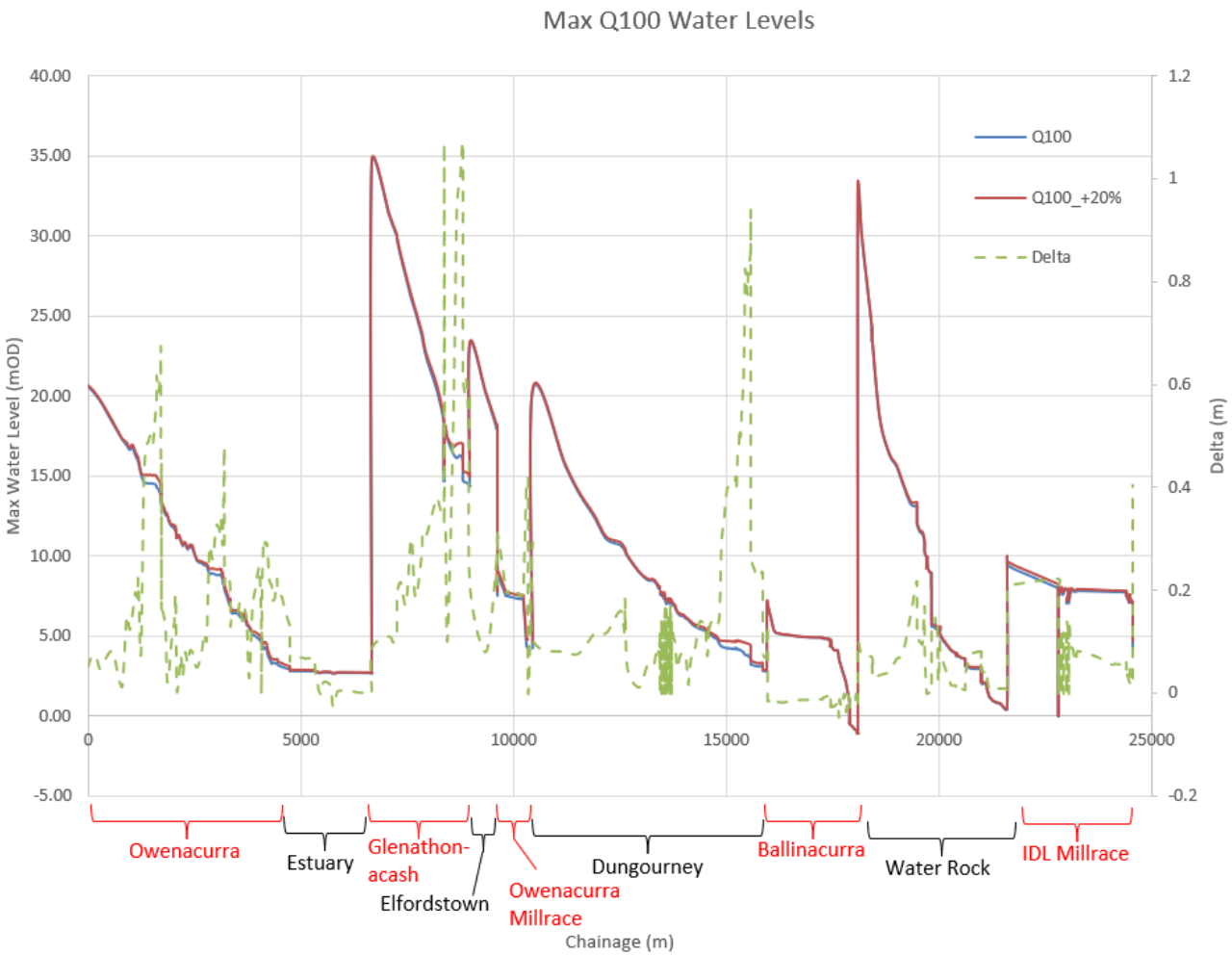


Figure 43 Q100 Max Water Levels- Base line vs +20% Sensitivity Longitudinal Plot

It is noted that an uplift of 20% is deemed to be conservative. Given the inherent uncertainty over small catchment hydrology however (i.e. for the Glenathonacash stream), a 20% uplift is deemed appropriate for the baseline assessment.

11.5.4 Increased Roughness Sensitivity Testing

The hydraulic model was simulated with a +15% increase in the channel roughness. It was evident from the results that the roughness sensitivity is less sensitive than the hydrology sensitivity as the increases in the maximum water level were not as significant.

11.5.5 Structure Coefficient Sensitivity Testing

The CFRAM guidance recommends assessment of the afflux at critical structures which are likely to be sensitive to changes in the head loss coefficients. The model was therefore rerun with changes in the head loss coefficients to the key structures in the model: Lewis Bridge, Lidl Bridge and Moore's Bridge. From the results, it is evident that the modelled maximum water levels are not sensitive to the changes in the structure coefficients.

11.5.6 Tidal level uncertainty Analysis

The uncertainty in the design tidal water levels has been accounted for by adopting the uncertainty estimate for Cork Harbour as calculated by the Lower Lee FRS tidal water level study. A summary of the assessment is presented in the following table.

Table 42 Modelled water level uncertainty assessment undertaken as part of the Lower Lee FRS project

Parameter	Uncertainty Allowance	Comment
Boundary condition – peak design tidal level at the open sea boundary	150mm	Allowance is taken from the ICWWS Study
Model Schematisation	100mm	100mm allowance is based on the maximum observed error in the hydraulic model calibration events simulated as part of the LL study
Resonance	50mm	Allowance is based on engineering judgement
Spatially varying salinity	120mm	Based on the differences between the constant and spatially varying salinity model calibration runs undertaken as part of the LL study
Geoid and MSL to Malin conversion	50mm	This allowance is based on the range of MSL to OSGM15 conversion factors for the Cork Harbour prediction points as detailed in the ICWWS.
Total uncertainty allowance (least squares sum)	**228mm**	

As highlighted in the table an uncertainty allowance of 228mm was calculated for Cork Harbour as part of the Lower Lee study and has therefore been adopted as part of the freeboard assessment for Midleton for all the cross sections in the tidal reach.

11.6 CFRAM Method - Results

The results of each of the sensitivity model runs were imported into excel and a least squares calculation of the differences in the maximum water level between the sensitivity runs and the baseline was undertaken. The resulting estimates of total freeboard for the scheme area (i.e. the sum of the hydrological/hydraulics, superelevation and physical process freeboard) is presented in Figure 3.

It can be seen from the plot that the freeboard ranges from 10mm to 1.26m with an average value of circa 0.19m. By comparing the results against those presented in Figure 2 for the EA W187 method it can be seen that the CFRAM GN22 approach is generally more conservative, i.e. the CFRAM method calculates higher freeboard allowances across the scheme area.

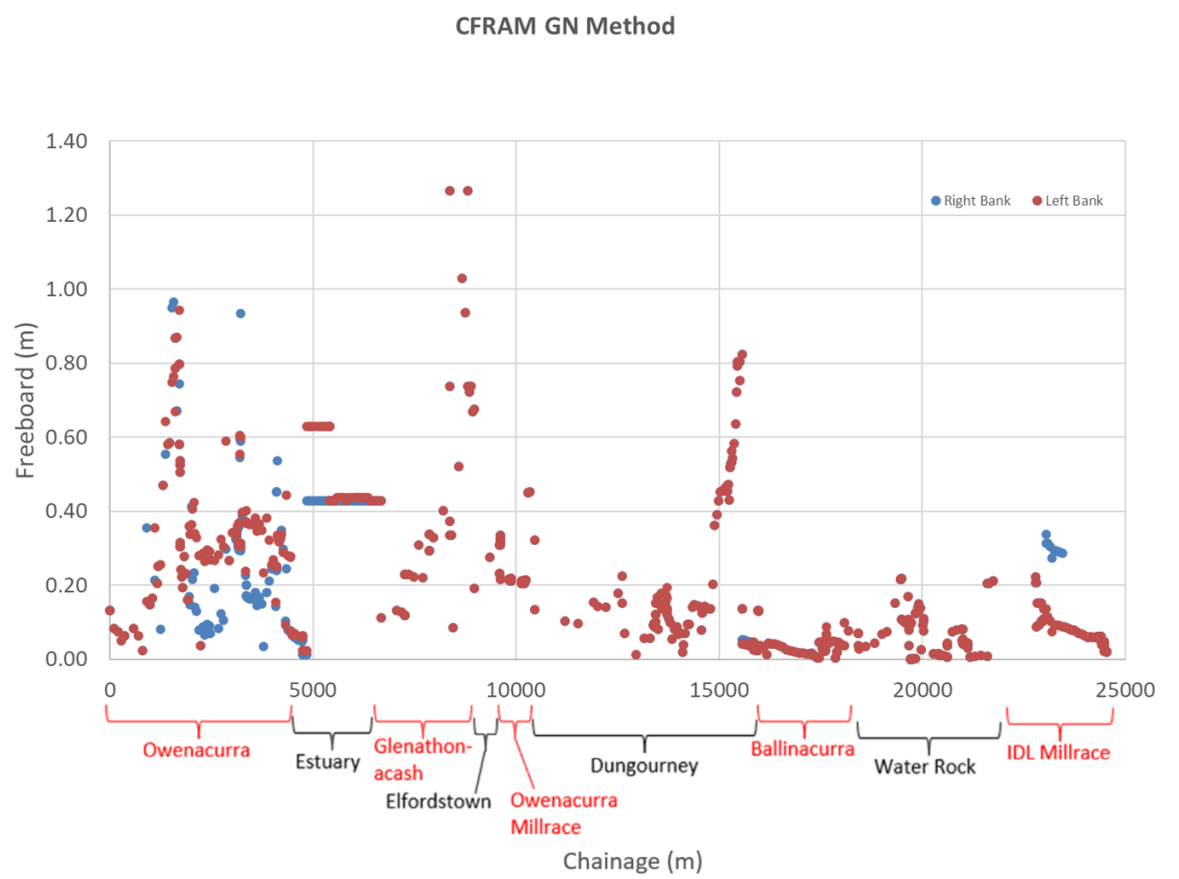


Figure 44 Freeboard estimates (CFRAM guidance note method)

From Figure 44 it can be seen that there are a large number of cross sections at which the freeboard requirement exceeds the proposed minimum requirement of 0.5m. To aid the reader in interpreting these results, the points are presented separately in Figure 45 for the right bank and in Figure 46 for the left bank with the Y axis modified in order to only show values greater than 0.5m. The cross section labels are also included on the plots.

It can be seen from the figure that there are a relatively large number of points on both banks that exceed 0.5m and can be grouped into four individual areas:

- Both upstream and downstream of Moore's Bridge on the Owenacurra where the freeboard requirement is generally less than 0.8m.
- Immediately downstream of the NRR (3OWE_3521) which has a large freeboard requirement due to superelevation at the bend in the river;
- Throughout most of the length of the Glenathonacash tributary. The maximum value of circa 1.26m is upstream of the arch bridge on the R626 which crossed over the Glenathonacash adjacent to Clohessy's Yard;
- Upstream of the Lewis Bridge throughout the Baby Walk and in the People's Park where the maximum freeboard requirement is circa 0.85m.

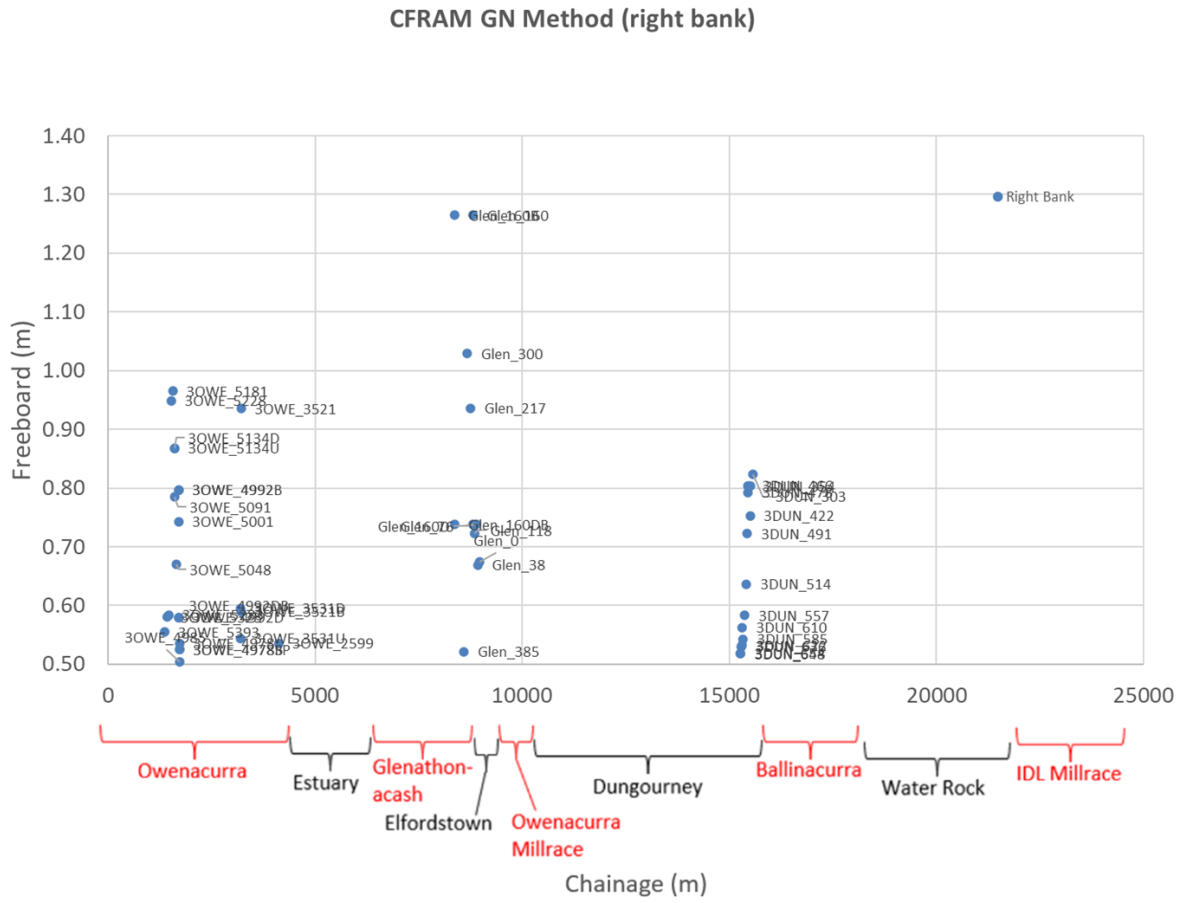


Figure 45 Freeboard estimates > 0.5m Right Bank (CFRAM guidance note method)

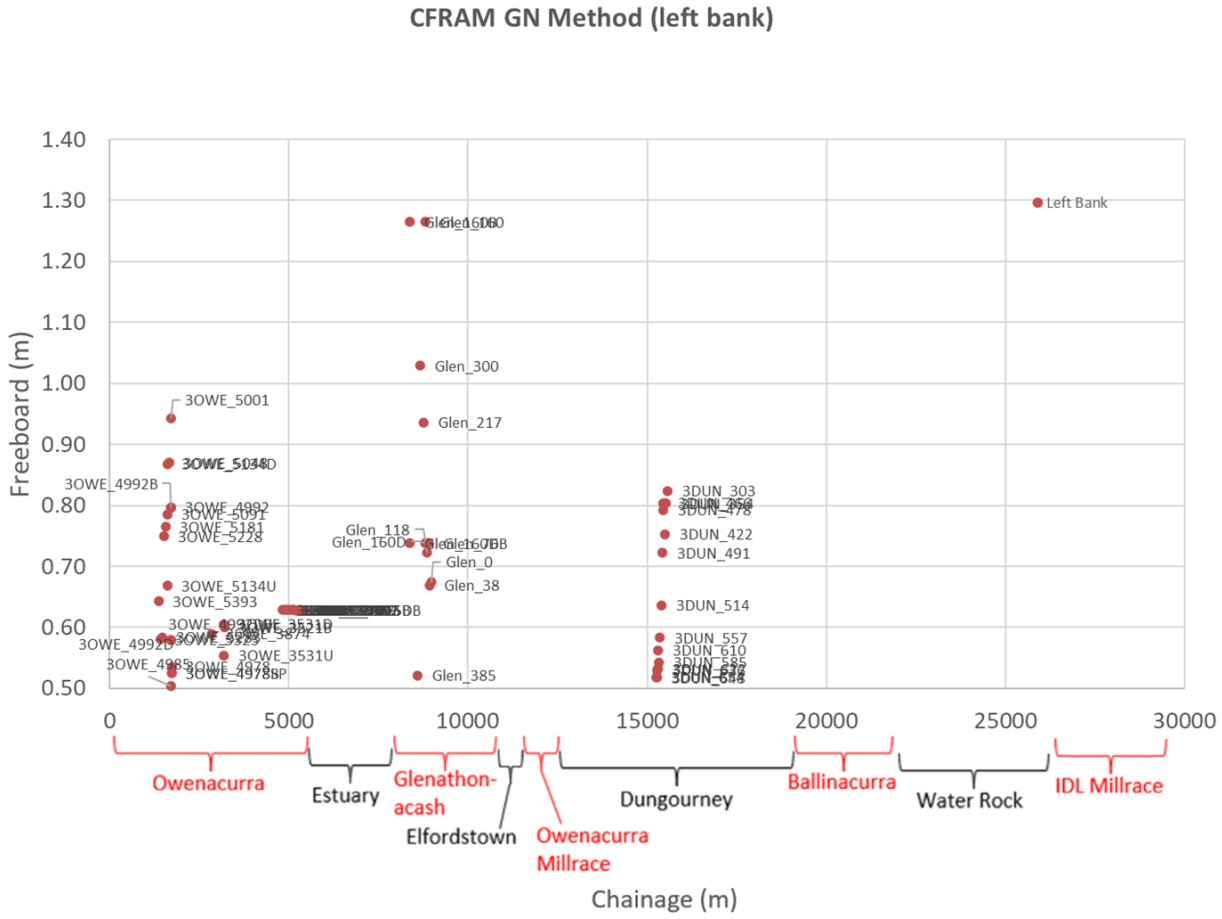


Figure 46 Freeboard estimates > 0.5m Left Bank (CFRAM guidance note method)

11.7 Top of wall defence levels

The top of wall (TOW) flood defence levels have been calculated at each cross section by adding the freeboard CFRAM GN22 requirement to the design water level. The height of the flood defence above ground on the dry side can then be estimated by subtracting the TOW level from the existing ground level at that point. The viability of the proposed wall heights in the context of their landscaping/visual impact has been assessed by considering the TOW level locally at each location. Key to the assessment is the recognition that wall heights in excess of 1.1m/1.2m are very likely to have a negative landscaping/visual impact when situated close to properties or are located in a public realm area of the town.

The following table presents the high level assessment for the four areas where the freeboard requirement is greater than 0.5m as noted above.

Table 43 High Level assessment of required defence heights

Area	Assessment	Conclusion
Upstream and downstream of Moore's Bridge	Required defence heights vary throughout the reach and generally less than 1.2m high for most of the reach. There are however a few sections (i.e. immediately upstream of Moore's Bridge in the landscaped area of Tir Cluain) where the required heights exceed 1.2m due to localised low points in the topography.	The required defence heights can be accommodated through this reach and no significant landscaping/visual impacts are foreseen. The defences upstream of Moore's Bridge will however need to be considered in order to ensure that they are integrated into the existing green areas of Tir Cluain.
Immediately downstream of the NRR	The high freeboard requirement is only applicable to the right bank and not to the left bank. However no defences are proposed for the right bank at this location as the existing ground levels on the Western side are higher than the design water level. It is noted that even if the design water level were to be increased by the superelevation allowance, there would still be no properties at risk on the right bank.	It is therefore not proposed to construct defences on the right bank over this length of reach. (Note: Freeboard only defences are discussed further later in the chapter.)
Glenathonacash tributary	The required defence heights will exceed 2.0m/2.5m along the Glenathonacash with the freeboard requirement applied	While the required defence heights along this reach are greater than 2m, no negative landscaping/visual impacts are foreseen as the defences are not impacting on any amenity areas or any residential properties. The proposed length of the defences may need to be increased in order to accommodate the freeboard requirement along the reach. It is noted that some sections of the left bank are space constrained and will require further consideration as part of the detailed design. A further detailed topographic survey of the area will inform on this.
Baby Walk/People's Park	The required defence heights along Baby Walk and in the People's Park are generally less than 2.0m with a few localised areas where the heights exceed 2.0m. It is noted that the existing wall height along Baby Walk is circa 1.5/1.6m high.	Defence heights of circa 2.0m would have significant visual impact locally which is one of the prime amenity areas of the town.

Of the four areas for which the CFRAM GN 22 method estimates a freeboard requirement greater than 0.5m, only the reach along the Baby Walk/People's Par involves a significant visual and landscaping impact. The EA W187 method however estimates a much lower freeboard requirement for this reach. It is therefore appropriate to consider both the design water levels and the associated sensitivity runs used to inform the CFRAM GN 22 freeboard assessment in order to ensure that the CFRAM method is not overly conservative. This is discussed in the next section of the report.

11.8 Conservatism of the design water levels through the Baby Walk/People's Park

The boundary conditions used to inform the scheme design hydraulic model runs[14] are conservative due to the key assumption on Joint Probability i.e. that the peak of the tide, the peak of the fluvial event and the seiche event all occur at the same time. The conservatism is however deemed appropriate as it ensures a robustness in the design of the works.

Adopting the same approach for the CFRAM GN 22 sensitivity runs is however deemed to be overly conservative particularly as regards the 20% uplift in flow sensitivity. The joint probability assumption as noted above, coupled with a 20% increase in the peak flow is deemed to have a very low probability of occurrence and hence is overly conservative. The approach presented in the previous section of the report therefore risks overstating the freeboard requirements and hence overdesigning the scheme.

There are a number of ways in which this over conservatism can be addressed as part of the analysis:

- The CFRAM GN 22 sensitivity model runs could be simulated with the seiche removed from the downstream boundary conditions and/or phase differences introduced into the timing of the fluvial and tidal peaks;
- Less conservative percentage uplifts in the flow could be adopted for the flow sensitivity simulation runs[15].

The first of these approaches has not been considered as it would introduce an inconsistency between the scheme design water levels and the sensitivity runs undertaken to inform the freeboard assessment. The second of the approaches has therefore been adopted and is presented in the following section of the report.

11.9 Additional sensitivity analysis for the Baby Walk/People's Park

A reduced uplift in the hydrological flow of +10% was considered as part of the sensitivity analysis for the Baby Walk. The results of the model were used to inform an updated freeboard assessment through the reach from which the required TOW height was reassessed.

Figure 47 presents the required TOW levels through the Baby Walk/People's Park for both the 20% (baseline) uplift and 10% (sensitivity) uplift in flow scenarios.[16] The top of the existing wall along the Baby Walk is also indicated with the green line.

It can be seen from the figure that the TOW level for the 10% uplift in flow sensitivity is circa 320mm lower in the Baby Walk and circa 220mm lower in the People's Park when compared with the 20% uplift in flow scenario. It can also be seen from the figure that an average freeboard of 0.48m is achieved in the Baby Walk and 0.55m is achieved in the People's Park.

The top of the existing wall along the Baby Walk is set at circa 4.3mOD. It can be seen from the plot that the 10% uplift in flow sensitivity generally ties in with this level.

[14] The fluvially dominated design scenario involves simulating a 1% AEP river flow with the 20% AEP tidal event both of which are assumed to peak at the same time. The 20% AEP peak tidal level includes an allowance of 150mm for seiche which is applied throughout the full tidal cycle.

[15] The flow sensitivity makes by far the biggest contribution of all the sensitivities considered to the CFRAM GN 22 freeboard requirement. Only this sensitivity is therefore considered here.

[16] In practice the top of an RC wall or embankment would be constructed level and the required longitudinal gradient would be accounted for with vertical steps at appropriate locations.

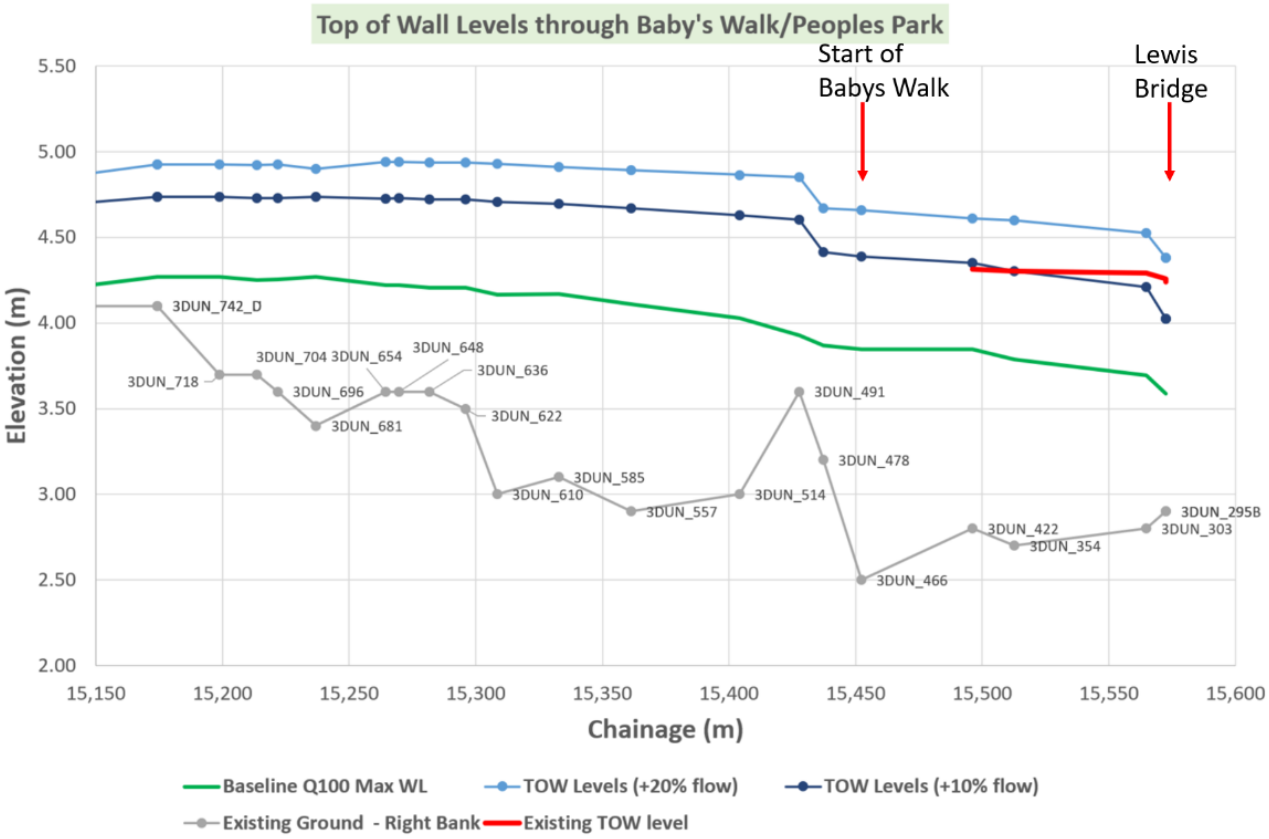


Figure 47 TOW levels and baseline water level through the Baby Walk and the People's Park

11.9.1 Conclusion

Given the findings of both the EA W187 method and the CFRAM GN 10% flow sensitivity and also by considering the local landscaping and visual constraints, it is proposed to adopt a freeboard allowance of 0.5m for the Baby Walk and the People's Park. The justification for this approach is given as:

- The 0.5m allowance is in keeping with the findings of the EA W187 method;
- The freeboard requirement estimated by the CFRAM GN 22 method with a 20% uplift in flow sensitivity is deemed to be overly conservative. When a reduced 10% uplift in flow sensitivity is considered the freeboard requirement through the reach is circa 0.5m and is therefore in keeping with the EA W187 method;
- Adopting a freeboard of 0.5m through this reach will result in the top of the flood defence wall being set at a level equivalent to the height of the existing stone wall. This is an important consideration as regards the landscaping and visual impact of the engineering works and the overall public perception of the scheme given the critical importance of the Baby Walk/People's Park to the local community.

11.10 Freeboard only defences

It is evident from the freeboard assessment that there are a number of locations with ground levels higher than the design water level, but lower than the design flood defence level, i.e. lower than the design water level plus the freeboard allowance.

It was agreed by the Steering Group that defences for these areas would be provided as part of the scheme given that the freeboard in effect is a consideration of the inherent uncertainty of the design water levels. These defences are referred to as "freeboard only defences" and are being limited to flood cells that are being defended as part of the proposed scheme i.e. freeboard only defences are proposed for any independent flood cells where defences have not already been proposed as part of the current scenario. This is in keeping with the approach taken on previous flood relief schemes implemented by the OPW in Ireland.

Figure 48 presents the locations of the Freeboard only defences. It can be seen from the figure that they are proposed at several locations along the Bailick Road, Roxboro Close and at Riversfield Estate.

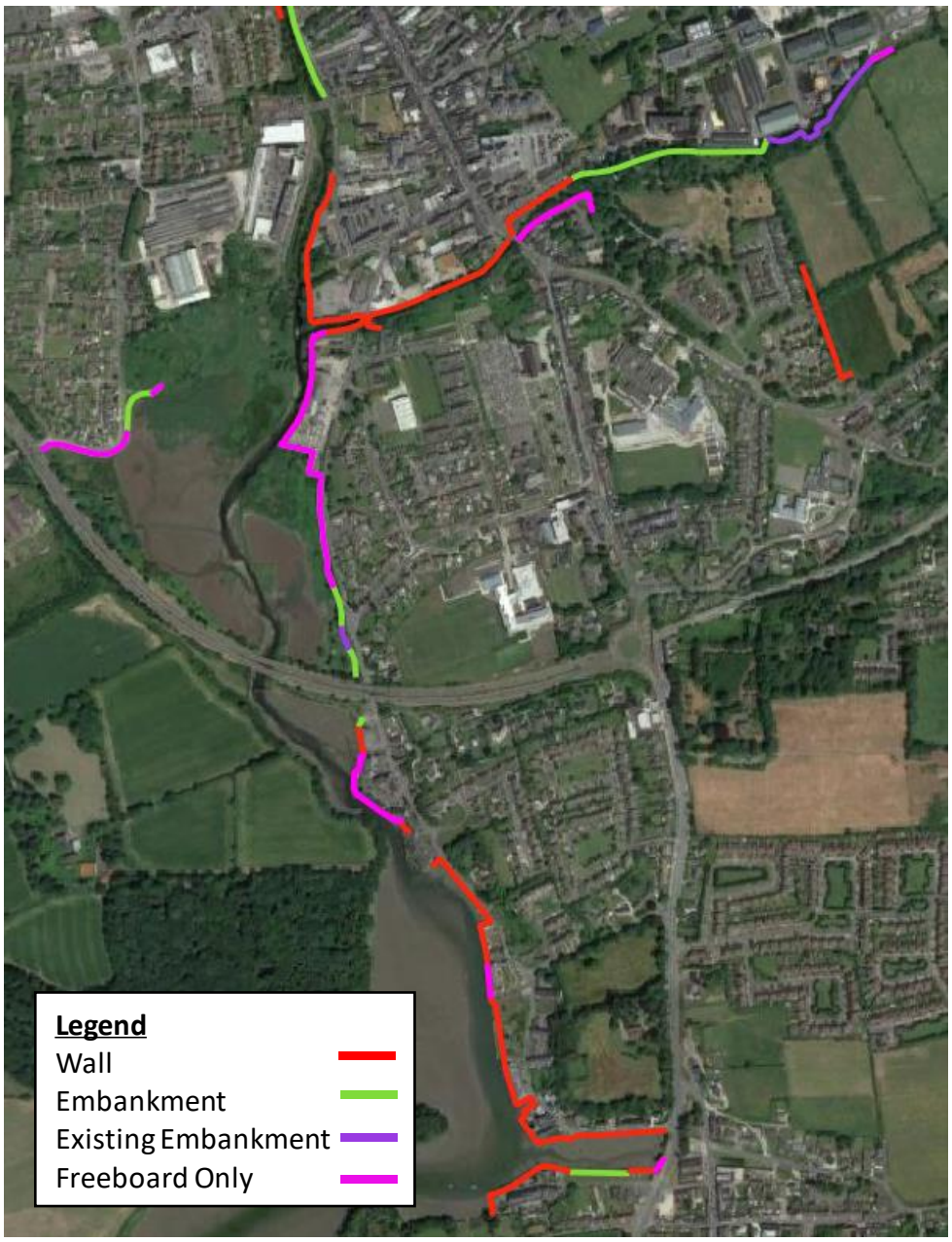


Figure 48 Freeboard Only Defences and Emerging Preferred Option

11.11 Summary of the Freeboard Assessment

It is proposed to adopt a minimum freeboard allowance of 0.5m for the entire scheme area. There are however a number of areas where higher freeboard allowances should be adopted. These are listed as:

- Both upstream and downstream of Moore's Bridge on the Owenacurra. A freeboard allowance of circa 0.7m/0.8m should be considered through this reach.
- Throughout most of the length of the Glenathonacash tributary. A minimum freeboard allowance of circa 0.75m/0.8m is recommended for this reach.

Freeboard only defences are to be considered at several locations along the Bailick Road, Roxboro Close and within the Riversfield Estate.

12. Accounting for Climate Change in the Design of the Scheme

12.1 Introduction

A Scheme Climate Change Adaptation Plan (SCCAP) has been undertaken as part of the Midleton FRS project. The principle behind a SCCAP is that interventions/modifications on a flood scheme (i.e. raising the height of an existing flood defence) are only implemented when they become needed in order to maintain the required standard of protection as flood risk is increased due to climate change. A SCCAP approach can therefore provide greater value for money than the more traditional approach of implementing a once-off intervention.

The primary objective of the study was to develop a set of viable climate change adaptation pathways for mitigating flood risk in Midleton in the future under various climate scenarios. The viability of the pathways were considered in the context of the BCRs of the various options/adaptation options as well as well as the technical, social and environmental impacts.

A short summary of the Midleton SCCAP is provided in the following section. The reader is referred to the Midleton SCCAP report for a detailed description of the work.

The implementation of an allowance for Climate Change as part of the Current Scenario scheme is considered later in the chapter.

12.2 Key Findings of the Midleton SCCAP

The findings of the Midleton SCCAP can be summarised as follows:

- The emerging preferring option is adaptable to the onset of climate change in both the MRFS and HEFS;
- There are three viable adaptation options for the scheme in the MRFS which in turn have a number of viable adaptations in the HEFS as indicated in the decision tree schematic below. The scheme therefore has considerable flexibility as regards adaptation planning;

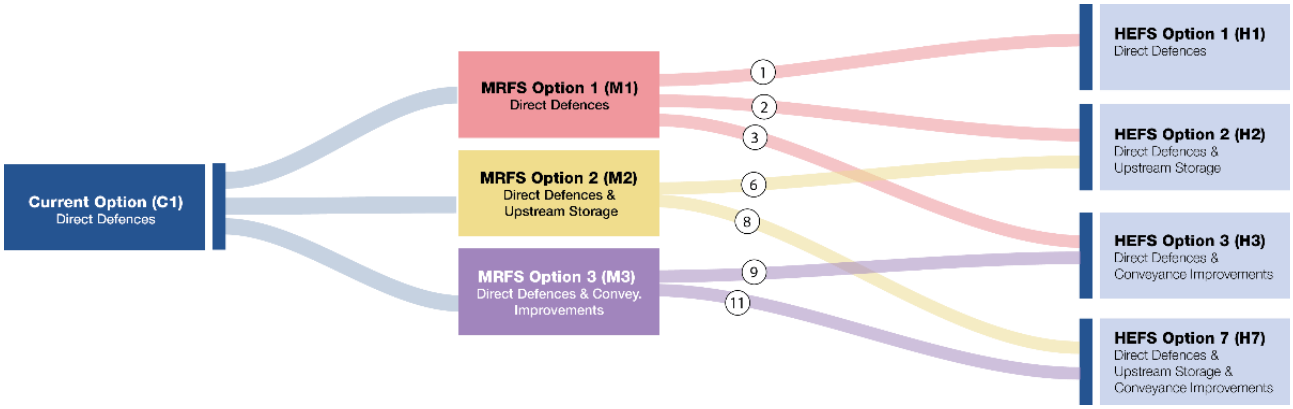


Figure 49 SCCAP Decision Tree – Viable pathways only

- From the MCA Light assessment, it is evident that some adaptation options perform better than others in a number of the criteria. There is however no significant advantage of any one option as they all generally perform well in the MCA scoring;
- Both the adaptation options and the full pathways for each of the scenarios considered are strongly cost beneficial;
- When the findings of both the MCA light and BCR analysis are considered, it is evident that there are no clear advantages of any one pathway over another as the both the BCR's and MCA scoring are all relatively similar across the study area;

- The target SoP of the scheme (1% Fluvial/0.5% Tidal AEP) will start to reduce once the scheme has been constructed when a linear onset of climate change is assumed. The tipping point[17] for the project has been defined as the MRFS T10 event. This is equivalent to a SLR scenario of circa 210mm above the present day which may occur in the next 17 to 46 years depending on the rate of climate change onset.
- The trigger point[18] will precede the tipping points by approximately 5 – 8 years.
- The project Steering Group have deemed that the estimated trigger and tipping points could potentially occur too soon after construction of the scheme. Consideration therefore needs to be given to adopting an assumptive allowance as part of the Current Scenario scheme in order to move the tipping point further into the future by increasing the SoP of the Scheme in the present day.
- The SCCAP will remain a "live" study even after the flood scheme for the current scenario has been constructed and will be reviewed and reassessed periodically as new knowledge on the changing climate is gathered.

The consideration of the assumptive allowance for the scheme is presented in the following section of the report.

12.3 Consideration of an assumptive allowance for the scheme

A fully assumptive approach to managing flood risk associated with climate change would involve designing the scheme in the present day to cater for the flood risk associated with the MRFS. Such an approach has been proposed for Areas 4 and 5 as outlined earlier in the report. The fully assumptive approach is not however proposed for Areas 1, 2 and 3 as it would not be cost-beneficial or socially acceptable in areas.

As noted in the previous section, it is however proposed to implement an assumptive allowance as part of the design of Areas 1, 2 and 3, i.e. to partly mitigate against future flood risk as part of the current scenario scheme. This approach will offer a higher SoP than the target SoP for a period of time after construction and move the tigger/tipping points further into the future. The length of time by which the tipping/trigger points are moved into the future is dependent on the magnitude of the assumptive allowance and the rate of climate change onset.

The proposed climate change assumptive allowance has been assessed on a flood cell basis. It takes into consideration the social, economic, environmental and visual impact of increasing defence heights and extents. It was agreed with the project Steering Group that, if viable, an additional +100mm climate change (CC) allowance would be provided in addition to the target SoP (Current 1% Fluvial/0.5% Tidal AEP) in order to shift the tipping/trigger points into the future.

In areas with high visual/amenity value, it is proposed to limit the maximum defence height to 1.1m above existing ground level. It is noted that in some cases, regrading of the local ground levels can be used to reduce the relative height of the defences. Where ground regrading is not feasible and inclusion of a 100mm CC assumptive allowance would lead to the defence height exceeding 1.1m in areas of visual/ social importance, the CC allowance was omitted. There were six defences in the vicinity of Moore's Bridge and Clohessy's Yard (Area 1) where no CC allowance was proposed due to these constraints. These are listed as:

- Proposed 1.1m Embankment at Tír Cluain (C01_E002_R) – Visual / social impact of increase in defence height
- Upgrades to existing embankment at Clohessy's Yard (C01_E001_L and C03_E002_L) – Land take requirements, proposed defence already circa 2.0m in parts

[17] Tipping points relate to the moment in time when the SoP offered by an existing flood protection option(s) falls below what is deemed to be an acceptable level. In many cases, this will equate to the original target SoP of the scheme. In some cases however it may be lower than this due to various social / economic / environmental constraints;

[18] Trigger points relate to when the planning to implement an adaptation option (i.e. the raising the height of an existing flood defence) needs to commence in order to maintain the required SoP of a flood defence option;

- Proposed 1.1m wall along Moore's Lane (C01_L001_R) – Defence height is at proposed maximum of 1.1m.
- Proposed embankment along left bank upstream of Carrigogna Bridge (C03_E001_L) and Carrigogna Bridge parapet (C03_B001) – Proposed defence is 2.0m in parts, visual / social impact of increase in defence height.

For the majority of the proposed defences however implementing a 100mm CC allowance was achievable. There were also a number of defences in the fluvial dominated reach, where an allowance greater than 100mm was possible without incurring any adverse social/visual/landscaping issues.

In determining the final flood defence heights, two further points are noted:

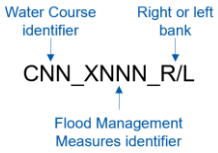
- The proposed assumptive allowance is consistent within flood cells such that the SoP provided is uniform across a particular area.
- Due to constructability constraints, the top of the proposed defence walls will be stepped and will not be sloped in line with existing ground levels. There will therefore be sections of the constructed defences where the SoP will be greater than what is stated in this options report. As a minimum however, the stated SoP will be achieved across the entirety of the proposed defence.

The following sections of the report (Sections 12.5, 12.6 and 0) outline the climate change allowances for the defences in each of the key areas.

12.4 Naming System of Emerging Preferred Option Elements

For ease of reference to the reader, the various elements of the flood relief scheme have been assigned a unique identifier, as per the following format:

WatercourseIdentifier_FloodManagementMeasureIdentifier_Right / Left Bank



Watercourse and Flood Management Measures Identifiers are listed below:

Watercourse identifier	
Owenacurra	C01
Estuary	C02
Glenathonacash	C03
Owenacurra Millrace	C04
Dungourney	C05
Ballinacurra	C06
Water Rock Upper	C07
Water Rock Lower	C08
IDL Millrace	C09

Flood Management Measures identifier	
Bridge	B
Channel	CH
Culvert	CU
Culvert Maintenance	CM
Demountable Barrier	DB
Embankment	E
Flood Gate	FG
Flap Valve	FV
Groundwater Cut-off	GWC
Headwall	HW
Walls and Buildings	L

Watercourse identifier	

Flood Management Measures identifier	
Flood Wall with Demountable Barrier on top	LDB
Mills, Mill Weirs & Mill Races	M
Pump installations / station	P
Penstocks	PS
Roads / Regrading	R
Rising Main	RM
Stormwater sewer / Surface water drainage	SW
Weirs	W

This naming convention has been adopted in the tables in the next section of the report.

12.5 Area 1 & 2: Tír Cluain to Riverside Way

Areas 1 and 2 are fluvially dominated. The reaches where it is deemed feasible to provide a CC allowance, and therefore increase the SoP in the Current scenario, is detailed in the table below. Defences where a climate change allowance is being proposed are shaded in orange. Defences where no climate change allowance are proposed are shaded in green. As the climate change allowance is being implemented as part of the Current scenario scheme, the SoP of the scheme upon construction will be greater than the Target SoP.

The increased SoP offered has been estimated by linearly interpolating between the target SoP design level and the Current 0.1% Fluvial/0.1% Tidal AEP design levels and this is presented in the final column of the tables below.

Table 44 Area 1&2 Tír Cluain to Riverside Way – Climate Change Allowance and Proposed SOP

Defence Ref.	Location	Description	Proposed CC Allowance	Proposed defence height above ground	Approximate Proposed Standard of Protection
C01_E001_R	Rear of Tir Cluain	Embankment	+130mm	1.0m [1]	>Current Q1000
C01_E002_R	Tir Cluain	Embankment	0 mm	1.1m	Current Q100
C01_E001_L	Clohessy's Yard	Existing Embankment	0 mm	1.3-2.0m	Current Q100
C01_B001	Moore's Bridge	Parapet	+150mm	1.1m	Current Q300
C01_L001_R	Moore's Lane	Wall	0 mm	1.1m	Current Q100
C01_L001_L	Left Bank Downstream of Moore's Bridge	Wall	+130mm	1.1m	Current Q800
C01_E002_L	Willowbank	Existing Embankment	+100mm	0.4m	Current Q300
C01_L002_L	Left Bank Upstream of Northern Relief Road	Wall	+300mm	1.1m	Current Q1000
C01_E003_L	Left Bank Downstream of Northern Relief Road	Embankment	+100mm	1.0m [1]	Current Q300
C01_E004_L	Millbrook	Existing Embankment	+100mm	0.4m	Current Q500
C01_L003_L	Mill Race Apartments/ My Place	Wall	+100mm	0.6m [1]	Current Q300
C01_L002_R	Right Bank Upstream of Cork Road Bridge	Wall	+100mm	0.8m [1]	Current Q400
C03_E001_L	Left Bank Upstream of Carrigogna Bridge	Embankment	0 mm	2.0m	Current Q100
C03_B001	Carrigogna Bridge	Parapet	0 mm	1.1m	Current Q100
C03_E002_L	Clohessy's Yard	Existing Embankment	0 mm	1.3m	Current Q100

12.6 Area 3 (North): Town Centre and Bailick Road to Choctaw Park

Area 3 (North) is tidally dominated. It can be seen from the table below that it is feasible to include a 100mm allowance for climate change through this area.

Table 45 Area 3 (North) Town Centre and Bailick Road to Choctaw Park – Climate Change Allowance and Proposed SOP

Defence Ref.	Location	Description	Proposed CC Allowance	Proposed defence height above ground	Approximate Proposed Standard of Protection
C01_L003_R	The Woodlands	Wall	+100mm	0.8m [1]	Current Q300
C01_E005_L	Riverside Way - Thomas Street Lower	Embankment	+100mm	0.4m	Current Q500/ T700
C01_L004_L	Riverside Way - O'Farrell's Funeral Home	Wall	+100mm	1.2m [1]	Current T700
C01_L005_L	Kennedy Park - ESB Site	Wall [4]	+100mm	1.1m [3]	Current T700
C02_L001_L	Bailick Road - Irish Water Site / Chadwicks	Wall	+100mm	0.75m [1,]	Current T700
C02_E001_R	Riversfield Estate	Embankment	+100mm	1.1m [1]	Current T700
C02_E001_L	Bailick Road - Chadwicks to Choctaw Park	Embankment	+100mm	1.1m [1]	Current T700
C02_E002_L	Choctaw Park	Existing Embankment	+100mm	1.1m [1]	Current T700
C02_E003_L	Choctaw Park	Embankment	+100mm	1.05m [1]	Current T700
C05_E001_R	Irish Distillers – WWTP	Embankment	+100mm	0.85m [1]	Current Q700
C05_E002_R	Irish Distillers – WWTP	Existing Embankment	+100mm	1.1m [1]	>Current Q1000
C05_L001_L	GAA Grounds	Wall	+100mm	1.2m	>Current Q1000
C05_E003_R	Irish Distillers	Embankment	+100mm	1.4m [1]	Current Q200
C05_E004_R	Peoples Park	Embankment	+100mm	1.7m [2]	Current Q200
C05_L001_R	The Baby Walk	Wall	+100mm	1.2m [2]	Current Q200/ T700
C05_L002_L	Roxboro Close	Wall	+100mm	1.1m	Current Q200/ T700
C05_L002_R	Midleton House to Upstream of Bailick Rd Bridge	Wall	+100mm	1.2m [1, 2]	Current T700
C05_B001	Bailick Road Bridge	Parapet	+100mm	1.1m	>Current Q1000
C05_L003_R	Downstream of Bailick Road Bridge – ESB site	Wall	+100mm	1.2m [3]	>Current Q1000
C05_L003_L	Downstream of Bailick Road Bridge – Irish Water site	Wall	+100mm	1.2m	>Current Q1000

12.7 Area 3 (South): Bailick Road

Area 3 (South) is tidally dominated area. It can be seen from the table below that it is feasible to include a 100mm allowance for climate change through this area.

Table 46 Area 3 (South) Bailick Road – Climate Change Allowance and Proposed SOP

Defence Ref.	Location	Description	Proposed CC Allowance	Proposed defence height above ground	Approximate Proposed Standard of Protection
C02_E004_L	Carpark Downstream of N25	Embankment	+100mm	1.3m [2]	Current T700
C02_L002_L	Carpark Downstream of N25	Wall	+100mm	1.2m [1]	Current T700
C02_L003_L	Cois ná hAbhann	Wall	+100mm	0.6m [1]	Current T700
C02_L004_L	The Moorings	Wall	+100mm	0.4m [1]	Current T700
C02_L005_L	The Granary	Wall	+100mm	0.6m [1]	Current T700
C02_L006_L	Bailick Road	Wall	+100mm	1.2m [1, 2]	Current T700
C02_L007_L	Old Grain Store	Wall	+100mm	1.2m [1]	Current T700
C02_L008_L	Woodquay Apartments	Wall	+100mm	0.5m [1]	Current T700
C02_L009_L	Brownfield Site	Wall [4]	+100mm	1.2m [3]	Current T700
C02_L010_L	Charleston Wharf	Wall	+100mm	1.2- 1.4m [1,2]	Current T700
C02_L011_L	Maltings	Wall	+100mm	1.2- 1.4m [1,2]	Current T700
C02_L012_L	North of Ballinacurra Estuary	Wall	+100mm	1.1m [1]	Current T700
C02_L013_L	South of Ballinacurra Estuary	Wall	+100mm	1.2m [2]	Current T700
C02_L014_L	South Quay Apartments	Wall	+100mm	1.1m [1]	Current T700

[1] Proposed defence height adjusted after Public Participation Day 3 (July 2022) to provide climate change allowance.

[2] Defence height relative to ground level to be achieved by regrading existing ground level in sections along alignment.

[3] Defence type has changed from an embankment to a wall after Public Participation Day 3 (July 2022)

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

It is proposed that a fully assumptive approach be adopted in Area 4 in the present day. The flood mitigation measures are therefore to be designed to accommodate the MRFS and HEFS standard of protection. A climate change allowance assessment for this area is therefore not required.

12.9 Area 5: Ballinacurra

It is also proposed that a fully assumptive approach be adopted in Area 5 in the present day. The flood mitigation measures are therefore to be designed to accommodate the MRFS and HEFS standard of protection. A climate change allowance assessment for this area is therefore not required.

13. Refinement of Preferred Scheme Post PPD3

13.1 Introduction

A number of refinements to the emerging preferred scheme are proposed based on the following set of considerations:

- Feedback from members of the public/landowners on the emerging preferred option as presented at PPD 3;
- Findings of the Freeboard analysis (Section 11);
- Climate change assumptive allowance (Section 12);
- Quay wall condition assessment and remediation works requirements;
- Interaction with other engineering projects being implemented in Midleton;
- Further assessment of the proposed scheme.

The refinements to the scheme are detailed in this section.

13.2 Total Flood Defence Level

The total defence height of walls and embankments has been derived as the sum of the following criteria:

- defended scenario 1% AEP fluvial/0.5% AEP tidal design water level
- the total freeboard which as noted in Section 11 is the sum of three separate freeboard allowances:
  - hydrological/hydraulic uncertainty
  - super elevation
  - physical processes which includes for settlement of embankments and also wave overtopping in the estuary
- proposed climate change assumptive allowance (as detailed in Section 12).

Figure 50 and Figure 51 provides schematics of how the proposed defence levels have been derived. It is noted that the figures are not drawn to scale and are indicative only.

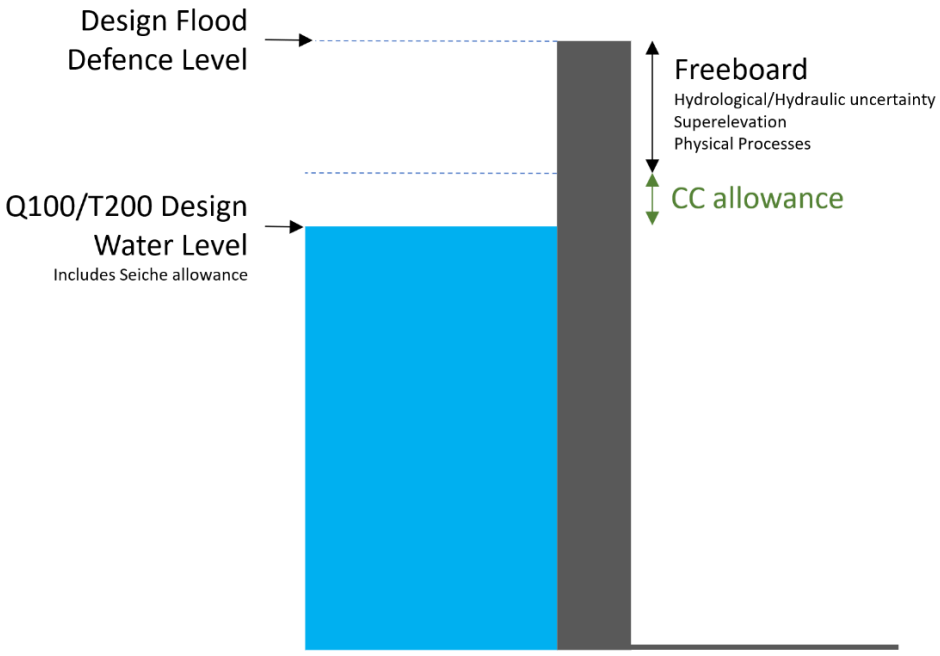


Figure 50 Indicative Sketch of Proposed Flood Defence Wall

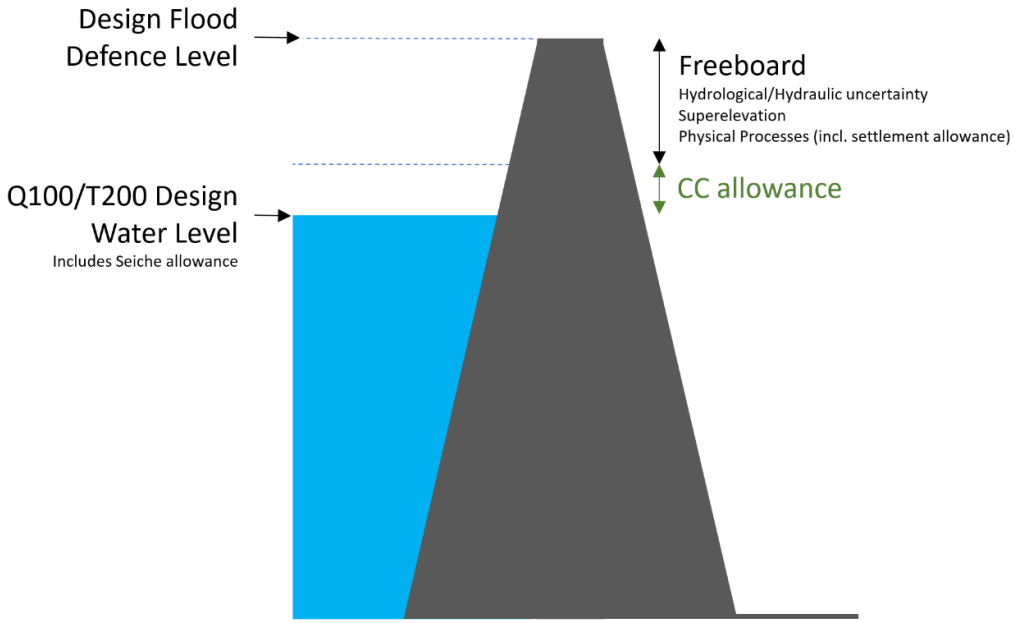


Figure 51 Indicative Sketch of Proposed Flood Defence Embankment

13.3 Area 1&2: Tír Cluain to Riverside Way

A number of refinements have been made to the emerging preferred option in Areas 1 and 2. These are outlined below. Some of the refinements have been finalised and the scheme has been adjusted accordingly. Some refinements however are subject to design development as they require additional surveys. This work will be undertaken early in Stage 2 of the project.

13.3.1 Willowbank and Millbrook Existing Flood Defence Embankments

Following feedback from local residents at PPD2, it was agreed to include the existing embankments at Willowbank and Millbrook as part of the scheme. Subject to a condition survey, this could include upgrade or maintenance of existing embankments as required.

13.3.2 Moore's Bridge / Moore's Lane

Following feedback from local residents on potential tree removal at PPD2, an option to move the road and the flood defence wall away from the river edge was presented at PPD3. This alternative alignment would require construction within a number of private gardens and has also received negative feedback from local residents.

As part of the design development, an arborist survey will be completed in the area to inform the preferred alignment of the defences though the reach.

13.4 Area 3: Town Centre and Bailick Rd

13.4.1 Old Gasworks Site / Kennedy Park

Following submission from the landowner, it was agreed that the proposed 1.2m high embankment will be replaced with a flood defence wall. This will ensure consistency in defence type along the Owenacurra River and will reduce maintenance requirements associated with the upkeep of the embankment.

13.4.2 ESB Site

Following consultation with Irish Water, it was agreed that the proposed 1.2m high embankment be replaced with a flood defence wall to facilitate essential infrastructure works within the site.

13.4.3 People's Park

Flood defence embankments are proposed for the People's Park. It is noted that the footprint of these embankments could exceed a width of 10m. The alignment of the defences therefore need to be considered as part of the overall landscaping of the engineering works through this area. As part of the design development, an arborist survey will be completed to inform the preferred alignment.

13.4.4 GAA Grounds

During consultation with the GAA, the problem of pluvial run off from the Youghal Road into the undeveloped field to south of site adjacent to Youghal Road was raised as a concern. This will be considered as part of the design development of the proposed Youghal Road drainage upgrade works.

13.4.5 Bailick Road Existing Quay Walls

Due to the condition of the existing quay walls and the requirement to construct parapet walls on or adjacent to these walls, it was agreed that remediation works will very likely be required along some lengths. An initial visual assessment has been undertaken by Arup as part of the design. The costs associated with the quay wall remediation works have been included in the updated cost estimate.

As part of the design development, quay wall condition surveys will be completed in the area to inform the preferred construction methodologies to undertake the wall upgrades.

13.4.6 The Granary Development Quay wall

As presented at PPD3, the ground floor levels of The Granary Development are above the design flood level plus freeboard such that the development is outside the SoP of the scheme. Defences are therefore not required along the back gardens of the properties. There are however some works required within the development to tie in with the flood defence walls at either end of the site.

Several submissions were received from the local residents requesting the Granary Quay Wall to be included as part of the flood defence scheme due to the poor condition of the existing quay wall. The poor condition of the wall was confirmed by Arup as part of our initial visual assessment of the wall.

A recent topographical survey has been undertaken at the Granary Development and confirmed that the lowest existing finished floor level recorded within the development is above the required flood defence level to achieve the 0.5% Tidal AEP SoP of 3.6mOD, (which includes seiche allowance, 300mm freeboard and 200mm wave overtopping allowance). This has confirmed that the development is not at risk of flooding in the design SoP. It is considered that remediation of the quay wall is not required for flood defence

purposes and would present significant challenges in terms of cost implications, site access challenges and construction of works in an SPA and SAC environment. Hence, it is not proposed to include the remediation of the Granary Quay Wall within the current scheme.

It is noted that should defences be required in this area for the climate change scenario, it will be considered as part of a potential future scheme, as per the Scheme Climate Change Adaptation Plan (SCCAP) Report.

13.4.7 Bailick Road Brownfield Site

Following submission from the landowner of the site between Woodquay Apartments (North) and Charleston Wharf (South), it was agreed that the proposed 1.3m high embankment be replaced with a flood defence wall. This will ensure consistency in defence type along Bailick Road and will reduce maintenance requirements associated with embankment upkeep.

13.4.8 Riversfield Estate / Dwyer's Rd

There were a number of submissions received from the local residents of Riversfield Estate requesting that a walkway not be located on top of the proposed flood defence embankment to maintain privacy. Additional topographical survey data is required in the area to confirm that there is sufficient space available to allow for the walkway and embankment be located side by side.

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

13.5.1 IDL Mill Race

Following consultation with the IDL, it was agreed that further investigations would be undertaken to establish if flood defence embankments are required adjacent to the IDL Mill Race channel in order to prevent inundation of the IDL Mill Race which may increase flood risk downstream. Additional topographic survey data is required to inform this further investigation and will be procured as part of the Stage 2 of the project.

13.5.2 Drainage of Greenway

Feedback at PPD3 included queries on the drainage of the Greenway post flood event. This will be developed in the next stage of design. Topographic survey data is required to inform the drainage design development in this area.

13.6 Area 5: Ballinacurra

13.6.1 Kearney's Cross Open Channel

There were a number of submissions received from local residents in Ballinacurra requesting that the open channel, existing stone wall and culvert directly adjacent to the road at Kearney's Cross be maintained due to its environmental, visual and heritage significance. This will be carefully considered in the design development.

13.7 Summary of Emerging Preferred Scheme

Based on the scheme refinements detailed above, the final scheme elements for each area are outlined in Table 47 to Table 51 and correspond with Figure 52 to Figure 56 below.

Table 47 Area 1&2 Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C01_E001_R	Rear of Tir Cluain	Embankment	1.0m	171
C01_E001_R	Rear of Tir Cluain	Existing Embankment	1.0m	82
C01_E002_R	Tir Cluain	Embankment	1.1m	139

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C01_E001_L	Clohessy's Yard	Embankment	1.3-2.0m	139
C01_B001	Moore's Bridge	Parapet	1.1m	52
C01_L001_R	Moore's Lane	Wall	1.1m	311
C01_L001_L	Left Bank Downstream of Moore's Bridge	Wall	1.1m	173
C01_E002_L	Willowbank	Existing Embankment	0.4m	453
C01_L002_L	Left Bank Upstream of Northern Relief Road	Wall	1.1m	108
C01_B002	Bridge Downstream of Northern Relief Road	Removal	-	-
C01_E003_L	Left Bank Downstream of Northern Relief Road	Embankment	1.0m	175
C01_E004_L	Millbrook	Existing Embankment	0.4m	425
C01_L003_L	Mill Race Apartments/ My Place	Wall	0.6m	228
C01_L002_R	Right Bank Upstream of Cork Road Bridge	Wall	0.8m	36
C03_E001_L	Left Bank Upstream of Carrigogna Bridge	Embankment	2.0m	200
C03_B001	Carrigogna Bridge	Parapet	1.1m	18
C03_E002_L	Clohessy's Yard	Embankment	1.3m	124
C01_P001_L	Clohessy's Yard	Pumping Station	-	-
C03_P001_L	Carrigogna Bridge	Pumping Station	-	-
C01_P002_L	NRR Bridge	Pumping Station	-	-
C01_P003_L	The Courtyard Development	Pumping Station	-	-
C04_PS001	Owenacurra Millrace Culvert Inlet	Penstock/ flow control structure	-	-
C04_CM001	Owenacurra Culvert Upper	Existing culvert	-	497
C04_CM002	Owenacurra Culvert Lower	Existing culvert	-	76

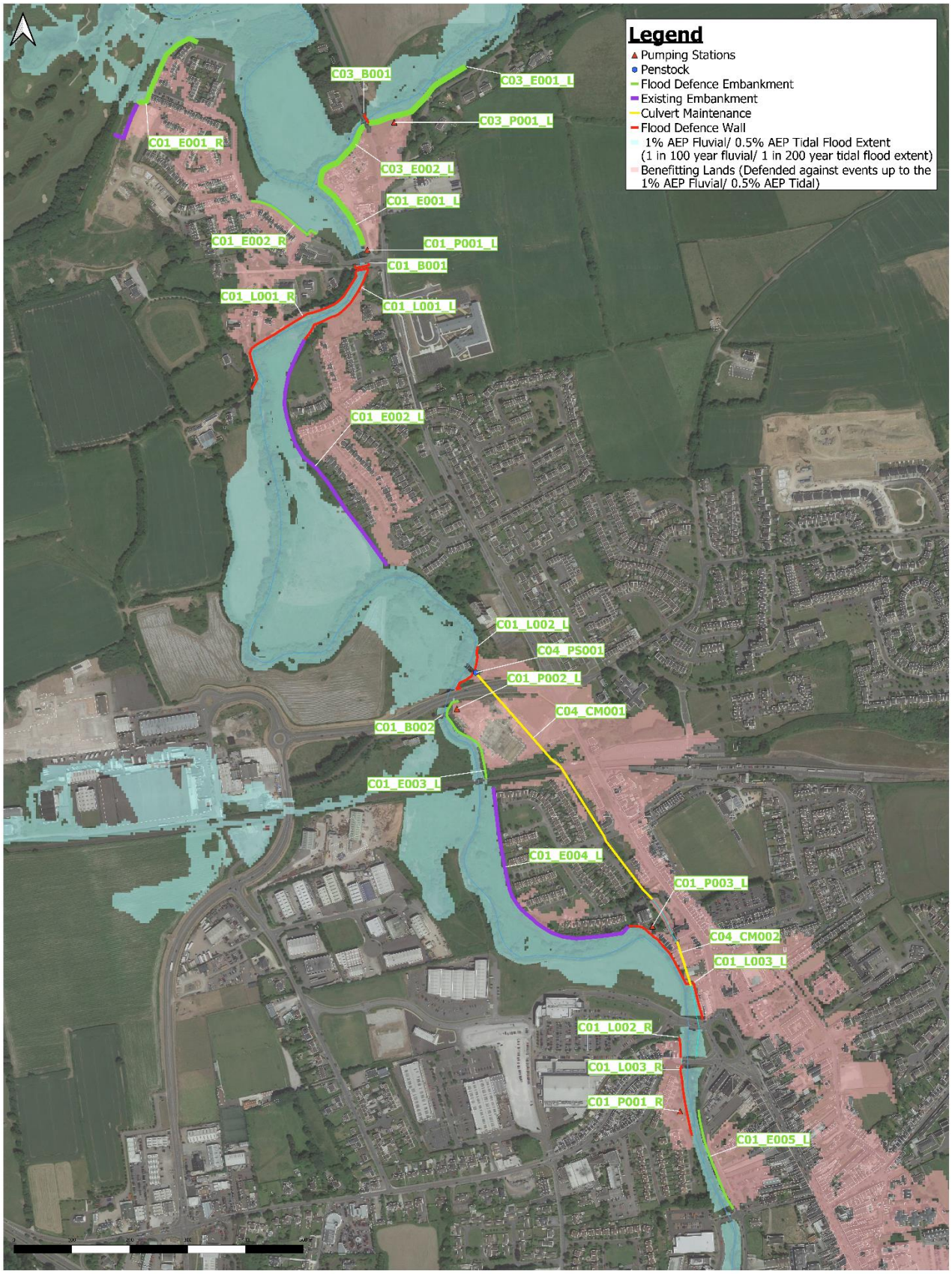


Figure 52 Area 1&2 Refined Emerging Preferred Option

Table 48 Area 3 (North) Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C01_L003_R	The Woodlands	Wall	0.8m	124
C01_E005_L	Riverside Way - Thomas Street Lower	Embankment	0.4m	183
C01_L004_L	Riverside Way - O'Farrell's Funeral Home	Wall	1.2m	176
C01_L005_L	Kennedy Park - ESB Site	Wall	1.1m	76
C02_L001_L	Bailick Road - Irish Water Site / Chadwick's	Wall	0.75m	188
C02_E001_R	Riversfield Estate	Embankment	1.1m	268
C02_E001_L	Bailick Road – Chadwick's to Choctaw Park	Embankment	1.1m	360
C02_E002_L	Choctaw Park	Existing Embankment	1.05m	40
C02_E003_L	Choctaw Park	Embankment	1.1m	52
C05_E001_R	Irish Distillers – WWTP	Embankment	0.85m	36
C05_E002_R	Irish Distillers – WWTP	Existing Embankment	1.1m	250
C05_L001_L	GAA Grounds	Wall	1.5m	215
C05_E003_R	Irish Distillers	Embankment	1.4m	127
C05_E004_R	Peoples Park	Embankment	1.7m	212
C05_L001_R	The Baby Walk	Wall	1.2m	159
C05_L002_L	Roxboro Close	Wall	1.1m	162
C05_L002_R	Midleton House and Upstream of Bailick Rd Bridge	Wall	1.2m	286
C05_B001	Bailick Road Bridge	Parapet	1.1m	33
C05_L003_R	Downstream of Bailick Road Bridge	Wall	1.2m	87
C05_L003_L	Downstream of Bailick Road Bridge	Wall	1.2m	81
C01_P001_R	Woodlands	Pumping Station	-	-
C05_P001_L	GAA Land	Pumping Station	-	-
C05_P002_L	Roxboro Close	Pumping Station	-	-
C05_P001_R	The Baby Walk	Pumping Station	-	-
C05_P002_R	Upstream of Bailick Road Bridge	Pumping Station	-	-
C05_SW001_L	Youghal Road	Surface water drainage upgrade	-	-
C05_SW002_L	St. Mary's Road	Surface water drainage upgrade	-	-
C05_DB001_R	The Baby Walk	Demountable Barrier	1.2m	4
C05_FV001_R	Peoples Park	Flap Valve at IDL Mill race outlet	-	-
C05_FV002_R	The Baby Walk	Flap Valve at IDL Mill race outlet	-	-

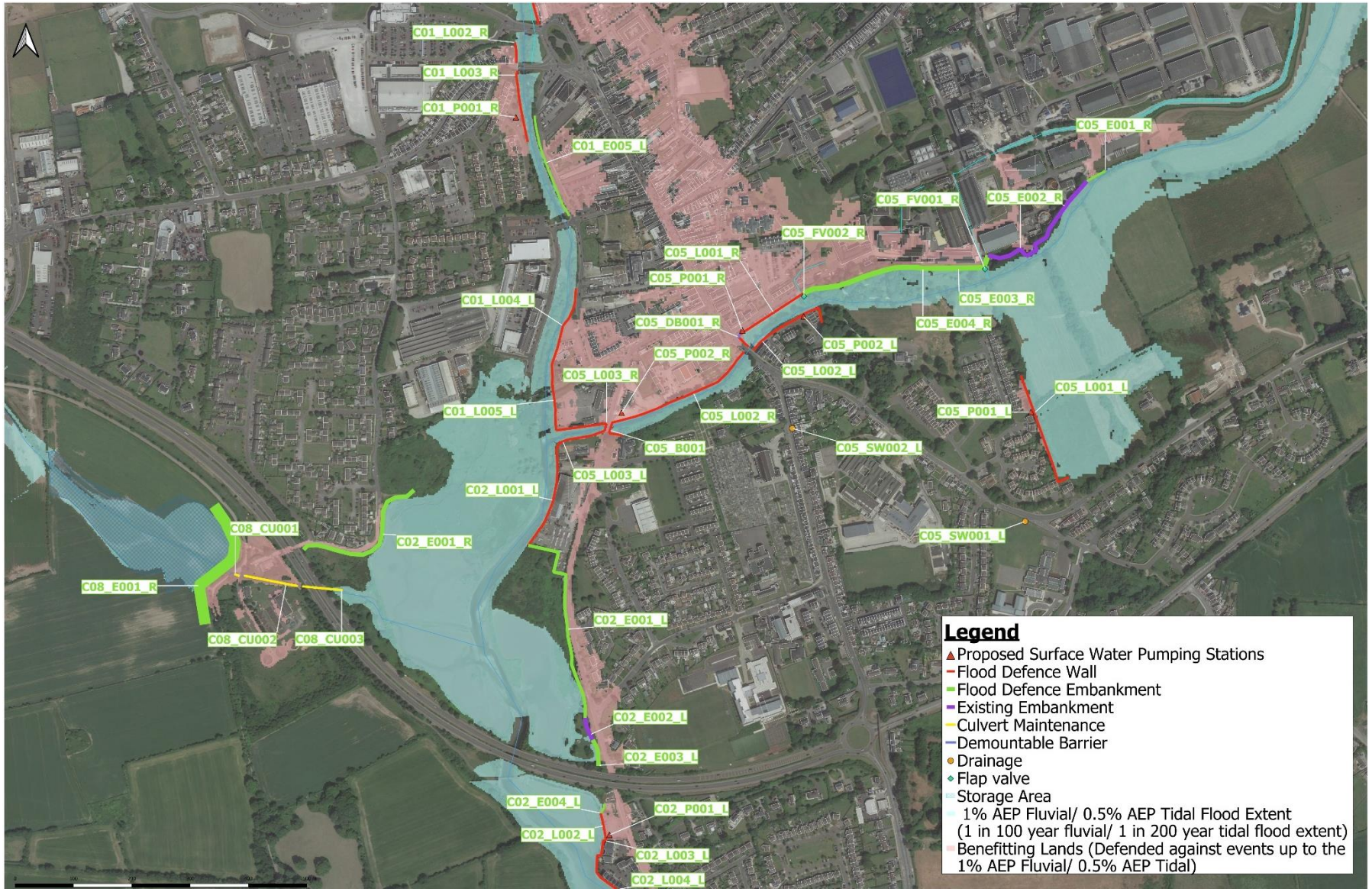


Figure 53 Area 3 (North) Refined Emerging Preferred Option

Table 49 Area 3 (South) Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C02_E004_L	Carpark Downstream of N25	Embankment	1.3m	18
C02_L002_L	Carpark Downstream of N25	Wall	1.2m	48
C02_L003_L	Cois ná hAbhann	Wall	0.6m	75
C02_L004_L	The Moorings	Wall	0.4m	83
C02_L005_L	The Granary	Wall	0.6m	26
C02_L006_L	Bailick Road	Wall	1.2m	134
C02_L007_L	Old Grain Store	Wall	1.2m	81
C02_L008_L	Woodquay Apartments	Wall	0.5m	63
C02_L009_L	Brownfield Site	Wall	1.2m	89
C02_L010_L	Charleston Wharf	Wall	1.2- 1.4m	124
C02_L011_L	Maltings	Wall	1.2- 1.4m	88
C02_L012_L	North of Ballinacurra Estuary	Wall	1.1m	214
C02_L013_L	South of Ballinacurra Estuary	Wall	1.2m	68
C02_E005_L	South of Ballinacurra Estuary	Embankment	1.5m	97
C02_L014_L	South Quay Apartments	Wall	1.1m	180
C02_P001_L	Carpark Downstream of N25	Pumping Station	-	-
C02_P002_L	The Granary	Pumping Station	-	-
C02_P003_L	Charleston Wharf/ Maltings	Pumping Station	-	-
C02_P004_L	South of Ballinacurra Estuary	Pumping Station	-	-
C08_E001_R	Upstream of WWTP	Embankment	-	242
C08_CU001	Upstream of WWTP	Culvert	-	7
C08_CU002	WWTP	Culvert	-	91
C08_CU003	Under N25	Culvert	-	66

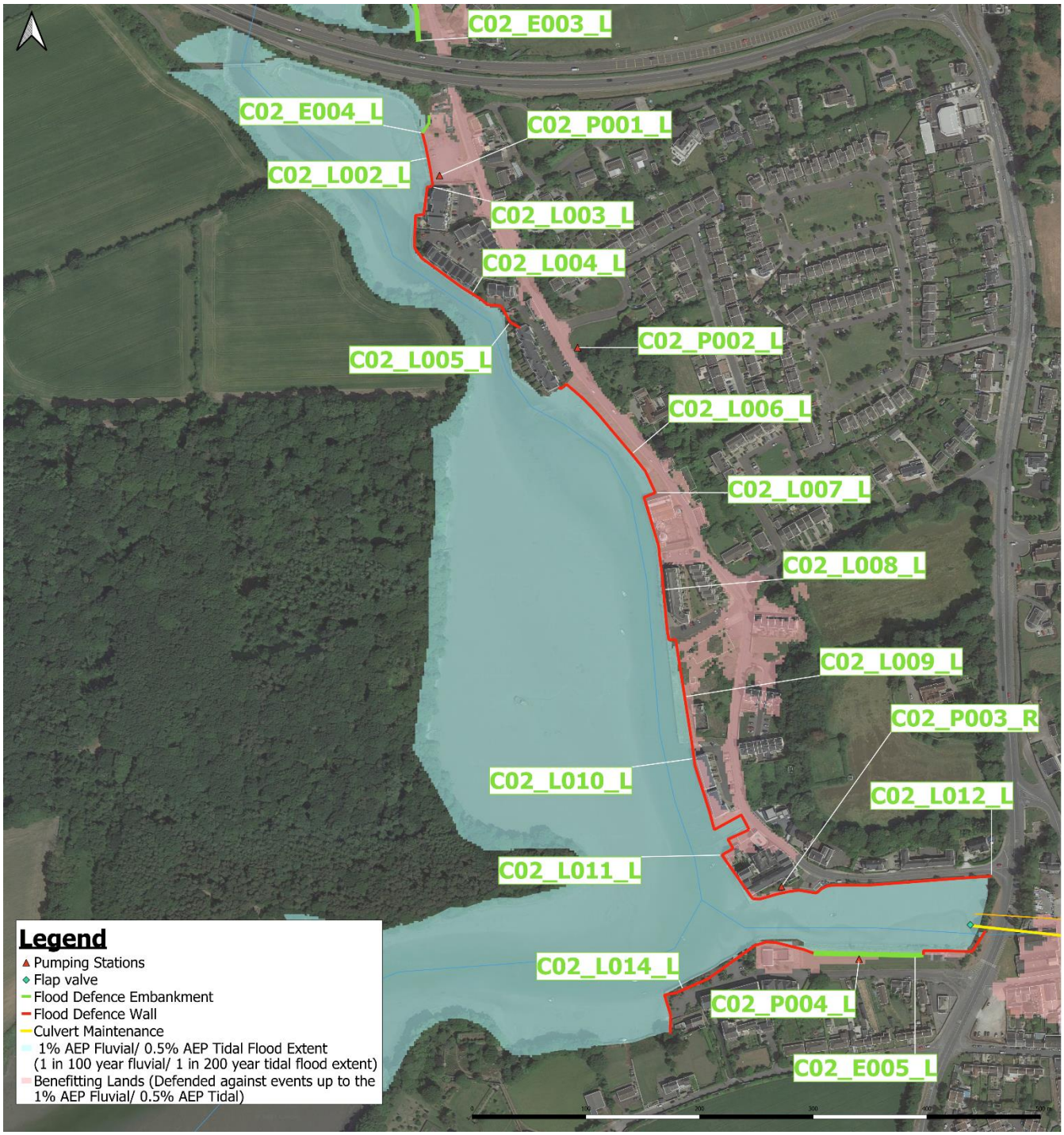


Figure 54 Area 3 (South) Refined Emerging Preferred Option

Table 50 Area 4 Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C09_P001_R	Dry side of proposed Embankment	Pumping Station	-	-
C09_E001_R	Greenway Embankment	Embankment	2.2- 3.1m	968
C09_GWC001	Greenway Embankment	Groundwater Cut-off	-	203
C09_CU001_R	Greenway Embankment	Culvert	-	62
C04_HW001_R	Under proposed embankment	Headwall	-	-
C09_CH001_R	Greenway Embankment	Open Channel	-	111
C09_PS001	IDL Millrace	Penstocks	-	-
C09_R001_R	Greenway Embankment	Regrading	-	483

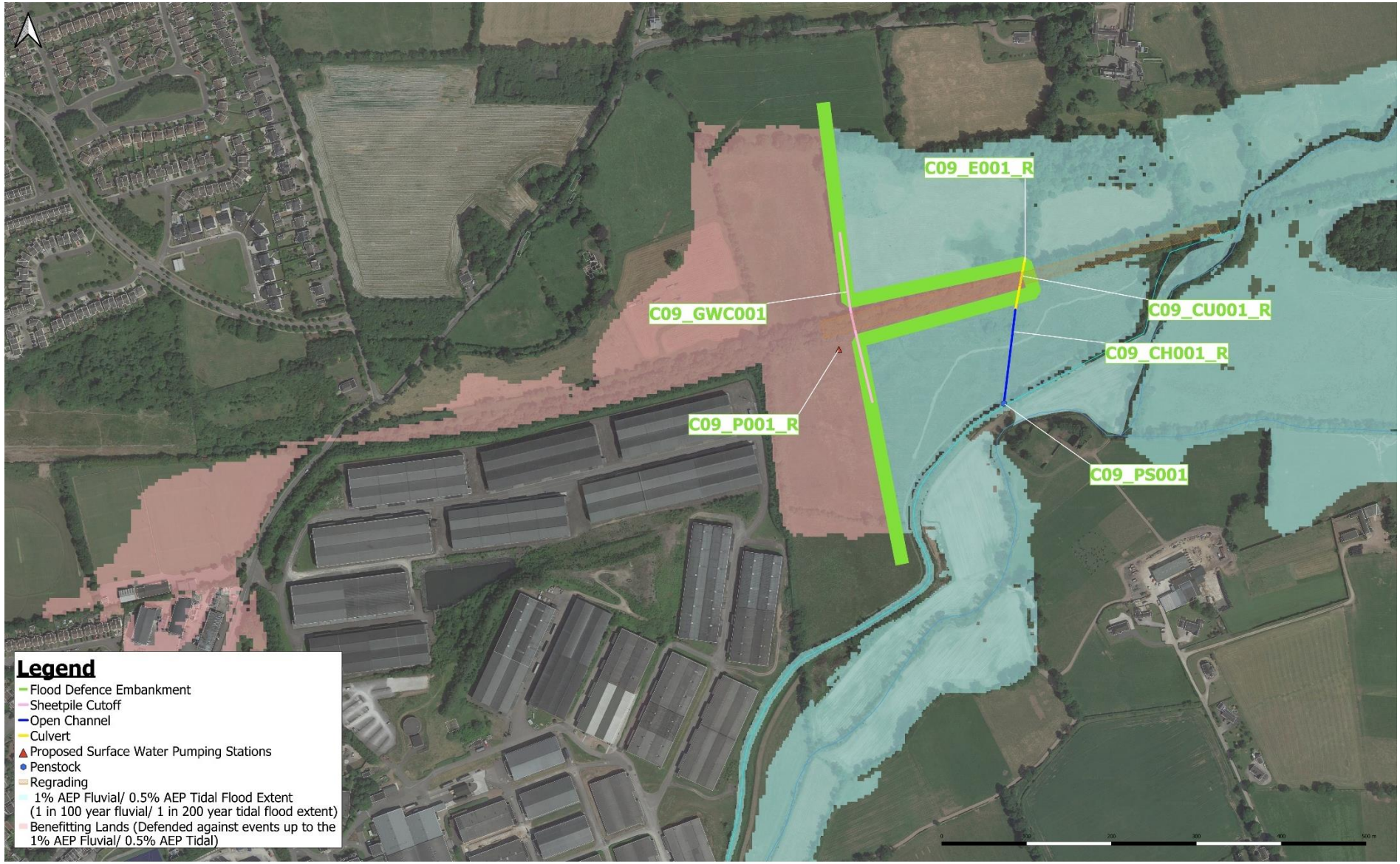


Figure 55 Area 4 Refined Emerging Preferred Option

Table 51 Area 5 Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C06_E001_L	Upper Ballinacurra	Storage Area Embankment	1.7m	171
C06_E001_R	Upper Ballinacurra	Storage Area Embankment	0.9m	157
C06_E002_L	Upper Ballinacurra	Storage Area Embankment	0.7m	87
C06_E002_R	Upper Ballinacurra	Storage Area Embankment	1.4m	78
C06_E003_R	Upper Ballinacurra	Storage Area Embankment	2.1m	190
C06_SW001	Upper Ballinacurra	Spillway	-	-
C06_PS001	Upper Ballinacurra	Penstock/ flow control structure	-	-
C06_CM001	Upstream of Kearney's Cross	Culvert maintenance	-	19
C06_CH001	Kearney's Cross	Channel re-alignment	-	50
C06_RM001	Upstream of Co-op	Rising Main	-	99
C06_P001_R	Upstream of Co-op	Pump Station	-	-
C06_FV001	Estuary	Flap Valve upgrade	-	-
C06_CM002	Upstream of Kearney's Cross	Culvert maintenance	-	43
C06_CM003	Downstream of Kearney's Cross	Culvert maintenance	-	17
C06_CM004	Under Co-op	Culvert maintenance	-	98

Figure 56 Area 5 Refined Emerging Preferred Option

13.8 Cost Estimate of Emerging Preferred Option

The emerging preferred option has been costed as per the June 2021 unit cost rates and is detailed in Table 28.

Table 52 Summary of the total project costs for each of the reasonable alternatives

Option	Cost Estimate (June 2021 rates)
Area 1&2: Tír Cluain to Riverside Way : Option 1&2B – Direct Defences Only	€7.5M
Area 3 (North): Town Centre and Bailick Road to Choctaw Park : Option 3A – Direct Defences Only	€12.4M
Area 3 (South): Bailick Road : Option 3A – Direct Defences Only	€13.1M
Area 4: Lauriston Estate/Rugby Club/East of IDL : Option 4E: Groundwater cut-offs and direct defences east of the current IDL site and along Greenway	€6.6M
Area 5: Ballinacurra : Option 5B-1: Upstream storage – Refined storage area (smaller footprint than Option 5B) and over pumping	€2.0M
TOTAL	**€41.6M**

Based on analysis of the project costs in each area, the total project costs are in the region of €41.6million as per the June 2021 rates.

When the % uplift due to inflation is considered as discussed in Section 7.1.2, the costs in the present day are in the region of €46.1million.

13.9 Benefit Update

As discussed in Section 9.5, the Water Rock area upstream of the railway line has been removed from the benefit assessment, therefore the benefit assessment has been updated.

The baseline benefit (4%DR) associated with the various sources of flooding for the two primary flood cells is presented in Table 53 below. The results account for the 15.2% uplift due to inflation as discussed in Section 7.3.4.

Table 53 Damages Avoided/ Benefit Results

Watercourse	Fluvial	Tidal	Groundwater	Pluvial
Owenacurra/ Dungourney	€37.92M	€5.36M	€1.84M	€0.81M*
Ballinacurra	€5.12M	n/a**	n/a	n/a
Total per source	€43.45M	€5.36M	€1.84M	€0.81M
TOTAL				**€51.05M**

* Calculated pluvial benefit is provisional.

** Tidal flap gate at Ballinacurra is assumed to function as part of damages calculation. Tidal benefit is therefore n/a.

13.10 Benefit Cost Ratio (BCR) Update

The total project costs are in the region of €46.1 million and the total benefit is estimated to be circa €51.05 million. This results in a Benefit Cost Ratio of approximately 1.1 for the baseline scenario (4%DR).

14. Refinement of Preferred Scheme Post Storm Babet

14.1 Introduction

On the 18th October 2023, Midleton was severely flooded during Storm Babet. A detailed hydrology assessment was carried out after this event. This assessment concluded that:

- The Q100 design flow (based on 2018 hydrology) for the Ballyedmond gauge location is circa 66.67m3/s and for the post Babet Hydrology is circa 70.14m3/s.
- From the revised rating curve and updated hydrological analysis the design flows for the scheme are increased by 5.2% when compared with the 2018 Hydrology report.
- The uplifted flows require changes to a number of defences in the fluvially dominated area of the scheme. While required changes to the scheme varies between the individual defences, on average the increase in defence height is circa 100mm and the average increase in length of the defences is circa 10m. These changes to the defences are deemed to be modest and can be accommodated as part of the current scheme without any significant impact on the environmental and/or landscape heritage constraints.

Refinements to the proposed scheme due to the revision in the hydrology and increase in design flows post Storm Babet are detailed in this section.

It should be noted that some of the defence references have changed due to the change in defence type.

The final defence heights and alignments will be developed and finalised through the planning design development, and will be informed by the final topographic survey, the revised freeboard assessment and the ground investigation surveys.

14.2 Area 1 & 2: Tir Cluain to Riverside Way

The modification to the proposed scheme due to the revision in the hydrology and increase in design flows is as follows:

- Due to embankment land take requirements at Clohessy's Yard, the proposed defence has been changed to a wall (C01_L002_L).

Table 54 Area 1&2 Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length
C01_E001_R	Rear of Tir Cluain	Embankment	1.05m	253m
C01_E002_R	Tir Cluain	Embankment	1.25m	263m
C01_L001_L	Clohessy's Yard	Wall	1.25-1.95m	139m
C01_B001*	Moore's Bridge*	Parapet	1.25m	52m
C01_L001_R	Moore's Lane	Wall	1.15m	311m
C01_L002_L	Left Bank Downstream of Moore's Bridge	Wall	1.15m	173m
C01_E001_L	Willowbank	Existing Embankment	0.45m	453m
C01_L003_L	Left Bank Upstream of Northern Relief Road	Wall	1.15m	108m
C01_B002	Bridge Downstream of Northern Relief Road	Removal	-	-
C01_E002_L	Left Bank Downstream of Northern Relief Road	Embankment	1.15m	175m
C01_E003_L	Millbrook	Existing Embankment	0.45m	425m
C01_L004_L	Mill Race Apartments/ My Place	Wall	0.7m	228m

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length
C01_L002_R	Right Bank Upstream of Cork Road Bridge	Wall	0.9m	36m
C03_E001_L	Left Bank Upstream of Carrigogna Bridge	Embankment	2.15m	134m
C03_B001	Carrigogna Bridge	Parapet	1.25m	35m
C03_L001_L	Clohessy's Yard	Wall	1.25m	124m
C01_P001_L	Clohessy's Yard	Pumping Station	-	-
C03_P001_L	Carrigogna Bridge	Pumping Station	-	-
C01_P002_L	NRR Bridge	Pumping Station	-	-
C01_P003_L	The Courtyard Development	Pumping Station	-	-
C04_PS001	Owenacurra Millrace Culvert Inlet	Penstock/ flow control structure	-	-
C04_CM001	Owenacurra Culvert Upper	Existing culvert	-	497m
C04_CM002	Owenacurra Culvert Lower	Existing culvert	-	76m

*Future status of Moore's Bridge to be confirmed

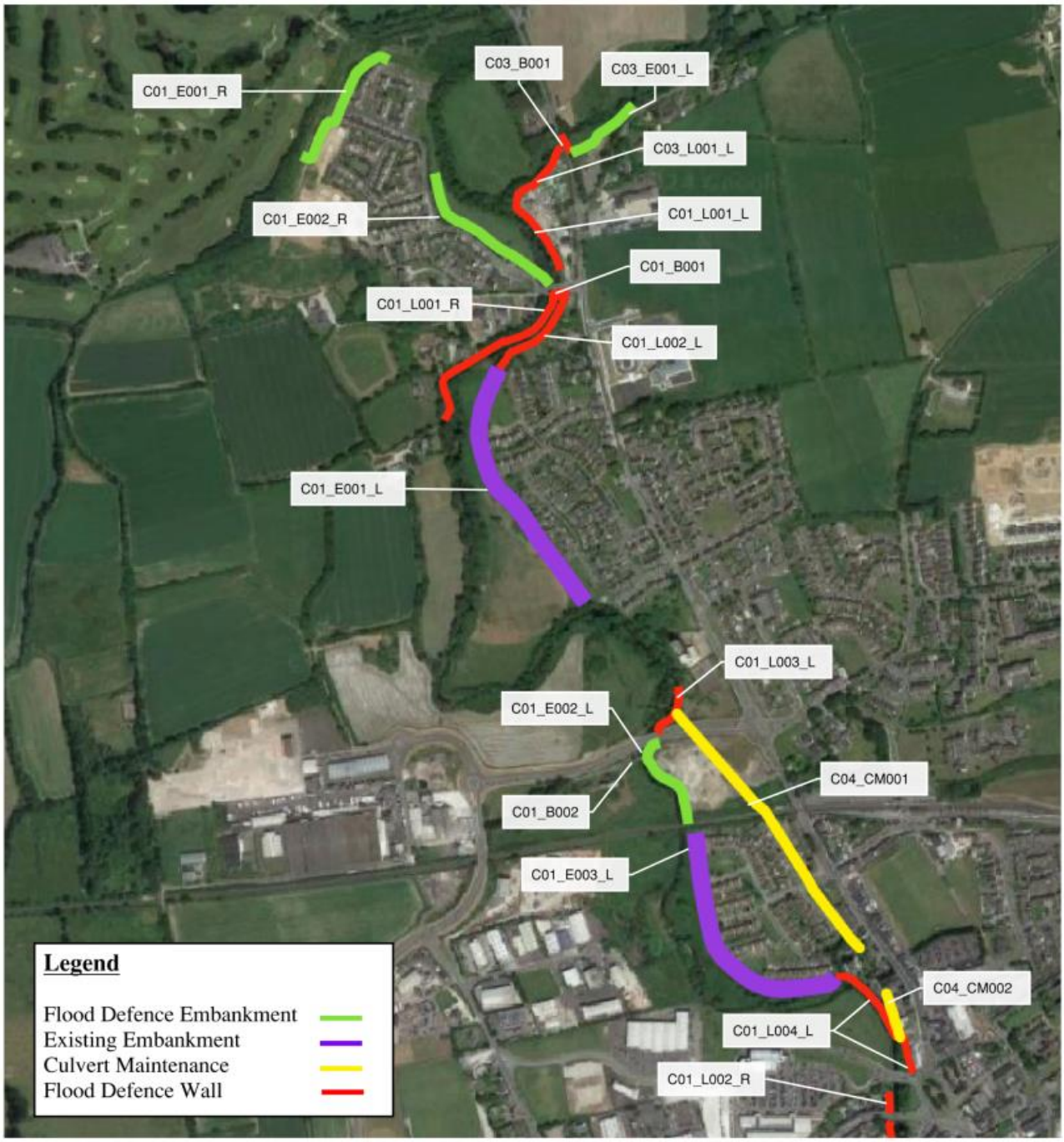


Figure 57 Area 1&2 Refined Emerging Preferred Scheme

14.3 Area 3 (North): Town Centre and Bailick Road to Choctaw Park

The modifications to the proposed scheme due to the revision in the hydrology and increase in design flows are as follows:

- It is noted that two additional defences are proposed in Area 3 (North) due to the increase in design flows, an embankment/ wall arrangement immediately upstream of Lidl Bridge on the right bank and a wall immediately downstream of Lewis Bridge on the left bank, defence reference C01_E003_R/ C01_L004_R and C05_L003_L respectively.
- The proposed embankment along Riverside Way has been changed to a wall (C01_L005_L) due to space constraints and interaction with the proposed cycleway.
- The proposed embankment along Riversfield Estate has been changed to a combination of an embankment and a wall due to space constraints (C02_E001_R, C02_L001_R, C02_E002_R).

- There have been several refinements to the defence alignment along the right bank of the Dungourney, particularly though People's Park (C05_E004_R) to mitigate the impact on trees.
- At two specific locations along the boundary of the IDL site where there are space constraints, it is proposed to change sections of the defence to walls, C05_L001_R and C05_L002_R.

Table 55 Area 3 (North) Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C01_L003_R	The Woodlands	Wall	0.9m	124
C01_L005_L	Riverside Way - Thomas Street Lower	Wall	0.25m	190
C01_E003_R	Upstream of Lidl Bridge	Embankment	0.5m	29
C01_L004_R	Upstream of Lidl Bridge	Wall	0.3m	31
C01_L006_L	Riverside Way - O'Farrell's Funeral Home	Wall	1.25m	176
C01_L007_L	Kennedy Park - ESB Site	Wall	1.1m	76
C02_L001_L	Bailick Road - Irish Water Site / Chadwick's	Wall	0.75m	188
C02_E001_R	Riversfield Estate	Embankment	1.1m	53
C02_L001_R	Riversfield Estate	Wall	0.9m	123
C02_E002_R	Riversfield Estate	Embankment	1.1m	90
C02_E001_L	Bailick Road – Chadwick's to Choctaw Park	Embankment	1.1m	351
C02_E002_L	Choctaw Park	Embankment	1.05m	32
C02_E003_L	Choctaw Park	Embankment	1.1m	50
C05_E001_R	Irish Distillers – WWTP	Embankment	1.05m	20
C05_L001_R	Irish Distillers – WWTP	Wall	0.85m	20
C05_E002_R	Irish Distillers – WWTP	Embankment	1.3m	152
C05_L002_R	Irish Distillers – Millrace Outlet	Wall	1.1m	61
C05_L001_L	GAA Grounds	Wall	1.7m	215
C05_E003_R	Irish Distillers	Embankment	1.65m	177
C05_E004_R	Peoples Park	Embankment	2.0m	210
C05_L003_R	The Baby Walk	Wall	1.45m	129
C05_L004_R	The Baby Walk – Lewis Bridge Parapet	Wall	1.45m	24
C05_L002_L	Roxboro Close	Wall	1.35m	163
C05_L003_L	Left Bank downstream of Lewis Bridge	Wall	1.0m	77
C05_L005_R	Midleton House and Upstream of Bailick Rd Bridge	Wall	1.25m	263
C05_L004_L	Upstream of Bailick Rd Bridge	Wall	1.1m	24
C05_B001	Bailick Road Bridge	Parapet	1.1m	33
C05_L006_R	Downstream of Bailick Road Bridge	Wall	1.2m	87
C05_L005_L	Downstream of Bailick Road Bridge	Wall	1.25m	81
C01_P001_R	Woodlands	Pumping Station	-	-

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C05_P001_L	GAA Land	Pumping Station	-	-
C05_P002_L	Roxboro Close	Pumping Station	-	-
C05_P001_R	The Baby Walk	Pumping Station	-	-
C05_P002_R	Upstream of Bailick Road Bridge	Pumping Station	-	-
C05_SW001_L	Youghal Road	Surface water drainage upgrade	-	-
C05_SW002_L	St. Mary's Road	Surface water drainage upgrade	-	-
C05_DB001_R	The Baby Walk	Demountable Barrier	1.4m	4
C05_FV001_R	People's Park	Flap Valve at IDL Mill race outlet	-	-
C05_FV002_R	The Baby Walk	Flap Valve at IDL Mill race outlet	-	-
C08_E001_R	Upstream of WWTP	Embankment	-	241
C08_CU001	Upstream of WWTP	Culvert	-	7
C08_CU002	WWTP	Culvert	-	91
C08_CU003	Under N25	Culvert	-	66

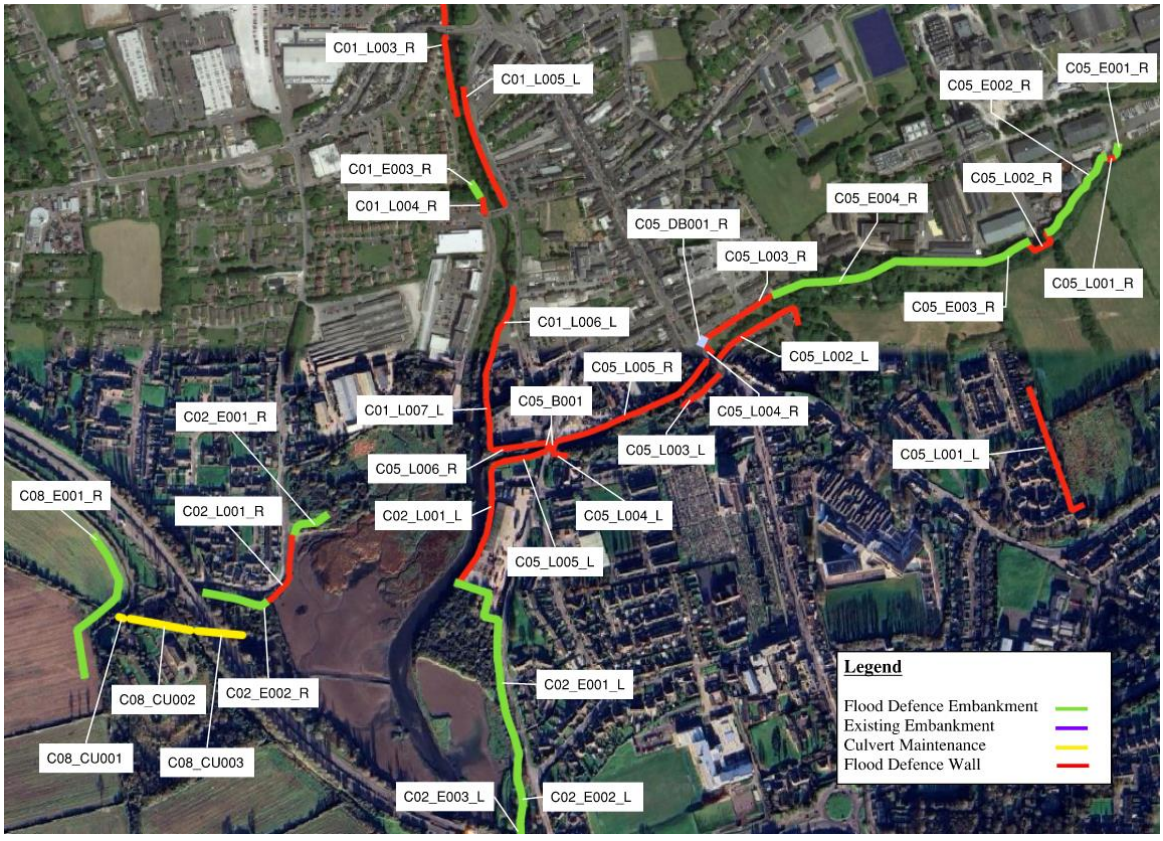


Figure 58 Area 3 (North) Refined Emerging Preferred Scheme

14.4 Area 3 (South): Bailick Road

The modification to the proposed scheme due to the revision in the hydrology and increase in design flows is as follows:

- The originally proposed embankment in the carpark downstream of the N25 has been replaced with a flood defence wall (C02_L002_L) and regrading (C02_R001_L) to facilitate the existing walkway.
- The embankment South of Ballinacurra Estuary has been replaced with a flood defence wall (C02_L014_L) and regrading (C02_R002_L) to limit interaction with Uisce Éireann services in this area.

Table 56 Area 3 (South) Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C02_R001_L	Carpark Downstream of N25	Regrading	-	53
C02_L002_L	Carpark Downstream of N25	Retaining Wall	-	17
C02_L003_L	Carpark Downstream of N25	Wall	1.2m	84
C02_L004_L	Cois na hAbhann	Wall	0.6m	65
C02_L005_L	The Moorings	Wall	0.4m	92
C02_L006_L	The Granary	Wall	0.6m	5
C02_L007_L	Bailick Road	Wall	1.2m	135
C02_L008_L	Old Grain Store	Wall	1.2m	84
C02_L009_L	Woodquay Apartments	Wall	0.5m	63
C02_L010_L	Brownfield Site	Wall	1.2m	89
C02_L011_L	Charleston Wharf	Wall	1.2- 1.4m	124
C02_L012_L	Maltings	Wall	1.2- 1.4m	91
C02_L013_L	North of Ballinacurra Estuary	Wall	1.1m	216
C02_L014_L	South of Ballinacurra Estuary	Wall	1.2m	58
C02_L015_L	South of Ballinacurra Estuary	Wall	1.3m	114
C02_R002_L	South of Ballinacurra Estuary	Regrading	-	97
C02_L016_L	South Quay Apartments	Wall	1.1m	161
C02_P001_L	Carpark Downstream of N25	Pumping Station	-	-
C02_P002_L	The Granary	Pumping Station	-	-
C02_P003_L	Charleston Wharf/ Maltings	Pumping Station	-	-
C02_P004_L	South of Ballinacurra Estuary	Pumping Station	-	-

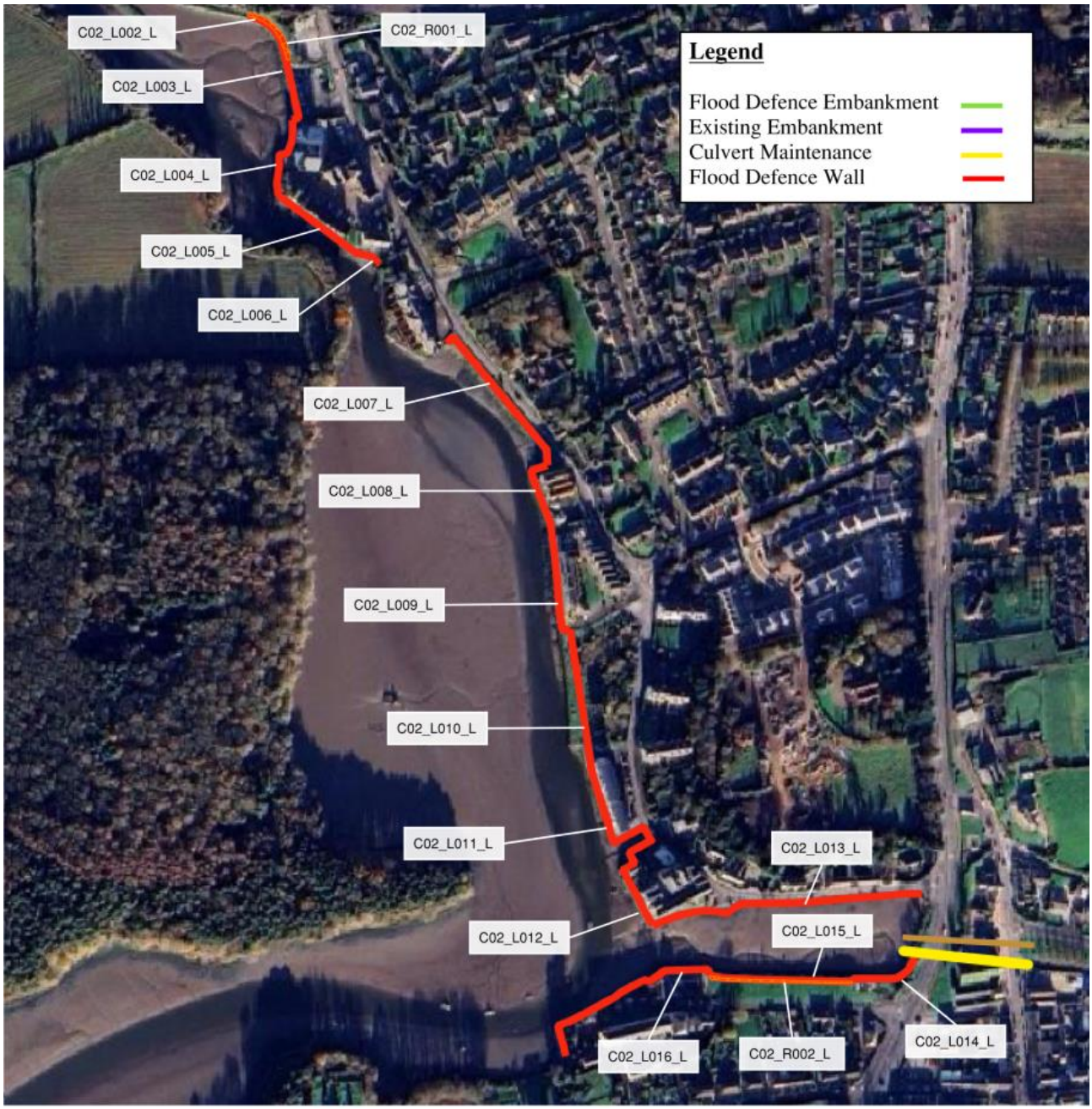


Figure 59 Area 3 (South) Refined Emerging Preferred Scheme

14.5 Area 4 Lauriston Estate / Rugby Club / East of IDL

It is proposed that the assumptive approach be adopted in the present day in Area 4 and that the embankment (C09_E001_R) be designed to accommodate the MRFS and HEFS required standard of protection. The dimensions of the proposed defences will therefore be revised to ensure the uplift in the flow is accommodated.

Table 57 Area 4 Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C09_P001_R	Dry side of proposed Embankment	Pumping Station	-	-
C09_E001_R	Greenway Embankment	Embankment	2.5m	864
C09_GWC001	Greenway Embankment	Groundwater Cut-off	-	202
C09_CU001_R	Greenway Embankment	Culvert	-	62
C04_HW001_R	Under proposed embankment	Headwall	-	-
C09_CH001_R	Greenway Embankment	Open Channel	-	111
C09_PS001	IDL Millrace	Penstocks	-	-
C09_R001_R	Greenway Embankment	Regrading	-	483

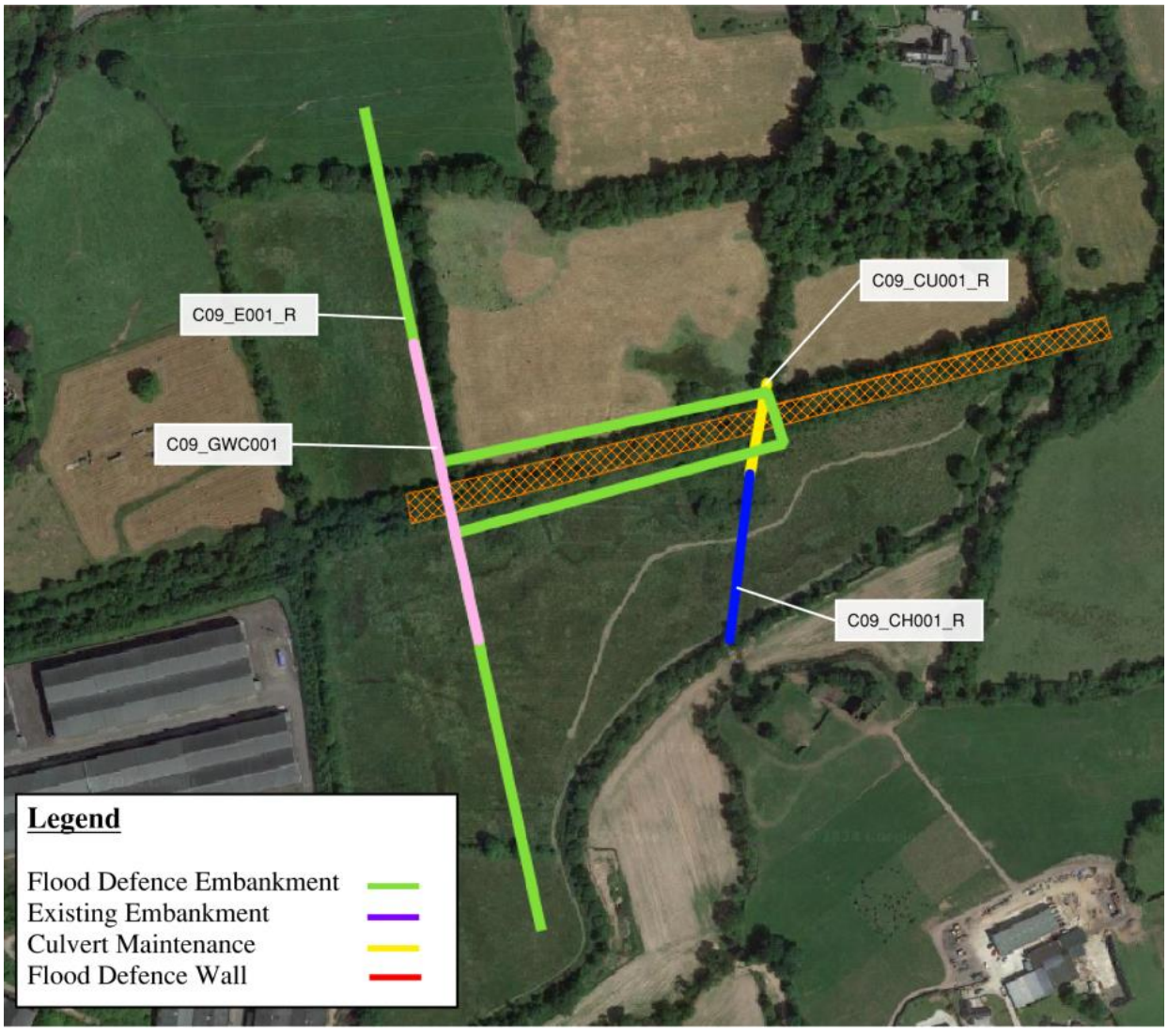


Figure 60 Area 4: Refined Emerging Preferred Scheme

14.6 Area 5 Ballinacurra

It is proposed that the assumptive approach be adopted in the present day in Area 5. The upstream storage will therefore be designed to accommodate the MRFS and HEFS required standard of protection. The dimensions of the proposed defences associated with the storage option will therefore be revised to ensure the uplift in the flow is accommodated.

Table 58 Area 5 Refined Emerging Preferred Scheme Elements

Defence Ref.	Location	Description	Proposed defence height above ground	Defence Length (m)
C06_E001_L	Upper Ballinacurra	Storage Area Embankment	1.7m	160
C06_E001_R	Upper Ballinacurra	Storage Area Embankment	0.9m	157
C06_E002_L	Upper Ballinacurra	Storage Area Embankment	0.7m	87
C06_E002_R	Upper Ballinacurra	Storage Area Embankment	1.4m	78
C06_E003_R	Upper Ballinacurra	Storage Area Embankment	2.1m	190
C06_R001_L	Upper Ballinacurra	Regrading	-	24
C06_SW001	Upper Ballinacurra	Spillway	-	-
C06_PS001	Upper Ballinacurra	Penstock/ flow control structure	-	-
C06_CM001	Upstream of Kearney's Cross	Culvert maintenance	-	19
C06_CH001	Kearney's Cross	Channel re-alignment	-	50
C06_RM001	Upstream of Co-op	Rising Main	-	99
C06_P001_R	Upstream of Co-op	Pump Station	-	-
C06_FV001	Estuary	Flap Valve upgrade	-	-
C06_CM002	Upstream of Kearney's Cross	Culvert maintenance	-	43
C06_CM003	Downstream of Kearney's Cross	Culvert maintenance	-	17
C06_CM004	Under Co-op	Culvert maintenance	-	98

Figure 61 Area 5 Refined Emerging Preferred Scheme