OPW
Oifig na nOibreacha Poiblí
The Office of Public Works

Lower Lee (Cork City) Drainage Scheme
(Flood Relief Scheme)

Phasing Report

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ARUP

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Office of Public Works

Lower Lee (Cork City) Drainage Scheme

Assessment of Phasing Options

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1 Introduction

1.1 Background

The Lower Lee (Cork City) Drainage Scheme is a key deliverable of the OPW's National Flood Risk Management programme. The OPW are advancing this scheme as part of its mandate as the lead agency for flood risk management in Ireland. It is being developed in close co-operation with all key stakeholders, in particular; Cork City Council, Cork County Council and the ESB.

Arup in association with JBA Consulting were commissioned by the OPW as the engineering consultants to develop the Lower Lee Flood Relief Scheme.

There are five stages to the project:

- Stage I - Development of a number of flood defence options and the identification of a preferred Scheme.
- Stage II - Public exhibition.
- Stage III - Detailed design, confirmation and tender.
- Stage IV – Construction and
- Stage V - Handover of works.

This Assessment of Phasing Options Report is produced as part of Stage I of the project and covers the area from Inniscarra Dam to Cork City.

The scheme will be designed to provide protection to properties in the study area from the 1 in 100 year fluvial and 1 in 200 year tidal flood events on the Lee River. The current estimate (November 2016) of capital expenditure for the construction works required to implement this level of protection is circa €90 million, with the work consisting of over 19km of direct defences, a flow regulation structure at the head of the South Channel, bridge strengthening, an isolated number of demountable flood gates/barriers, road ramps, pumping stations, associated drainage and services diversions, as well as a Flood Forecasting System (FFS).

1.2 Approach

The methodology adopted was agreed in advance with OPW and largely adopted a qualitative approach which can be summarised as follows:

1. The Flood Forecasting System and implementation of Storage Areas is recommended to be implemented as soon as possible to provide some reduction in flood risk to Cork, prior to construction of the physical elements. Both of the aforementioned systems are assumed to work in tandem with the physical elements of the flood relief scheme.
2. Review of the current scenario flood characteristics (flood extents, depths and threshold of flooding).

3. Key flood risk areas were prioritised. This was done by reviewing flood risk maps for the current condition and interim stages for fluvial and tidal flooding as appropriate and prioritising areas with the lowest threshold of flooding and/or highest number of properties at flood risk.
4. Review of the flood relief measures for the selected area including; the associated cost, programme for construction and interdependency.
5. Review of flood risk for each of the interim stages. This was carried out by analysing hydraulic modelling results for the relevant interim stages and reviewing the number of properties at risk.
6. The overall project was then divided into suitably sized contract packages which take account of likely capital budgets, physical constraints, and interim benefits etc.
7. A further check of dependencies between each of the packages.
8. Review of traffic considerations particularly in the Cork Central Island area.

1.3 Report Structure

The report contains six main sections. The first section provides an introduction with brief background information to the study and includes an outline of the approach adopted in undertaking the phasing study.

Section 2 contains information on the current flood characteristics with Section 3 providing an overview of the proposed flood relief scheme.

Section 4 includes the main body of the report, which provides details on the rationale of each phase of the works, including a review of flood risk associated with the interim stage, an outline of each of the areas of works and associated costs.

Section 5 sets other considerations, such as potential interfaces with other public infrastructure projects, traffic management considerations, etc.

Section 6 summarises the proposed phasing of works.

2 Current Flood Characteristics

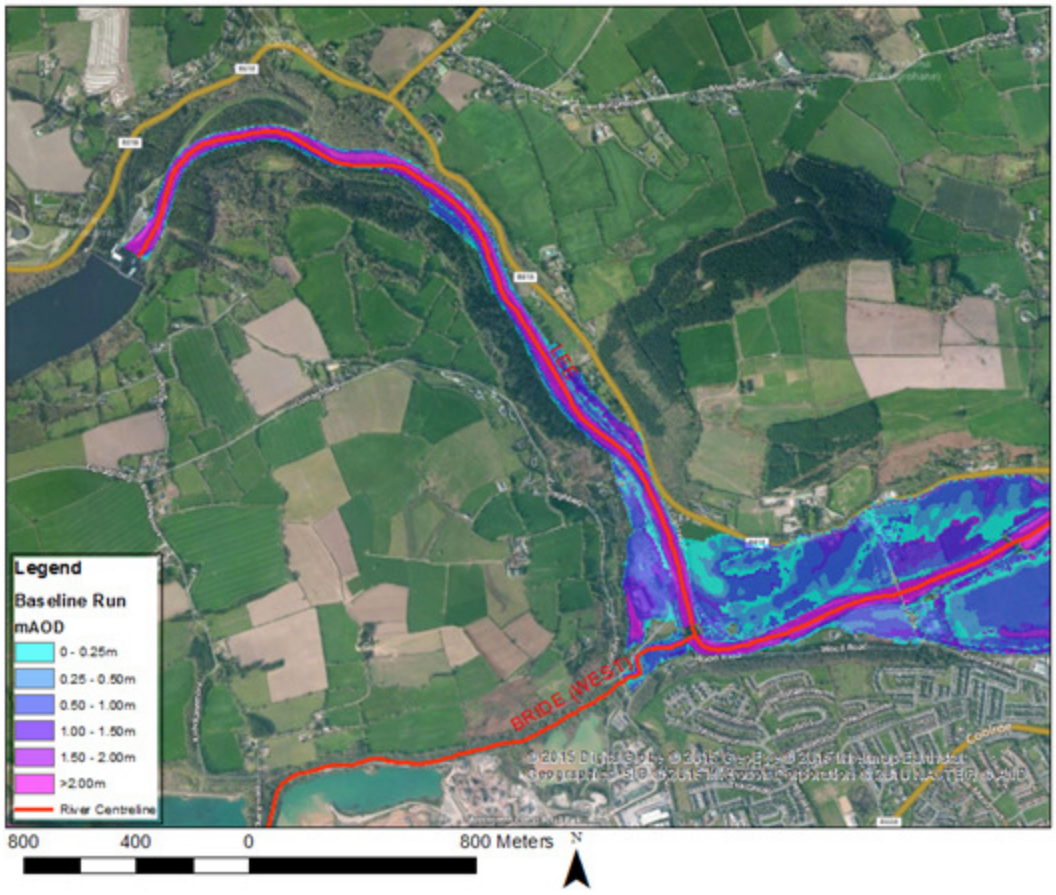
Flood inundation maps have been prepared for the Lower Lee study area. These maps show the predicted flood extents for a range of exceedance probabilities from the 50%AEP event to the 0.1%AEP event, and are based on a joint occurrence of fluvial and tidal flooding.

The following subsection provides detail on the current scenario flood characteristics across the study area.

2.1 Inniscarra

At Inniscarra there are a number of properties affected in the vicinity of Inniscarra Bridge and along the right bank upstream of the confluence with the River Bride, as can be seen in Figure 1.

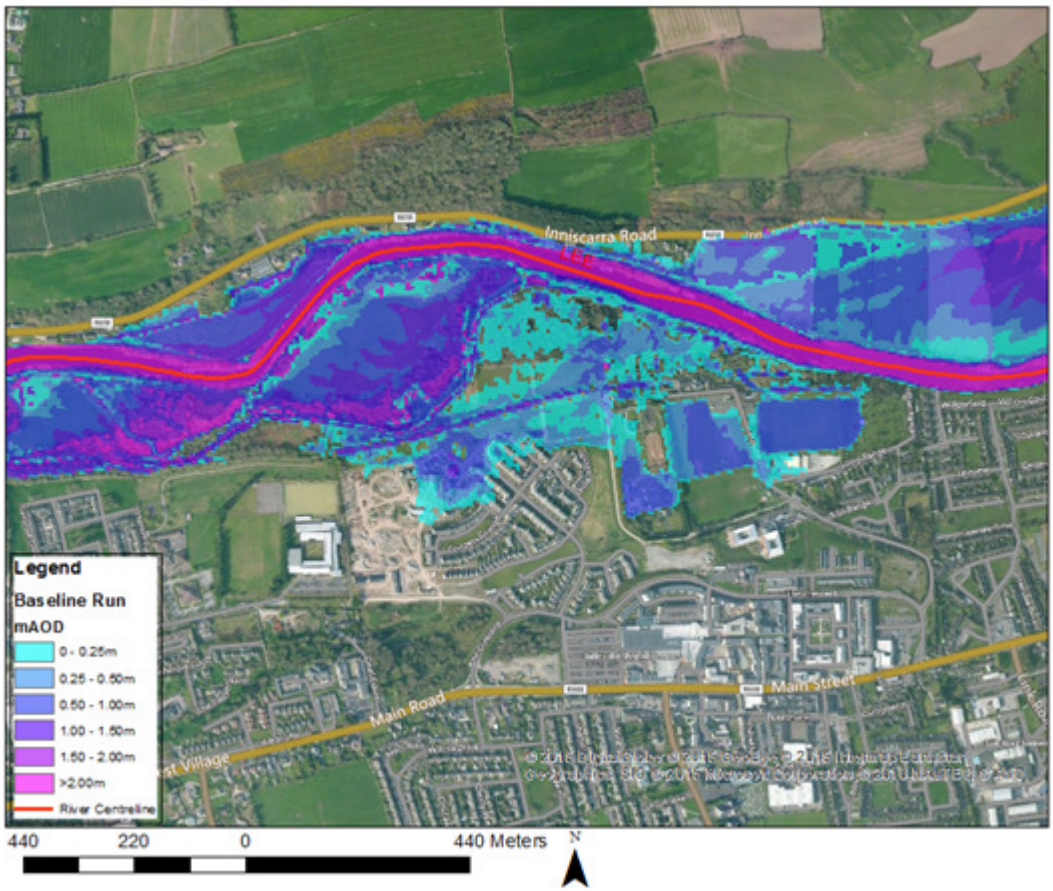
Figure 1: Flooding at Inniscarra - 1%AEP fluvial event



2.2 Ballincollig

Properties in Ballincollig are at flood risk from the River Lee during the 1% AEP event on both banks. Figure 2 presents the 1% AEP fluvial inundation map for this area.

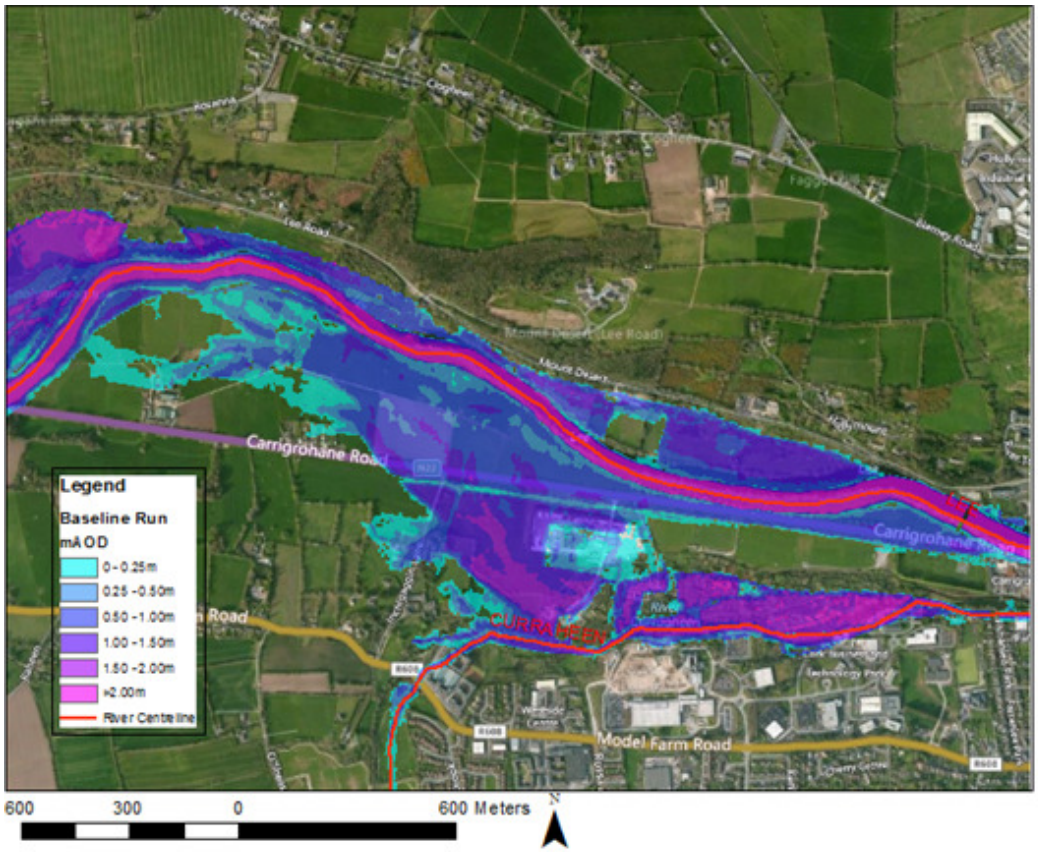
Figure 2: Flooding at Inniscarra - 1%AEP fluvial event



2.3 Inchigaggin

The Lower Lee and the Curragheen are separate rivers. However, during times of flood, the Lower Lee overtop the Carrigrohane Road (N22) and flood flows cross into the Curragheen River. This natural occurrence significantly increases the flow and flood risk along the Curragheen River. Figure 3 presents the flood depths for the 10% AEP event at Inchigaggin.

Figure 3: Cross flooding into the Curragheen River - 10%AEP fluvial event

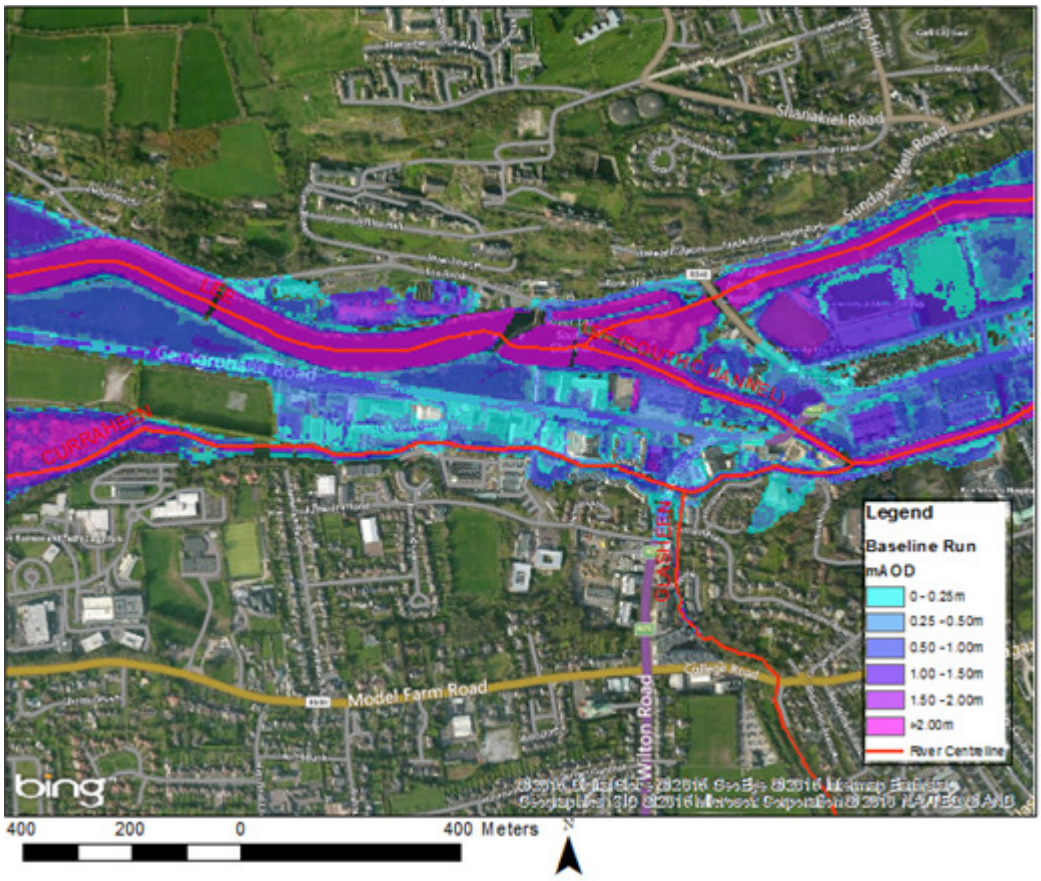


2.4 Flooding at Victoria's Cross

The cross catchment flow described above at Inchigaggin also occurs at Victoria's Cross.

Flood extents from the River Curragheen and the River Lee merge and almost all properties in this area are at flood risk during the 2% AEP fluvial event as presented in Figure 4.

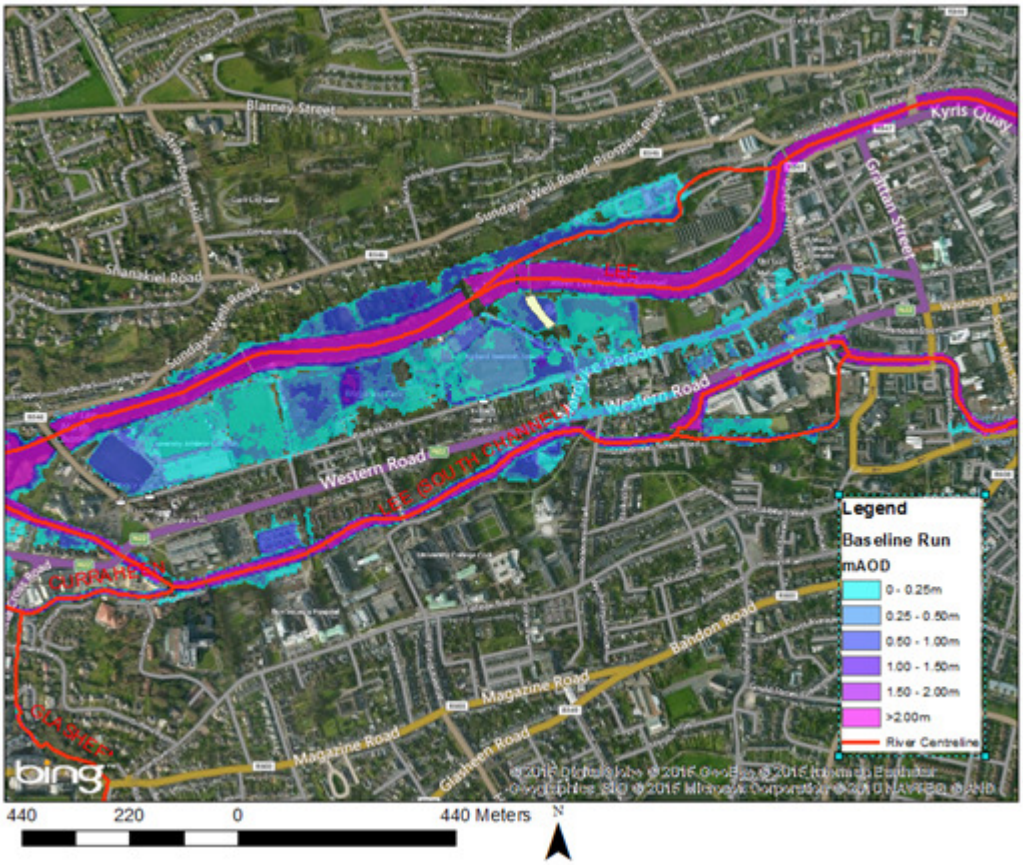
Figure 4: Flooding at Victoria Cross - 2%AEP fluvial event



2.5 Mardyke to Grenville Place

The western part of the central island contains areas of UCC's Mardyke complex and Fitzgerald Park north of the Mardyke Walk. Flooding from the North Channel occurs as the channel capacity is exceeded and waters overtop both the left and right banks into the floodplain with extensive flooding on the right bank during the 5%AEP event.

Figure 5: Flooding at Mardyke/Fitzgerald's Park - 5%AEP fluvial event



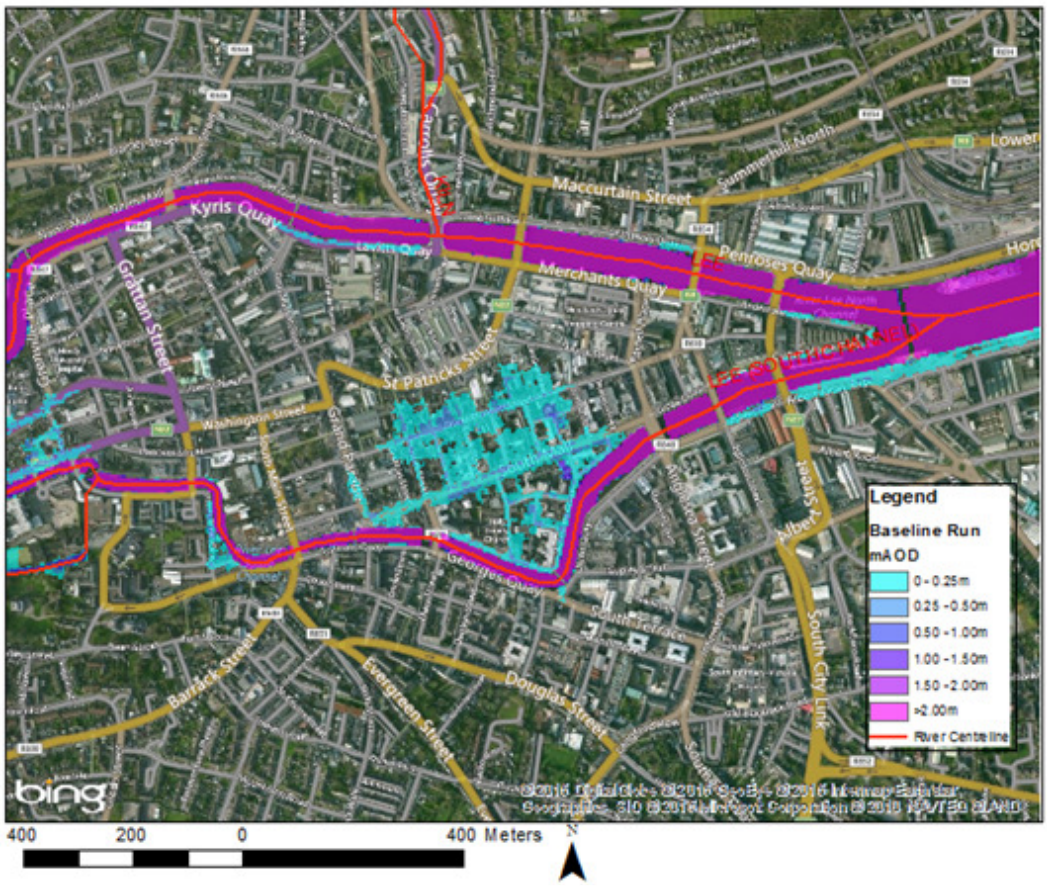
2.6 Flooding at Distillery Fields and Gill Abbey Weir area

Flooding is also evident from the North Channel at Distillery Fields with continuous flooding on the right bank also. The South Channel also has insufficient capacity to contain flood waters in the design event and flood on both left and right banks. There are several affected properties in the vicinity of the Gill Abbey Weir.

2.7 Central Island Cork City

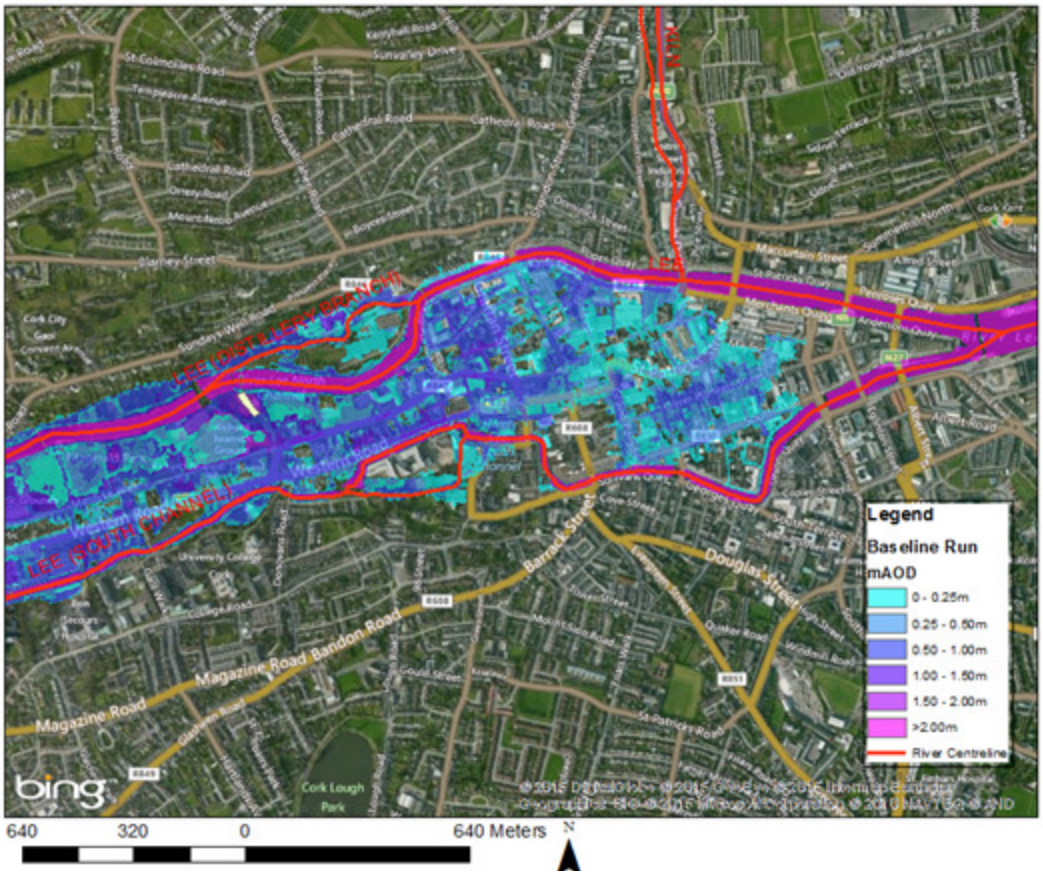
Cork City Centre lies on the eastern part of the Central Island, which is low lying and relatively flat. The more frequent flooding in this area is tidal with Morrison's Island typically overtopped and significant flooding of South Mall and Oliver Plunkett Street occurring during the 5% AEP tidal event. Figure 6 presents the 5%AEP tidal event at Cork City.

Figure 6: Flooding at Cork City - 5%AEP tidal event



During more extreme events, floodwaters also overtop upstream on the central island and travel east. Flooding originates from the right bank of the North Channel and left and right banks of the South Channel. Figure 7 shows the 2% AEP fluvial event in Cork City.

Figure 7: Flooding at Cork City - 2%AEP fluvial event



3 The Proposed Flood Relief Scheme

The proposed flood relief scheme for the Lower Lee and Cork City consists of a number of elements, which have been categorised as follows:

- Flood Forecasting and Early Warning System
- Optimised Dam Operating Procedures
- Designated flood plains (wash lands)
- Direct Defences
- Flow Regulation on South Channel

Each of these elements is outlined in the following subsections.

3.1 Flood Forecasting and Early Warning System

A flood forecasting and early warning system will play a significant role in the flood relief scheme for Cork City, in terms of predicting potentially significant flood events and allowing active management of the ESB dams both in advance of and during flood events, resulting in a decrease in peak flow for the design event. It will also provide a warning which allows property owners and authorities to take measures to mitigate against the effects of a flood event.

The flood forecasting system incorporates both tidal and fluvial forecasting. The tidal forecasting system is currently in place and the fluvial forecasting system is being developed. The fluvial element of the system will use predicted rainfall in the lead up to a flood event as well as real time data during the event.

The Flood Forecasting System would operate as follows:

- Operate continuously based on predicted rainfall ensembles, monitoring for potential extreme events.
- Provide an alarm to the operator, a number of days out, when a predicted significant rainfall event or a predicted tidal surge event is above a predefined threshold that may otherwise result in flooding.
- This would allow dam levels to be lowered at predefined spill rates which would not flood buildings, in preparation for/anticipation of the extreme event and
- Allow management of discharges in real time (if required) taking account of inflow from the Shournagh/Western Bride and tide levels.
- The Flood Warning System would be utilised for a number of purposes:
- Warning of increased advance discharges for recreational users of river and floodplain amenities downstream of Inniscarra.
- Warning to landowners of designated floodplain areas to allow livestock to be relocated.
- Warning to Cork City Council to erect demountable elements if necessary and

- Emergency Response Planning.
- The Flood Warning System dissemination would include the following:
  - Direct notification to landowners of storage areas.
  - Sirens in public amenity floodplain areas.
  - Local Authority websites and social media platforms.
  - Local Authority 'text alert' system and
  - Radio and television public alerts if necessary.

Please refer to the 'Lower Lee Flood Forecasting Report' (June 2016) for further information on the flood forecasting system and flood warning system.

3.2 Optimised Dam Operating Procedures

For the vast majority of time (outside of flood events) the ESB would continue to operate the dams as at present. Continuous monitoring and simulation of predicted rainfall using the new flood forecasting system will allow potentially significant flood events to be detected further in advance.

When a potentially significant event is detected, the optimised procedures would be called into action and require dam levels to be safely drawn down to create storage in advance of the event. This would be achieved by allowing for greater discharges (without causing flooding of buildings) in advance of a forecasted event by the designation of floodplain areas and construction of downstream direct defences to protect buildings.

Most of the time, reservoirs are operated to generate electricity in the most efficient way possible. During flood events, they are managed to ensure their safety and also to provide some protection to Cork.

Reservoir operation during flood events already has to observe certain rules and constraints. Some of these include:

- Prescribed discharges for given reservoir levels to ensure dam safety.
- Minimum allowable water levels.
- Maximum drawdown rates in Carrigadrohid.
- Maximum allowable discharge when the reservoirs are below their maximum normal operating level (MNOL).
- Outflows not to exceed inflows.

Changing how the reservoirs operate introduces more constraints and potential decisions. New procedures would:

- Draw the reservoirs down to a specific starting level 48 hours before a predicted flood event.
- Make increasingly large releases on the run up to a flood event as needed based on dam levels and future predicted inflows.

- Seek to trim the peak off the Lee flows to maintain flows below the scheme design flow in Cork (taking account of contributions from the Bride and Shournagh).

New operational procedures require four days' warning to be confident of managing the 100-year event. This lead time is used to create the necessary storage volume using pre-emptive releases.

As a result this measure would have to be combined with the proposed FFS, which is detailed above.

Please refer to the File Note 'Description of proposed Flood Operation Procedures' (June 2015) for further information.

3.3 Designated Upstream Floodplains (Washlands)

The existing channel/floodplain capacity in the Inniscarra/Ballincollig West area allows discharges from the dams of up to 200m^3/s approx. without flooding buildings whereas the existing 1 in 100 year design flow in this area is estimated to be 772m^3/s.

Floodplain areas upstream of Cork City will be designated as part of the scheme. The flow entering the area of interest can therefore be regulated to ensure that the capacity of the existing channel downstream is not exceeded. These designated areas would facilitate greater advance discharges of up to 300m^3/s from the dams in the lead up to an event.

3.4 Structural Measures

Structural measures for the Lower Lee Flood Relief Scheme consist mainly of a combination of new flood defence embankments and walls and/or replacement/upgrades to existing river walls.

There are also a number of areas in Cork Central Island where demountable defences are proposed to be provided.

3.5 Flow Regulation on the South Channel

A flow regulation structure is also to be provided at the upstream end of the South Channel, which will be used to manage the flow distribution between the North Channel and South Channel at Cork Central Island. This will be operated to ensure that flows in the South Channel will be limited to ensure that out of bank flooding does not occur on the South Channel. When activated, a higher proportion of the flow will be diverted to the North Channel where direct defences are being designed to cater for such increased flows.

4 Assessment of Phasing

This report assesses options for separating the proposed scheme into discrete work packages and prioritising these packages.

This process is described hereunder.

4.1 Identification of Work Packages

In order to assist in the assessment process, the scheme has been divided into separate 'work packages'. The packages have been identified based on local construction elements in discrete geographical areas and do not provide full protection on their own.

The identification and sequencing of the packages has been borne out of considering the following criteria/constraints:

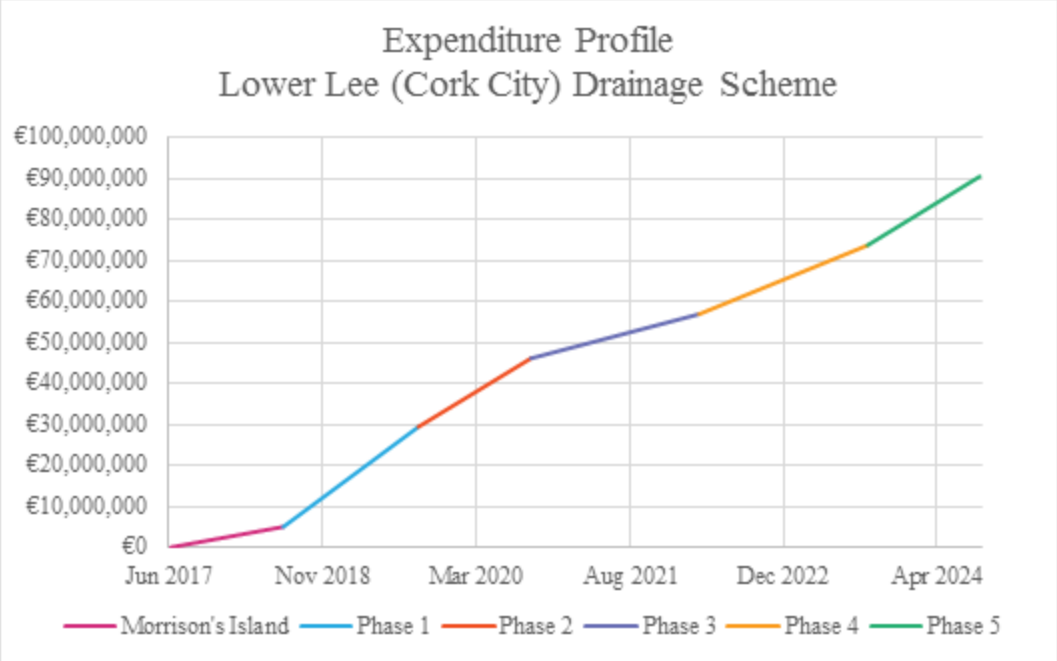
- Phase works in a way that maximises interim benefit in terms of incrementally reducing flood risk.
- Phasing of the scheme must be compatible with OPW's national multi-annual financial budget/spend profile. (For the purpose of this phasing report, and in discussion with the OPW, a desirable contract size of around €15 million has been assumed. Other practical considerations were taken into account resulting in estimated contract values of approximately €15m to €24m.).
- Ensuring construction contracts are of a scale which can reasonably be completed by a large enough number of contractors to ensure competitive tenders can be acquired.
- Ensuring contract phasing and timescales reasonably minimises disruption to businesses and landowners.

Five key packages have been defined and a brief description of each of these is outlined in the sections below.

An expenditure profile has been developed based on the current preliminary cost estimates of the various measures in combination with potential phasing of works. The cost estimates are suitable for the purpose of this report but it should be noted these are based on high-level estimates and will be reviewed and updated following the detailed design.

Figure 8 presents the expenditure profile for the Lower Lee Flood Relief Scheme.

Figure 8: Expenditure profile of Lower Lee flood relief scheme



For the purposes of this report, it has been assumed that flood defences for Morrison's Island are provided upfront under a Part 8 Planning permission and that completion of works on Morrison's Island will overlap with the commencement of Phase 1 of the Main Scheme works.

The following sections provide a summary of the various packages of works for each phase and describes the basis for the prioritising of each of the phases.

4.2 Phase 1 - West of Thomas Davis Bridge

4.2.1 Overview

Prioritising works west of Thomas Davis Bridge and particularly west of Salmon Weir has several benefits.

The main benefit is that it will facilitate the use of (interim) optimised operating rules for the dam discharges and thereby significantly reducing flood risk overall. This will be achieved by increasing the threshold at which flooding occurs west of Waterworks Weir (in the reach where tidal influence does not materially influence river levels) which will facilitate greater discharges without causing flooding, particularly at lower tides and over a significant proportion of the tidal cycle.

Another benefit of these works is that the defences will prevent overtopping of floodwater from the River Lee into the Curragheen River, which historically significantly added to flood risk along the Curragheen and South Channel.

It is envisaged that this phase would incorporate construction of the flow regulation structure at the head of the South Channel as this would provide flexibility and options in terms of managing flow between the North and South Channel depending on the relative scales of flow in the Lee, Curragheen, Glasheen and the tide level, thus significantly minimising flood risk in the South Channel.

Figure 9 to Figure 13 below provide an overview of the various measures included in this phase.

- Direct Defences at Inniscarra
- Direct defences at Ballincollig
- Direct defences at Leemount
- Direct defences at Inchigaggin
- Direct Defences at Lee Fields
- Direct defences at Kingsley and Sacred Heart
- Direct defences at Waterworks and on Lee Road
- Flow Control Structure into South Channel

The current estimate of these works is circa €24.4 Million. However, it should be noted that at this stage, there is significant uncertainty in relation to the cost in this reach as the potential source and proximity of embankment material is unknown and therefore has significant potential for variation.

Figure 9: Defences at Inniscarra

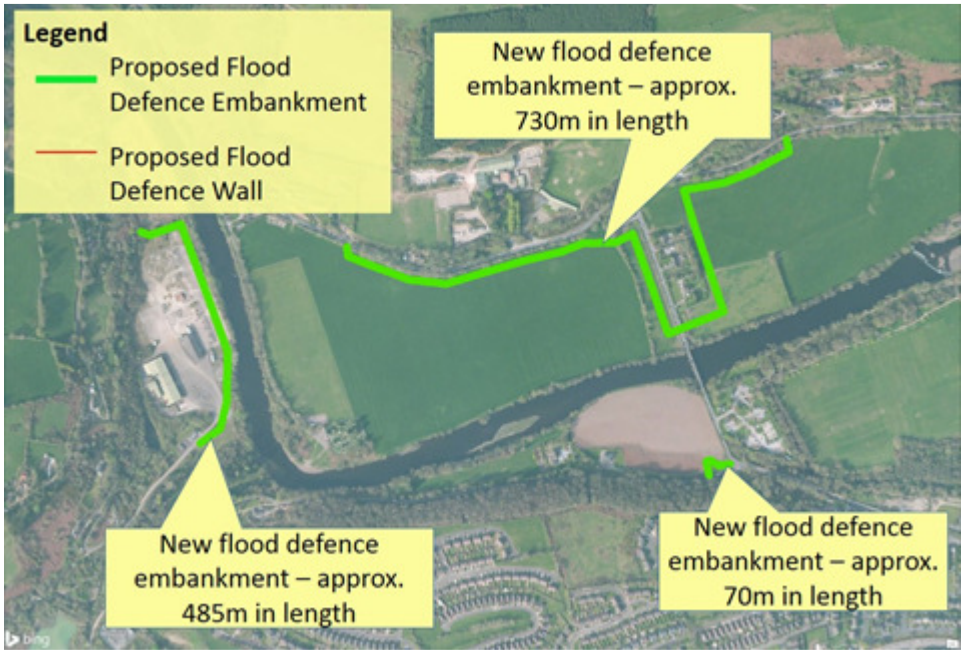


Figure 10: Defences at Ballincollig

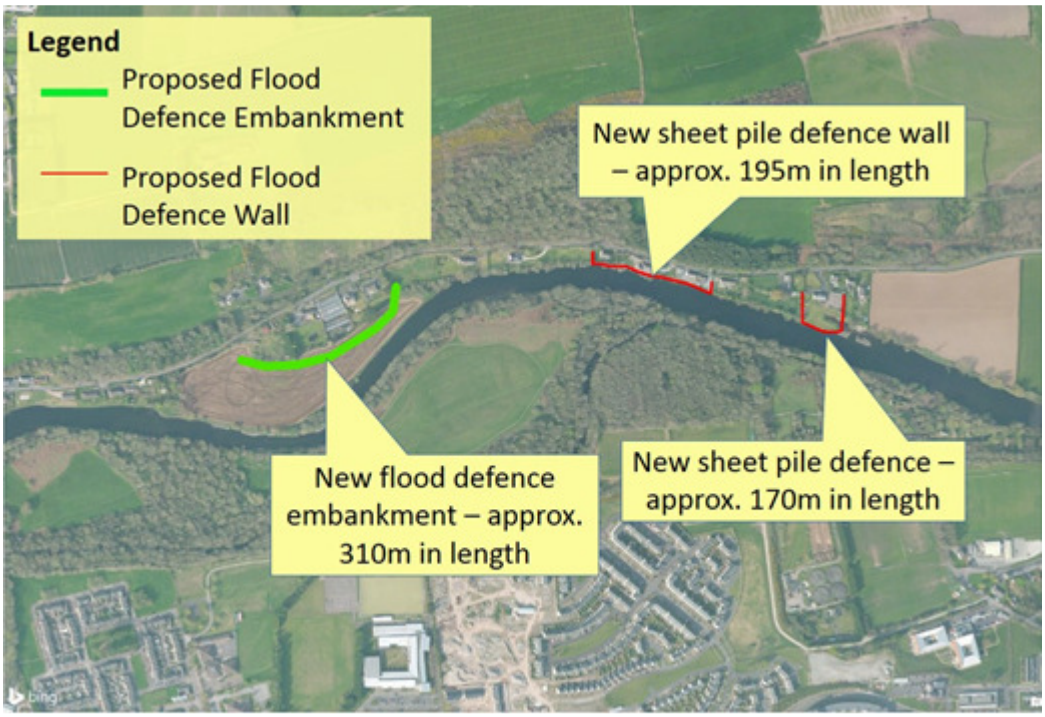


Figure 11: Defences at Leemount

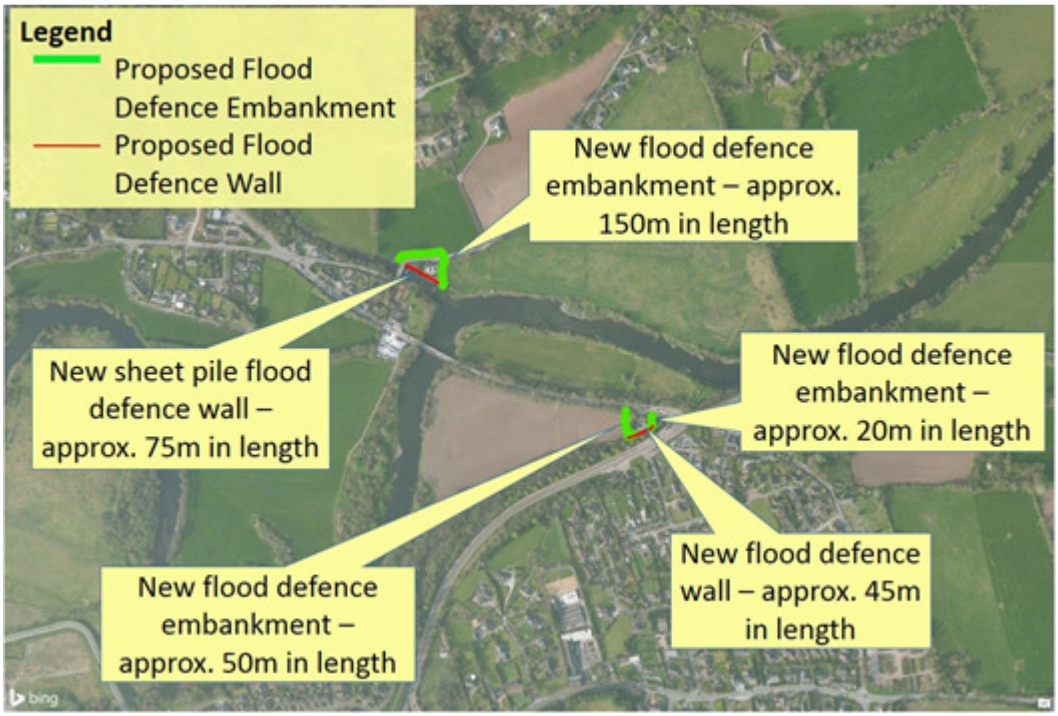


Figure 12: Defences at Inchaggagin

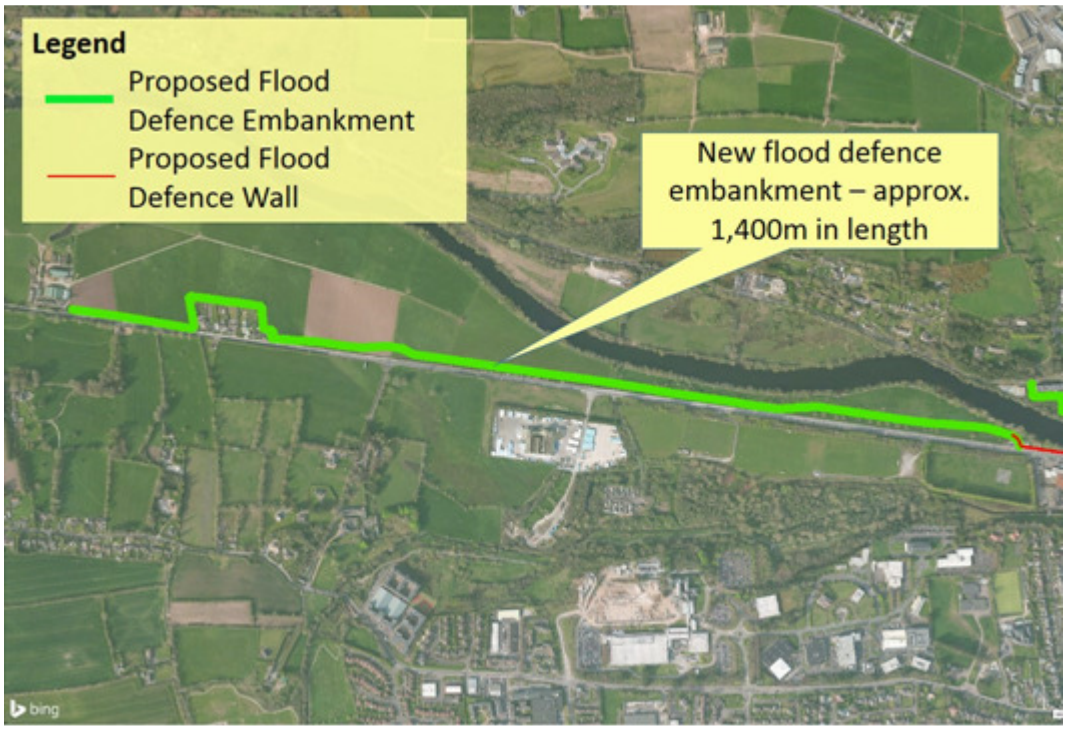
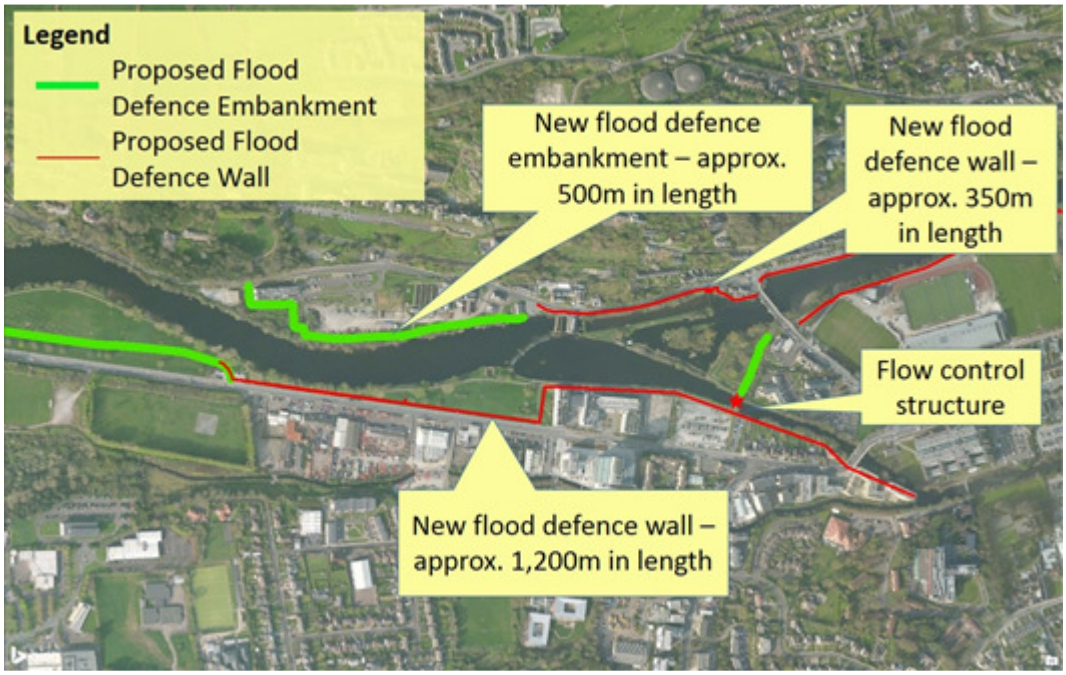


Figure 13: Defences at Kingsley/Sacred Heart/Lee Road



Flood risk associated with the baseline condition and Phase 1 is provided in Section 4.2.2 and 4.2.3 below.

4.2.2 Hydraulic Modelling - Baseline Condition

A number of baseline model runs were completed for the existing undefended scenario to compare against equivalent runs for the phased completion of the Lower Lee Flood Relief Scheme.

Table 1 below contains details of modelling runs 1 to 6, which represent the baseline condition of various fluvial conditions (Dam discharge and flow at waterworks weir) combined with the Medium High Water Spring (MHWS) tide or the 2 year tide.

Table 1: Details of baseline modelling runs

Run	Dam Discharge (m3/s)	Flow at Waterworks Weir (m3/s)	Curragheen (m3/s)	Glasheen (m3/s)	Tidal Level (m)	Comment
1	300	325	25.3	5.9	1.92	Baseline with MHWS
2	400	416	30.3	7.1	1.92	Baseline with MHWS
3	500	512	41.7	8.7	1.92	Baseline with MHWS
4	300	325	25.3	5.9	2.47	Baseline with 2-year tide
5	400	416	30.3	7.1	2.47	Baseline with 2-year tide
6	500	512	41.7	8.7	2.47	Baseline with 2-year tide

4.2.3 Hydraulic Modelling - Phase 1

In order to assess flood risk associated with Phase 1, a number of modelling runs were analysed for this interim phase of the works. Defences for this stage are illustrated in Figure 9 to Figure 13. Table 2 provides details of the model runs completed.

Table 2: Details of Phase 1 modelling runs

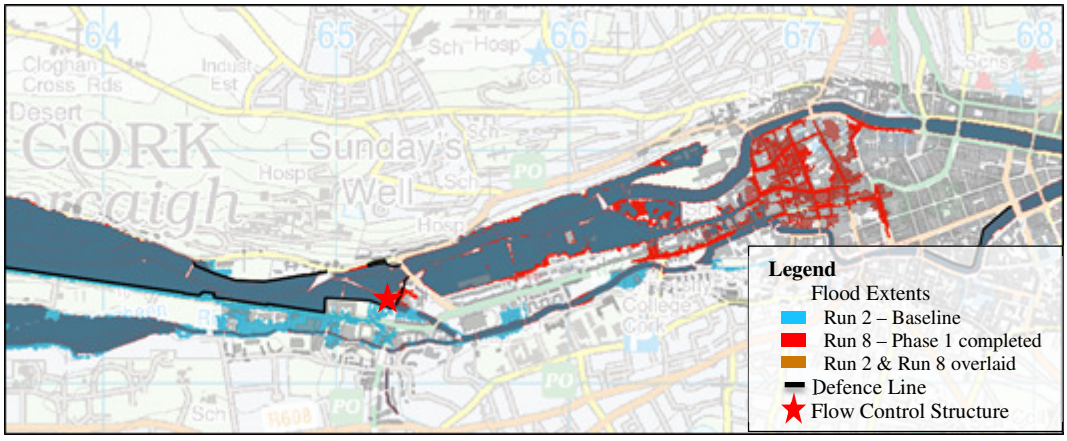
Run	Dam Discharge (m3/s)	Flow at Waterworks Weir (m3/s)	Curragheen (m3/s)	Glasheen (m3/s)	Tidal Level (m)	Comment
7	300	340	25.3	5.9	1.92	Phase 1 complete. Flow control structure closed, assuming Morrison's Quay also completed.
8	400	440	30.3	7.1	1.92	As Run 7 above
9	500	540	41.7	8.7	1.92	As Run 7 above
10	300	340	25.3	5.9	2.47	Phase 1 complete. Flow control structure closed,

Run	Dam Discharge (m3/s)	Flow at Waterworks Weir (m3/s)	Curragheen (m3/s)	Glasheen (m3/s)	Tidal Level (m)	Comment
						assuming Morrison's Quay not completed.
11	400	440	30.3	7.1	2.47	As Run 10 above
12	500	540	41.7	8.7	2.47	As Run 10 above
13	400	440	30.3	7.1	1.92	Phase 1 complete. Flow control structure opened, assuming Morrison's Quay also completed.
14	500	540	41.7	8.7	1.92	As Run 13 above

A tide level of 1.92m represents the MHWS condition and a tide level of 2.47m represents the 2-year tide.

Modelling results show that providing all of the measures listed in Section 4.2 and illustrated in Figure 9 to Figure 13 (including closing the flow control structure at the head of the South Channel), would see an increase in the flood extent from the North Channel in Cork City in comparison with the baseline condition at a discharge of 400m^3/s (runs 2 and 8). However, the flood risk on the South Channel is eliminated. Figure 14 illustrates this finding.

Figure 14: Maximum flood extents showing baseline and interim condition for Run 2 and Run 8 (400m^3/s MHWS)



There are a number of reason for this as follows:

- Increased flow in the North Channel due to flow path into Curragheen being blocked off.
- Increased flow in the North Channel due to the flow control structure at the head of the South Channel being closed.
- Decreased flow in the Curragheen and South Channel as a result of the above.

These model runs were for particularly high flows, in which case, it may not be appropriate to close the control structure on the South Channel if this results in flooding on the North Channel. However, in lower flows, it may be prudent to close this structure. In essence, it is prudent to construct the structure in Phase 1 as it provides options. However, the merits of opening or closing it will need to be carefully considered given the particulars of a given event.

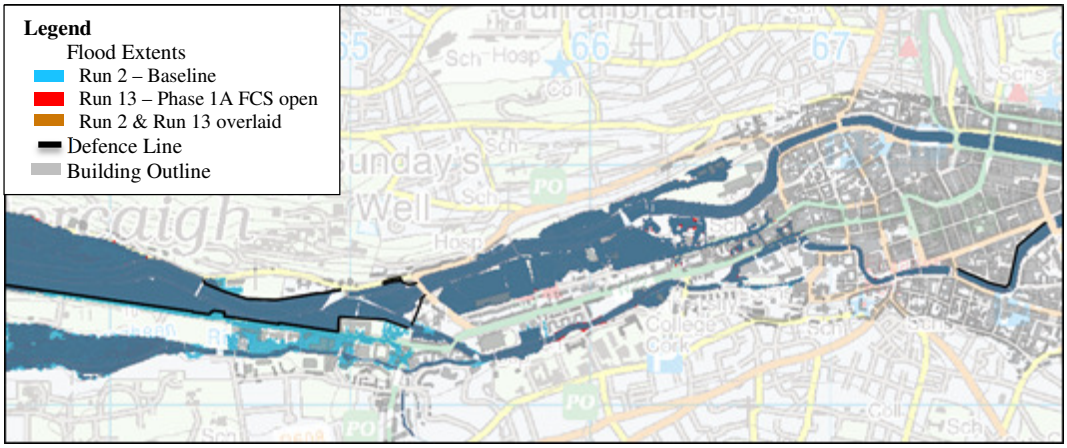
It should be further noted that Phase 1 will allow greater advance discharges which will reduce the peak flows and therefore, the flow reaching Waterworks Weir post the completion of Phase 1 will be less than in the existing case. However, as it is outside of the scope of this study to examine the statistical reduction in peak flow, it is not possible to directly compare the impacts of the same flood event in the pre- and post- situations.

Further analysis was therefore carried out with the aim of demonstrating that flood risk would not be worsened by the proposed phasing of the works.

A number of trial runs were tested and findings are outlined below.

The impact of leaving the flow control structure open with Phase 1 of the works in place was assessed using Run 13 and Run 14 as detailed in Table 2 and shown in Figure 15.

Figure 15: Maximum flood extents showing baseline and interim condition for Run 2 and Run 13 (400m^3/s MHWS)



Modelling results show that flood risk from the North Channel is largely unchanged for fluvial flows of 400m^3/s, whereas there is significant reduction in flooding on the Curragheen. This illustrates that the reduction in flow across the Carrigrohane Road feeding the Curragheen has a negligible impact on flood risk on the North Channel but significantly reduces flood risk on the Curragheen.

Whether to open or close the flow control chamber is therefore the critical question.

As confirmed by the recent December 2015 flooding, the limit of dam discharges before flooding occurs at Inniscarra is circa 200m^3/s - 220m^3/s with flooding in the city avoided, provided flows at Waterworks Weir are less than 350m^3/s when the tide is reasonable.

However, this results in flooding of the Carrigrohane Road and overflow into the Curragheen which caused some flooding to the rear of County Hall etc.

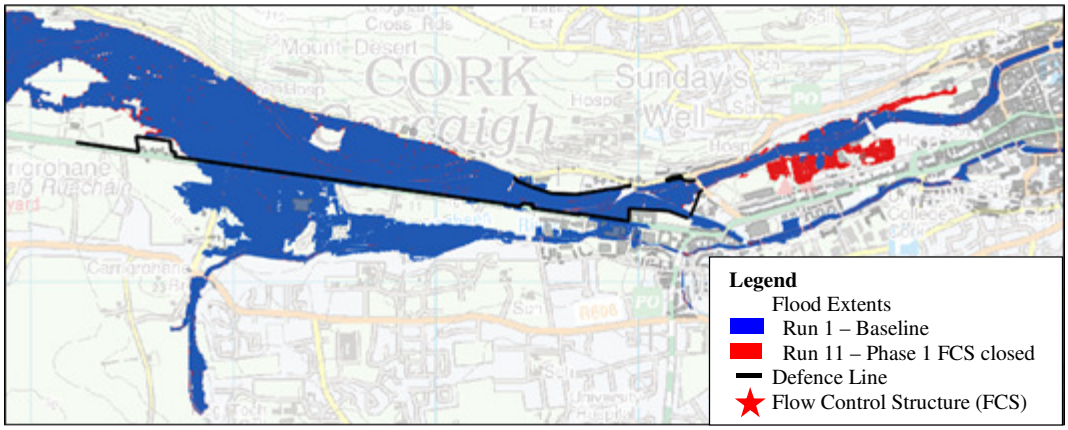
In essence, the ESB's current maximum advance discharge is limited to circa 200m^3/s because of the risk of flooding properties in Inniscarra. By constructing the Phase 1 works, these properties are protected, which means that the advance dam discharge can safely be increased to circa 350m^3/s less the flow in the downstream tributaries.

In advance of the flood event, the flow in the tributaries may be very moderate, meaning that it is quite probable that discharges up to 300m^3/s may be possible without causing flooding. This increase of up to 100m^3/s would be extremely beneficial in attenuating extreme events.

Figure 16 below illustrates the flood extents for a discharge of 300m^3/s from the dam with a low contribution of circa 25m^3/s from the downstream tributaries giving a flow of circa 325m^3/s at Waterworks weir. The run of the post scheme works show an increase in flood extents in the vicinity of the Mardyke/Fitzgerald's Park (because the flow control structure is shut) but this does not result in any flooding of buildings.

The above assumed a tidal level of a MHWS tide. If a 2 year tide was present, the safe flow (i.e. resulting in no flooding of buildings) at Waterworks Weir would reduce somewhat.

Figure 16: Maximum flood extents showing baseline and interim condition for Run 1 and Run 11 (300m^3/s MHWS)



4.3 Phase 2 - Thomas Davis Bridge to Bachelor's Quay West

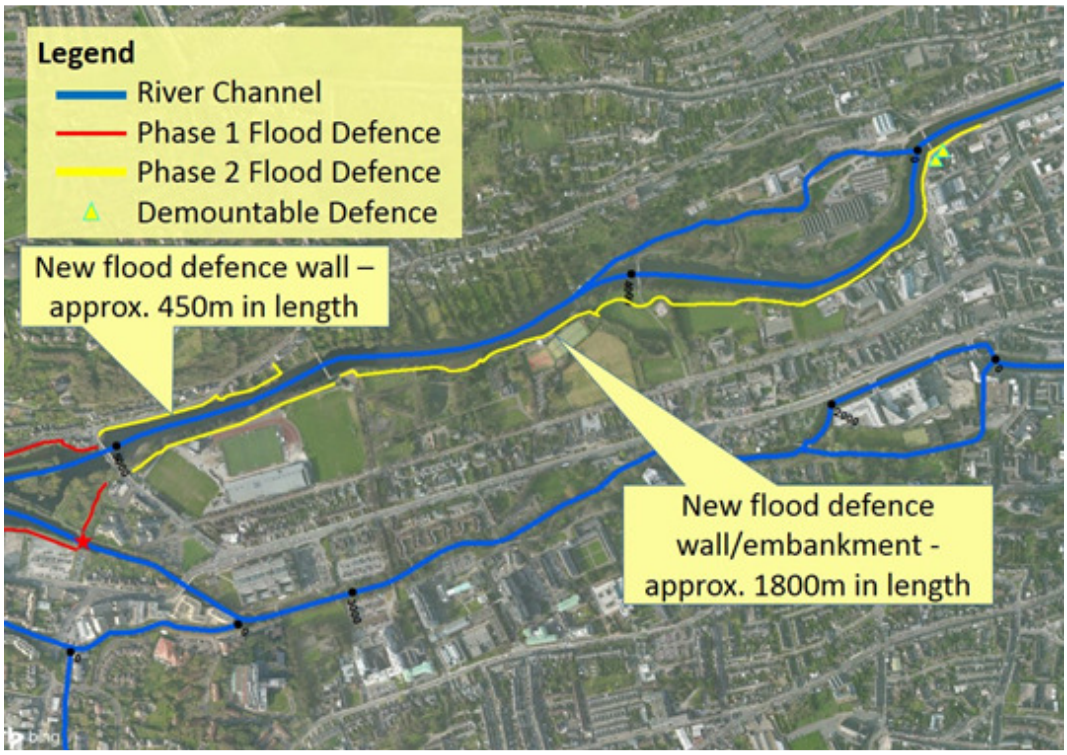
Increasing dam discharges to more than 300m^3/s would likely result in flooding of areas along the Mardyke Walk. Extending the defences further east along the North Channel would allow a further increases in safe discharges from the dam.

As a result defences between Thomas Davis Bridge and Bachelor's Quay West were considered as Phase 2.

Figure 17 provides an overview of the defences from Thomas Davis Bridge to Bachelor's Quay West. Cost for these defences are estimated at a capital cost of €17.8 Million and consist of the following direct defences and demountable defences in the following areas:

- Sunday's Well Rd
- Mardyke Sports Ground Wall
- Fitzgerald's Park
- Tennis Club/Cricket Club
- Presentation College
- Tyndall Institute
- Grenville Place
- Bachelor's Quay West

Figure 17: Defence lines between Thomas Davis Bridge and Bachelor's Quay West



4.3.1 Hydraulic Modelling - Phase 2

A number of model runs were set-up to assess the flood risk following completion of Phase 1 and 2 as illustrated in Table 3.

Table 3: Details of Phase 2 modelling runs

Run	Peak Reservoir Discharge (m3/s)	Flow at Waterworks Weir (m3/s)	Curragheen (m3/s)	Glasheen (m3/s)	Tidal Level (m)	Comment
15	400	440	30.3	7.1	1.92	Phase 1 and 2 completed. FCS open
16	500	540	41.7	8.7	1.92	As above
17	400	440	30.3	7.1	2.47	As above
18	500	540	41.7	8.7	2.47	As above

Completion of Phase 1 and 2 would facilitate dam releases of up to 400m^3/s or 440m^3/s at Waterworks Weir, without causing flooding. This compares to approximately 300m^3/s following completion of Phase 1 only.

This can be seen in Figure 18 below. We note that this includes a T2 (2 year) tide meaning that a higher flow could be released for the majority of the tidal cycle.

Figure 18: Maximum flood extents showing baseline and interim condition for Run 5 and Run 11 (400m^3/s T2 with and without Phase 1 and 2 defences)

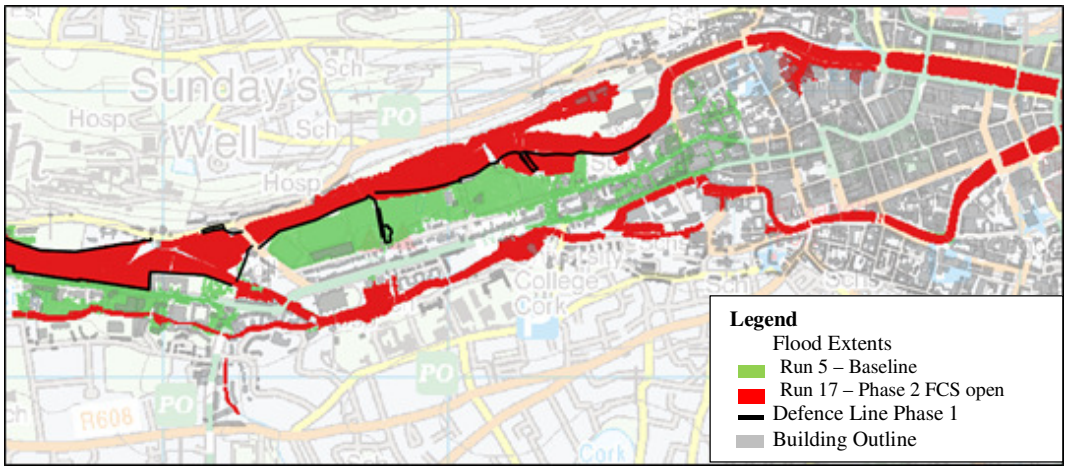
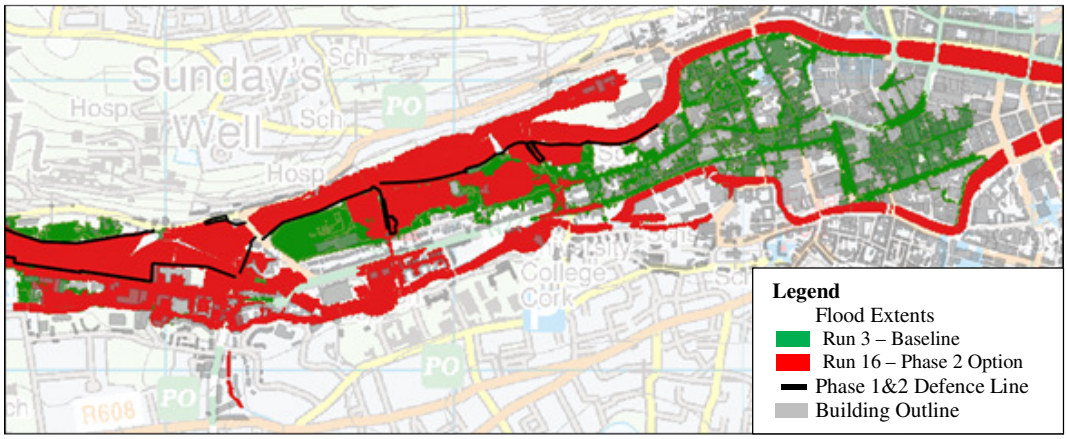


Figure 19 illustrates that after completion of Phase 1 and 2, flows at Waterworks Weir of circa 540m^3/s (approximately 1 in 100year design flow), whilst resulting in flooding when in combination with a 2 year tide, would result in significant reduction of flooding in the main commercial part of the city centre.

Figure 19: Maximum flood extents showing baseline and interim condition (Phase 1 and 2) for Run 3 and Run 16 (500m^3/s MHWS with and without Phase 1 and 2 defences)



Modelling results show a significant reduction in flood risk during this event without negative impact. The number of properties at risk from flooding reduces from 105 properties for the baseline condition to 26 properties during this scenario.

There are some areas that remain potentially at flood risk following completion of Phases 1 and 2, and these are located along the downstream reach of the Curragheen and the upper section of the South Channel, but only in a scenario where the flow regulation structure is not closed.

There is however a substantial reduction in the number of properties at flood risk. For the Baseline Scenario there are 673 number of properties at fluvial flood risk. This reduces to circa 36 properties at fluvial flood risk following completion of Phase 1 and 2. This occurs because the flow control structure has been modelled as being opened in these higher flow interim events.

Careful management of the flow regulation structure based on the particulars of a given event could further reduce the numbers of affected properties.

Please refer to Section 5.1 and 5.1.1 for more detail on the operation of the flow regulation structure.

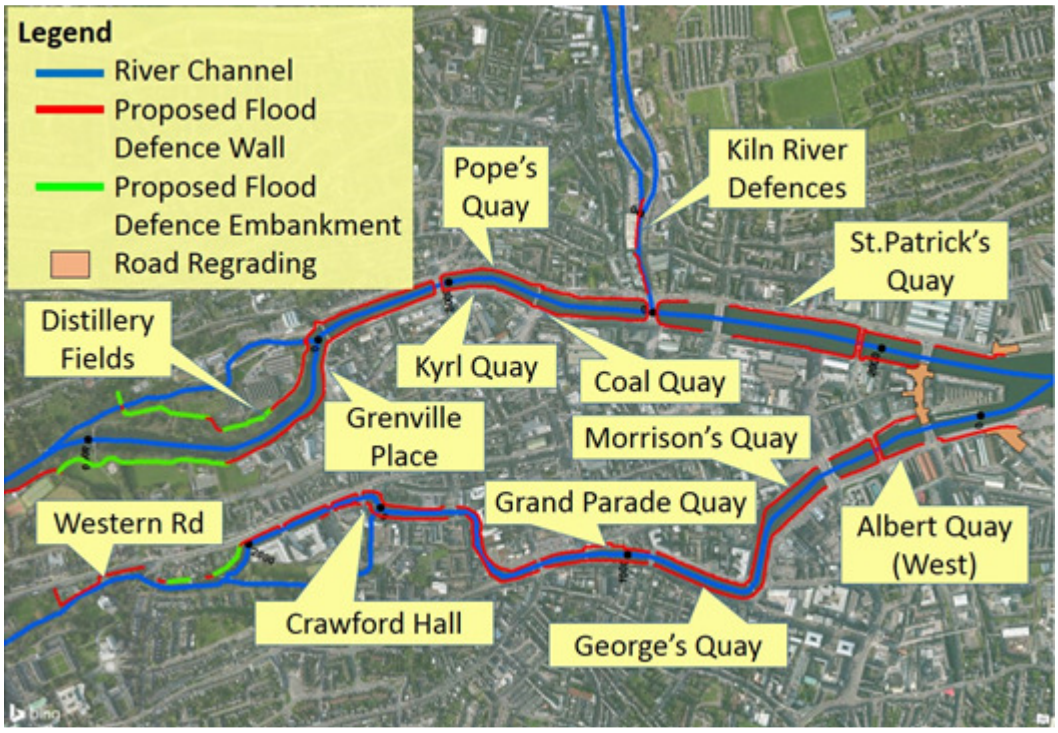
Remaining flood risk to Cork Central Island is mainly associated with tidal flooding and this is discussed in the following section.

4.4 Cork Central Island

The area of Cork Central Island is associated with the highest population density, highest commercial value, and also with the highest capital spend of the Lower Lee (Cork City) Drainage Scheme.

The proposed defences for the Central Island are illustrated in Figure 20 below.

Figure 20: Proposed flood defence works



The level of flood risk was assessed in order to prioritise works for the various sections of quays and embankments with the aim of providing defences to the most at risk areas first.

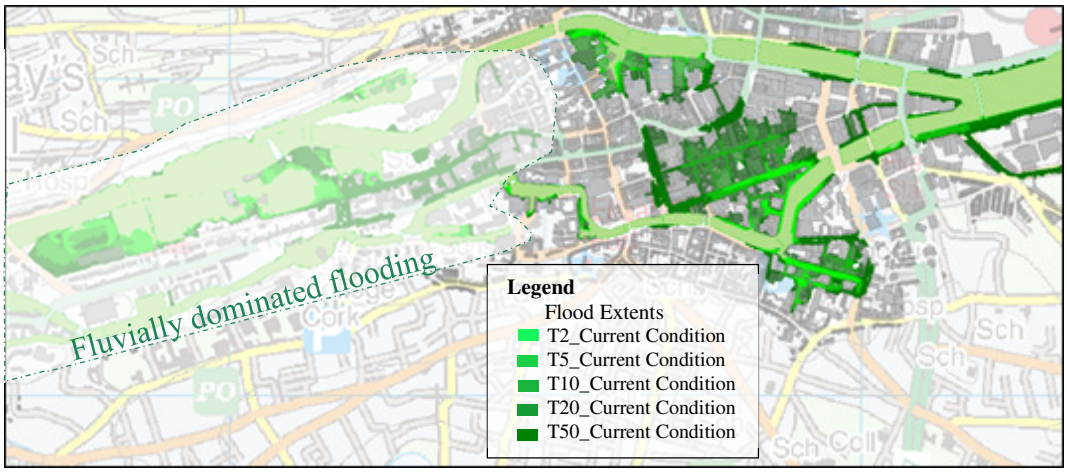
This was done by comparing the number of properties at risk for a range of return periods for both the tidal and fluvial flood risk.

Figure 21 presents the corresponding flood extents for tidally dominated runs with return periods from 2 years to 50 years.

This assessment was carried out with Phase 1 and 2 defences in place for the fluvially dominated events. However, when assessing tidal flood risk, current flood maps were used.

This approach was adopted in order to reduce the number of modelling runs required but it is also considered appropriate as Phase 1 and 2 defences would only have a marginal influence on tidally affected areas.

Figure 21: Flood extents for tidally dominated runs in the current condition



The flood extents shown in Figure 21 show that there are a number of areas affected depending on the severity of the event.

In order to prioritise the various areas, the number of properties at flood risk were identified for both tidally and fluvially dominated events for increasing return periods as shown in Table 4.

Table 4: Number of properties at flood risk

Return Period	Defences/ Embankments	Properties at Flood Risk following Phase 1	
		Tidal Event**	Fluvial Event
2	Kyrl's Quay/Coal Quay	9	0
2	Crawford Hall/Crosses Green*	6	0
5	Kyrl's Quay/Coal Quay	19	0
5	Crawford Hall/Crosses Green*	7	0
5	UCC Lower Grounds Wall	2	0
10	Morrison's Island	56	0
10	Kyrl's Quay/Coal Quay	27	0
10	George's Quay/ Union Quay	12	0
10	Crawford Hall/Crosses Green*	8	0
10	UCC Lower Grounds Wall	2	0
20	Morrison's Island	160	0
20	Kyrl's Quay/Coal Quay	38	0
20	George's Quay/Union Quay	22	0
20	Crawford Hall/Crosses Green*	8	0
20	UCC Lower Grounds Wall	2	2
20	Lee Distillery Branch	0	2
50	Morrison's Island	253	0

Return Period	Defences/ Embankments	Properties at Flood Risk following Phase 1	
		Tidal Event**	Fluvial Event
50	Kyrl's Quay/Coal Quay	54	0
50	George's Quay/Union Quay	35	0
50	Crawford Hall/Crosses Green*	12	0
50	Lapp's Quay	2	0
50	UCC Lower Grounds Wall	3	3
50	Lower Reach of Curragheen	0	15
50	Upper Reach of South Channel	0	14
50	Lee Distillery Branch	0	2
50	Carrigrohane Bridge	0	2
50	UCC/Mardyke Walk	0	1
* Number of properties estimated manually ** Current flood maps were adopted.			

Results show that following the completion of Phase 1 and 2, the majority of properties are at risk from tidal flooding rather than fluvial flooding.

There is also a clear pattern suggesting that the majority of properties at flood risk are associated with Morrison's Island, which is proposed to be advanced separately to the main contract via a Part 8 planning process.

The area of Kyrl's Quay/Coal Quay is second in terms of numbers of properties at risk, George's Quay is third with Crawford Hall/ Crosses Green fourth.

It is only during the 20 year return period events or higher that areas are shown to be at fluvial flood risk.

It is also important to note that the standard of protection at George's Quay can be raised to the 20 year tidal event by providing demountable defences locally at Trinity Bridge, which connects Morrison's Island to South Terrace/ George's Quay.

It is therefore recommended to include provision for demountable defences with the advance contract for Morrison's Island. An alternative to the provision of demountables could be local road raising along Union Quay and this could be combined with road works proposed in the area associated with the redevelopment of the old Brooks Haughton site.

Flooding in the area of the UCC Lower Grounds Wall (see Figure 21 and Figure 20) is associated with the fluvial component of the tidally dominated event. This area is protected if the flow control structure is fully operational.

The following sections detail the assessment and works for the relevant areas following completion of Phase 1.

4.4.1 Morrison's Island (Advance Contract – Phase 0)

Flooding of buildings at Morrison's Island typically occurs as a result of tidal flooding. Cork City Council has expressed a strong preference for prioritising flood defence works in this area, as this would defend against the vast majority of the typical tidal floods in Cork City. Works in this area consist of the following:

- Direct defences at Morrison's Quay
- Direct defences at Father Matthew Quay
- Local works to south of Trinity Footbridge

The cost of these works is estimated at €4 to €5 Million (ex VAT). (This is for the basic solution presented at the Emerging Preferred Option PID and excludes any potential betterment works/public realm improvements which may be incorporated by CCC as part of the Part 8 process).

A review of flood characteristics in this area shows that provision of defences for Morrison Island would not cut-off any significant beneficial escape routes for flood waters and would provide a significant reduction in the number of properties at tidal flood risk. There is also an opportunity to combine flood defence works at Morrison's Quay with the proposed public realm improvement works in that area. Further detail is provided in Section 4.4.1.1 below.

Figure 22 presents proposed defence lines for Morrison's Island consisting of direct defences at Morrison's Quay and Father Matthew Quay and demountable defences on Trinity Bridge.

Figure 22: Defence lines for Morrison's Island

4.4.1.1 Flood Risk at Morrison's Island – Interim Condition

As noted previously, Morrison's Island is one of the most frequently affected areas in Cork City in terms of tidal flooding, and there is a strong desire to prioritise defences for this area.

Model Runs 15 and 16 were set-up to test the impact of providing defences at Morrison's Island in parallel with Phase 1 and 2 works as outlined in Section 4.2 and Section 4.3 above.

Both of these runs also contain a significant fluvial component. Run 17 to Run 20 were then set-up to assess the impact of defences at Morrison's Island during a range of tidal events, without Phase 1 and 2 works in place, to test for any significant interdependency.

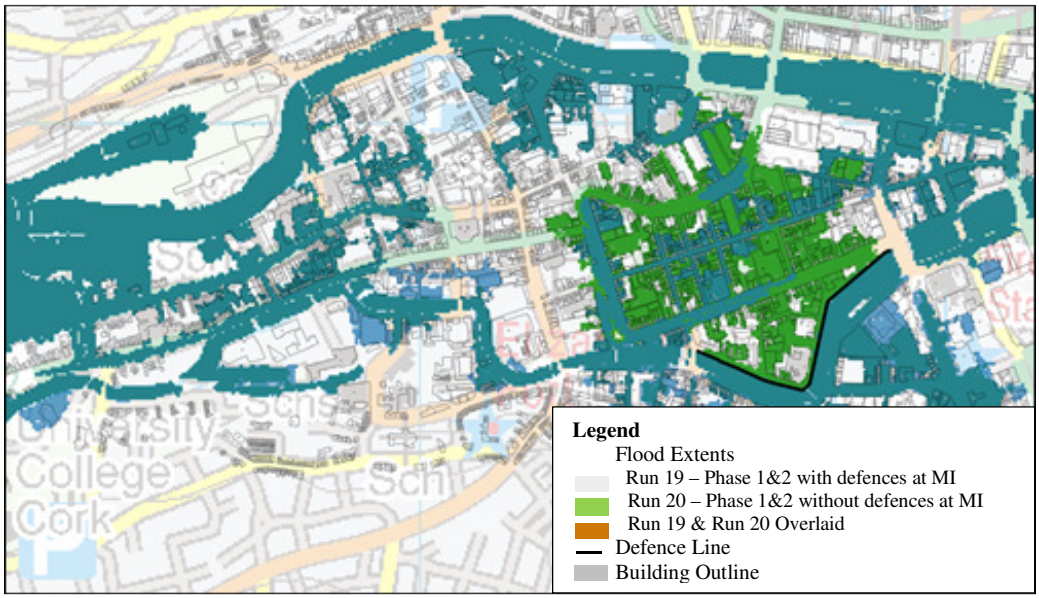
Details of the various runs are presented in Table 5 below.

Table 5: Details of modelling runs assessing the impact of defences at Morrison's Island

Run	Dam Discharge (m3/s)	Curragheen (m3/s)	Glasheen (m3/s)	Tidal Level (m)	Comment
19	250	30.3	7.1	2.91 (T100)	Phase 1 and 2 in place and with defences at Morrison's Island
20	250	30.3	7.1	2.91 (T100)	Phase 1 and 2 in place without defences at Morrison's Island
21	80	8.9	2	2.58 (T5)	Defences at Morrison's Island only
22	80	8.9	2	2.65 (T10)	Defences at Morrison's Island only
23	80	8.9	2	2.72 (T20)	Defences at Morrison's Island only
24	80	8.9	2	2.81 (T50)	Defences at Morrison's Island only
25	80	8.9	2	2.91 (T100)	Defences at Morrison's Island only

Figure 23 presents results for Run 19 and Run 20 and Figure 24 presents results for Run 17 to 21.

Figure 23: Maximum flood extents showing baseline and interim condition for Run 19 and Run 20 (Q250m^3/s & T100 with and without Morrison's Quay)



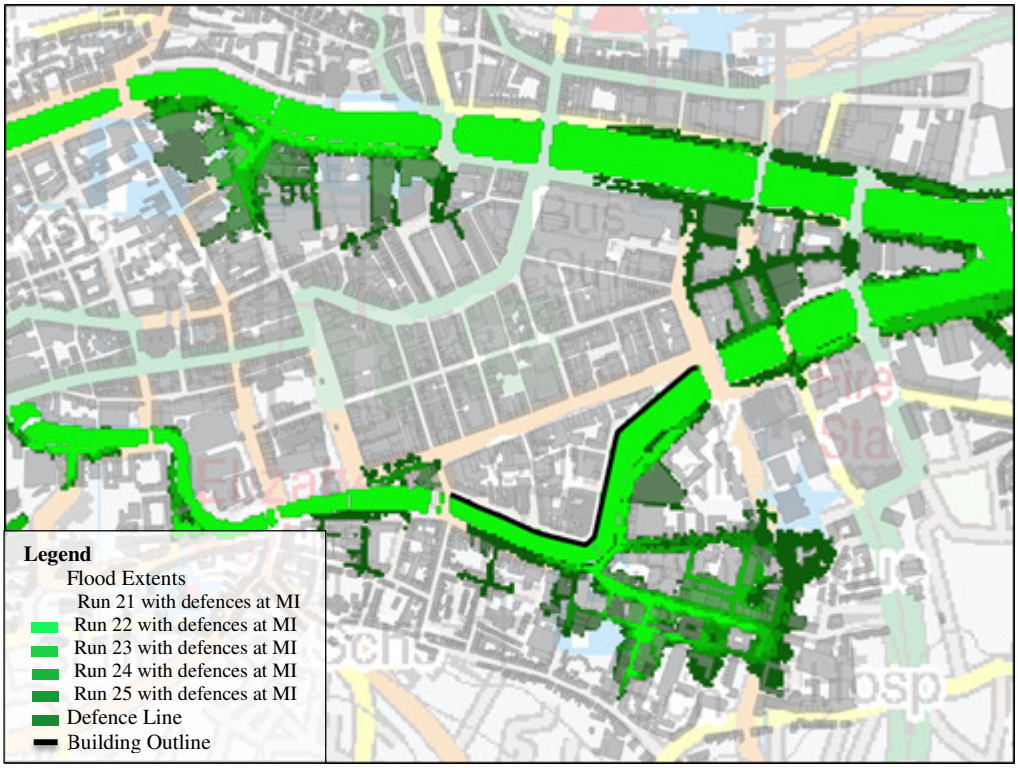
Analysis of modelling results suggest that there is a reduction of 261 in the number of properties at risk from flooding during this extreme event.

The total number of properties reduce from 688 to 427 without and with defences at Morrison's Island, respectively.

It should be noted that the above model runs contain a very significant discharge from the dam of 250m^3/s.

This would not be typical of major tidal events in the city and therefore the benefits of the defences at Morrison's Island were tested further for the more likely scenario of circa 80m^3/s discharge from the dam, i.e. only turbine in operation. The findings are shown in Figure 24 below.

Figure 24: Maximum flood extents showing interim condition for tidal flooding (Run 21 to Run 25 with Morrison's Quay)



It should be noted that Morrison's Island is a tidal floodplain and providing defences for Morrison's Island will reduce this floodplain. Flood levels will increase locally, which has the potential for an increase in flood levels (and thus extents) upstream along the South Channel.

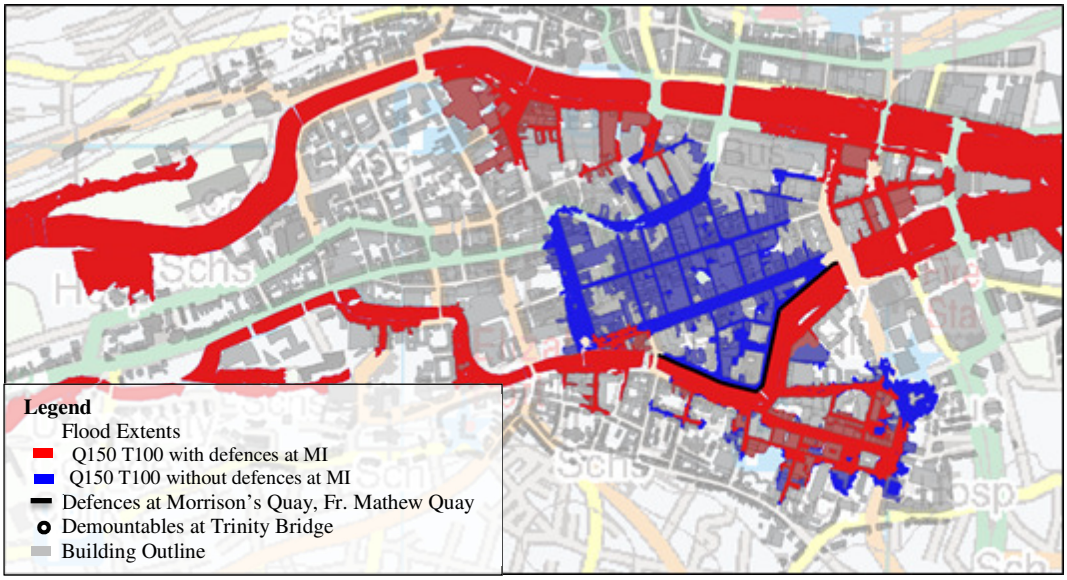
The tidal momentum, which in the existing condition would dissipate to some degree at Morrison's Island, may be forced further up the channel which could increase levels and result in a number of additional at-risk-areas (as shown in Figure 23 as light-blue).

This phenomenon was noted when including the high dam discharge of 250m^3/s. It is important to note however that this event represents an extreme condition consisting of the 100 year tide in combination with a dam release of 250m^3/s and so is highly unlikely.

This phenomenon was not observed when reducing the dam discharge to 150m^3/s or less and the number of properties at flood risk reduce from 488 to 114.

Figure 25 presents a comparison of maximum flood extents for these two scenarios.

Figure 25: Maximum flood extents for the 150m^3/s Discharge/T100 modelling runs with and without defences at Morrison's Island



Overall there is a very significant reduction in the number of properties at flood risk following the advancement of defences at Morrison's Island.

4.4.2 Trinity Bridge

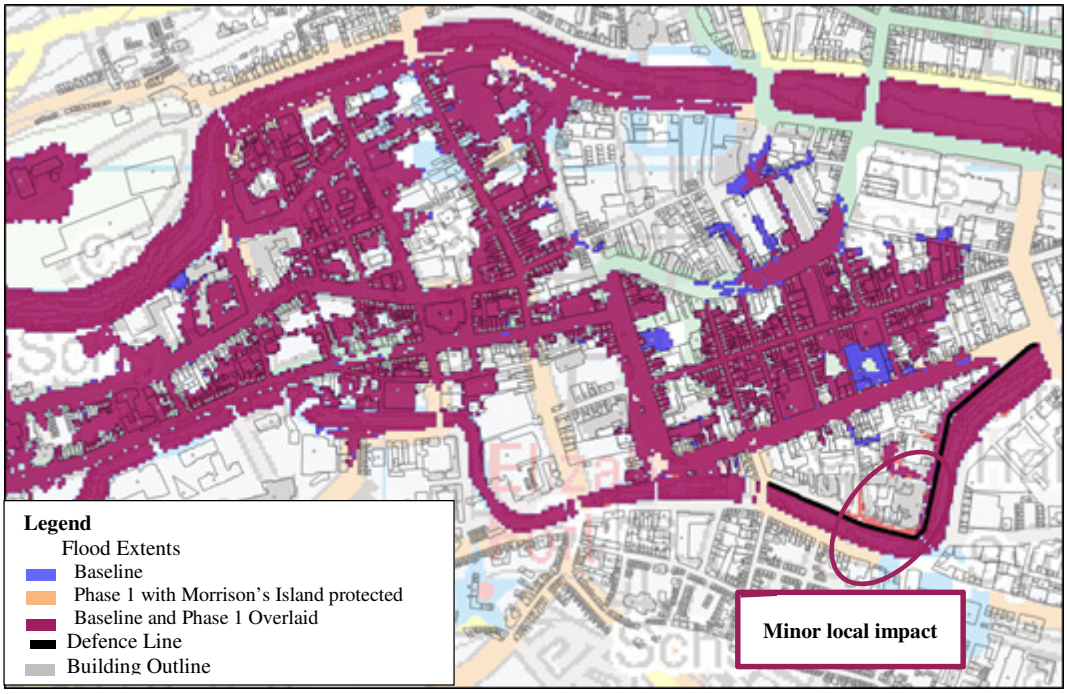
Trinity Pedestrian Bridge connects Morrison's Island and George's Quay. Upgrade works to Trinity Bridge in the form of demountable defences would protect the at-risk properties up to the 20 year return period. It is therefore recommended to include provision of demountable defences for both sides of Trinity Bridge as part of the works for Morrison's Island Advance Contract. An alternative could be the raising of local road level along Union Quay as this could be combined with road works in this area.

Figure 26: Trinity Bridge

4.4.3 Overland Flood Flow Routes

There is also a potential risk that defences at Morrison's Island could cut-off existing overland flood routes during extreme fluvial events and this was assessed by comparing Run 3 and Run 14, results of which are presented in Figure 27 below.

Figure 27: Maximum flood extents showing baseline and interim condition for baseline condition (Run 3) and Phase 1A with Morrison's Island Protected (Run 9) (Q500MHWS)



Modelling results show that providing defences at Morrison's Island would protect large areas of the Central Island from tidal flooding with only minor local impact during extreme fluvial events. This impact would not flood properties and would easily be dealt with by the provision of proposed surface water pumping stations as part of the Morrison's Island Contract.

4.5 Phase 3 Works

4.5.1 Phase 3 - Kyrl's Quay/Coal Quay

There are a number of gaps along both Kyrl's Quay and Coal Quay, which results in this area being at risk from flooding during the 2 year return period for tidal events. Figure 28 is a view of Kyrl's upstream of Cornmarket Street Bridge. Please refer to Figure 20 for a location plan.

Figure 28: View of Kyrl's Quay (Google Street View)

The number of properties at-risk from flooding in this area increases from 9 to 19 and 27, for the 2, 5 and 10 year return period tidal events respectively (see Table 4).

Due to the low threshold of flooding, it is recommended that works at Kyrl's Quay and Coal Quay be prioritised following completion of tidal defences at Morrison's Island. The works in this area consist of the following measures:

- New parapet construction on existing quay walls
- Demountable defences to pedestrian bridge
- Bridge parapet raising/strengthening

4.5.2 Phase 3 – Crosse's Green to Crawford Hall

There are an additional two areas along the South Channel, which are at significant flood risk during the 2 year tidal event or higher and these are located along Crawford Hall and Crosse's Green Quay as shown in Figure 23 and Figure 24. In each of these areas, there are 6 to 8 properties at flood risk and these areas should therefore also be prioritised following completion of Morrison's Island.

Figure 29 shows the existing defences at Crawford Hall.

Figure 29: View of existing defences at Crawford Hall

The works in this area consist of new parapet construction and remediation / replacement of existing quay walls.

As Wandesford Quay is between these two quays, it will be included in this phase.

4.5.3 Phase 3 - George's Quay and Union Quay

Providing demountable defences at Trinity Bridge (Figure 32) as part of the advanced works during the provision of works for Morrison's Island would increase the standard of protection in the existing condition from 5 years to 20 years.

Providing defences along George's Quay and Union Quay would protect an extensive area south of Cork Central Island with 35 properties at tidal flood risk during the 50 year return period.

The works in this area consist of new parapet construction and remediation of existing quay walls.

4.5.4 Phase 3 - Miscellaneous Additional Areas Misc

There are two additional areas with 2 to 3 properties at risk from flooding during the 10, 20 and 50 year return period as shown in Table 4 and these are located at:

- Lee Distillery Branch
- Lapp's Quay

Each of these areas could be included in subsequent phases of the works, however providing defences as part of Phase 3 would alleviate flood risk in these areas between 3 to 5 years earlier (see Figure 8) and this is discussed in the following sub-sections.

4.5.4.1 Lee Distillery Branch

The proposed works at the Lee Distillery Branch consists of works such as; Lee Distillery Branch Embankment, IDL Flood Defence Wall and IDL Mill Race Outfall. Figure 30 presents a view from St Vincent Bridge.

Figure 30: View of Lee Distillery Branch at St Vincent's Bridge

Providing defences in this area would be a continuation of Phase 2 defences along the fluvially dominated reach of the North Channel and thus provide a dual benefit.

Wise's Quay will also be included in this phase of works as it is directly adjacent to this area.

4.5.4.2 Lapp's Quay

The works along Lapp's Quay consist of new parapet and remediation of an existing quay wall. Figure 31 presents a view from Clontarf Bridge.

Figure 31: View of Lapps Quay West at St Vincent's Bridge from Clontarf Bridge

Flood risk in this area is associated with the 50year tide event. Providing defences in this area would be a continuation of the defences provided for Morrison's Island and these would protect 2 properties during the 50 year tidal event.

There are no significant negative impacts associated with prioritising defences at Lapp's Quay. This is because Lapp's Quay is located in a tidal flood risk area, the floodplain of which is considered to be relatively small.

4.5.5 Phase 3 Summary

As mentioned above, the works west of Thomas Davis Bridge and defences between Thomas Davis Bridge and Bachelor's Quay West will be provided in the initial phases.

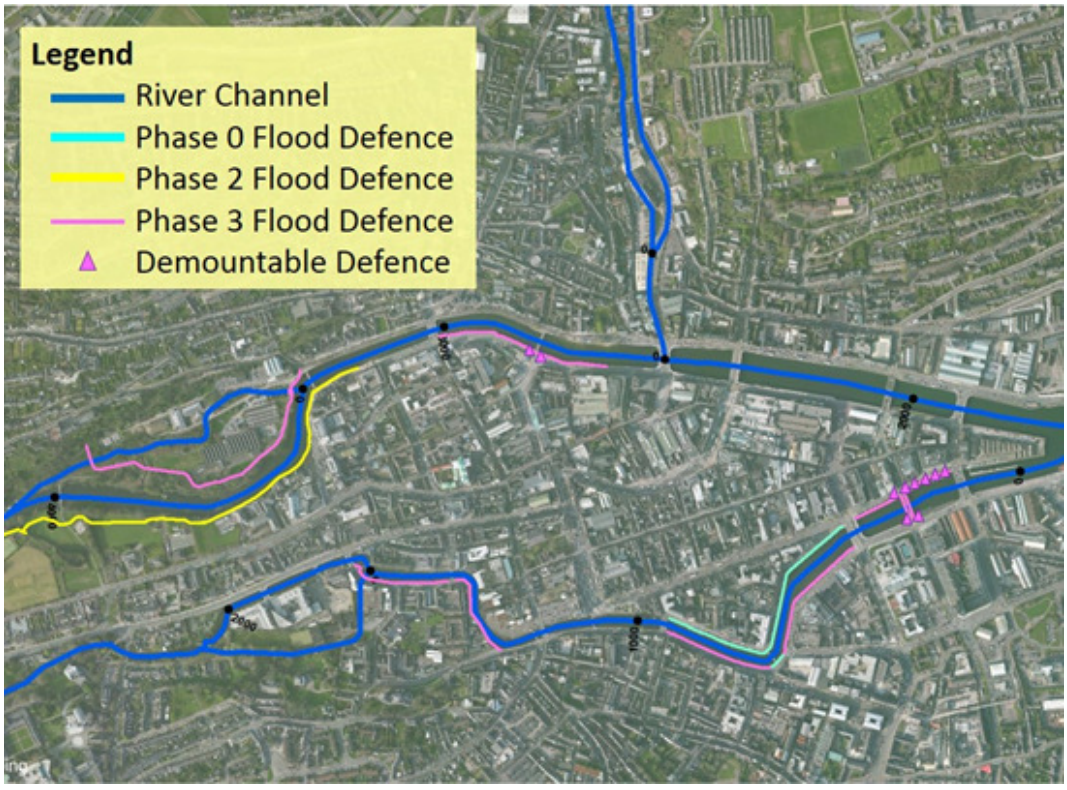
Morrison's Island is likely to be advanced outside of the main contract once funding is secured.

Once these works are complete, the most at-risk areas at Cork Central Island will be prioritised, as detailed in Section 4.5 and works will be combined in a phased manner, taking into account annual budget constraints as outlined in Section 4.1. Figure 32 and located at:

- Lee Distillery Branch
- Wise's Quay
- Kyrl's Quay
- Coal Quay
- Crawford Hall
- Wandesford Quay
- Crosse's Green Quay
- George's Quay
- Union Quay
- Lapp's Quay

The total capital cost for these areas is estimated at €10.8 Million. This includes direct defences and demountable defences at Kyrl's Quay/ Coal Quay and six sections of demountable defences at Lapp's Quay.

Figure 32: Defence lines and demountables – Phase 3



In order to reduce flood risk further, flows into the South Channel would have to be reduced and diverted into the North Channel.

This would only be achievable once flood defence along the North Channel are provided. It is therefore proposed to next prioritise works along the North Channel as Phase 4, which is detailed in the following section.

4.6 Phase 4 - North Channel Central Island

Once the discrete lengths of defences along the most at risk areas of the Central Island are completed during Phase 3, it is proposed that the remaining defences along the North Channel then be prioritised.

This is a priority over the remaining defences on the South Channel because it will provide protection against both tidal and fluvial flooding and will allow the final implementation of the Dam Optimisation and will allow the design fluvial flood event to be passed.

It will also allow full operation of the flow control structure which will then have the benefit of significantly reducing the flood risk along the Curragheen and the South Channel.

Phase 4 consist of works along numerous quays along the North Channel of Cork Central Island. Figure 33 presents the proposed defence lines.

Figure 33: Defence lines North Channel Central Island East – Phase 4

The remaining Phase 4 Direct Defences at Central Island East (south of North Channel) consist of works at:

- Custom House Street Regrading
- Anderson's Quay (East)
- Anderson's Quay (West)
- Merchant's Quay

- Lavitt's Quay (East)
- Bachelor's Quay East

The remaining Phase 4 Direct Defences Central Island East (north of North Channel) consist of works at:

- Penrose's Quay (East)
- Penrose Quay (East) Road Regrading at east end
- Penrose's Quay (West)
- St Patrick's Quay
- Kiln River
- Camden Place
- Pope's Quay (East)
- Pope's Quay (West)
- North Mall

The total capital cost for these areas is estimated at €15.7Million.

4.6.1 Modelling of Flood Risk following Phase 4

A number of runs were set-up to assess the flood risk following completion of Phase 4 and details are provided in Table 6.

Table 6: Details of Phase 4 modelling runs

Run	Peak Reservoir Discharge (m3/s)	Flow at Waterworks Weir (m3/s)	Curragheen (m3/s)	Glasheen (m3/s)	Tidal Level (m)	Comment
26	400	440	30.3	7.1	1.92	Phase 4 complete. FCS open
27	500	540	41.7	8.7	1.92	Phase 4 complete. FCS open
28	400	440	30.3	7.1	1.92	Phase 4 complete. FCS half open
29	500	540	41.7	8.7	1.92	Phase 4 complete. FCS half open

In order to provide an indication of the influence of the flow control structure (FCS), two different opening settings were selected, which are FCS open and FCS half closed.

Modelling results are presented in Figure 34 and Figure 35 below show a comparison of the baseline condition in comparison to the interim condition with Phase 1, 2, 3 and 4 defences in place.

Figure 34: Maximum flood extents showing baseline and interim condition (Phase 4) for Run 2 and Run 28 (Q400MHWS with and without Phase 1, 2, 3 and 4 defences)

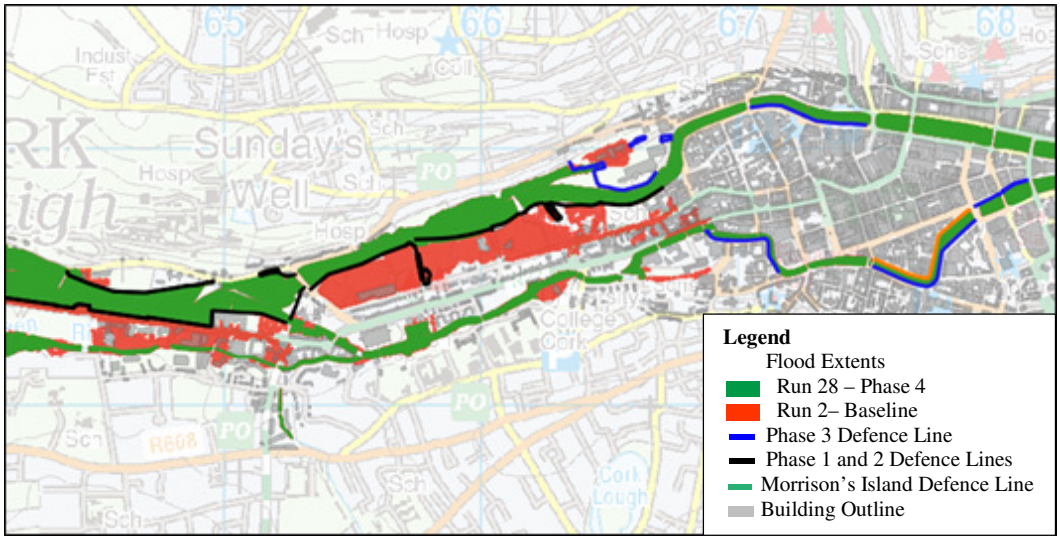
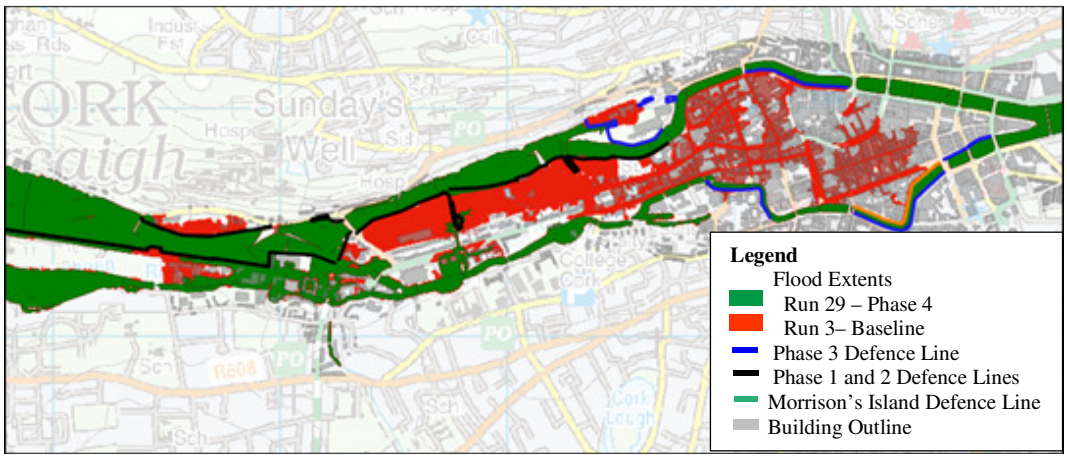


Figure 35: Maximum flood extents showing baseline and interim condition (Phase 4) for Run 3 and Run 29 (Q500MHWS with and without Phase 1, 2, 3 and 4 defences)



Modelling results of the 540m3/s run shows flooding along the lower section of the Curragheen and upper section of the South Channel with 16 properties at flood risk during this scenario.

This is due to the FCS only being half open during this run, which results in elevated water levels in the South Channel and causing flooding along the lower section of the Curragheen during this extreme event.

Closing the FCS completely will reduce water levels along the South Channel and thereby reduce flood levels along the Curragheen. Further information on the operation of the flow control structure is presented in Section 5.1 below.

4.7 Phase 5 - South Channel Central Island

Eliminating cross catchment flows from the Lower Lee into the Curragheen and South Channel as proposed under Phase 1 will significantly reduce fluvial flood risk along the upper and middle sections of the South Channel.

Flood risk will be further reduced once the flow control structure is fully operational, which is when defences along the North Channel are provided as part of Phase 4 of the works.

The remaining flood risk associated with the South Channel correspond to extreme events from the Curragheen, Glasheen, Shournagh and Bride rivers as well as tidal flood risk along the lower reach.

Figure 36 presents the proposed defence lines for Phase 5 of the works.

Figure 36: Defence lines South Channel Central Island – Phase 5

Phase 5 consists of works in the following areas:

- Victoria Road Regrading
- Albert Quay (East)
- Albert Quay (West)
- Terence MacSweeny Quay
- Sullivan's Quay
- French's Quay
- South Mall Properties
- Grand Parade Quay
- Dún Mhuire
- City Car Park
- Beamish and Crawford Yard
- Beamish and Crawford
- Beamish and Crawford Kegging
- Wandesford/Hanover St Properties
- Labour Exchange
- Waterside Quay
- Fisherman's Wharf
- Lancaster Quay
- Western Rd Former Petrol Station
- Inniscarrig Terrace
- Western Road

- Lancaster Lodge Quay

The total capital cost for these areas is estimated at €16.8 Million.

There may also be an opportunity to combine flood defence works at Albert Quay East with the proposed contra-flow bus lane and Albert Quay West with the proposal to reconstruct quay wall (funding not yet secured).

Also, works at Beamish and Crawford Site could be combined with the proposed Cork Events Centre to provide efficiency in terms of mobilisation and reducing disruption to the area (see Section 5.1).

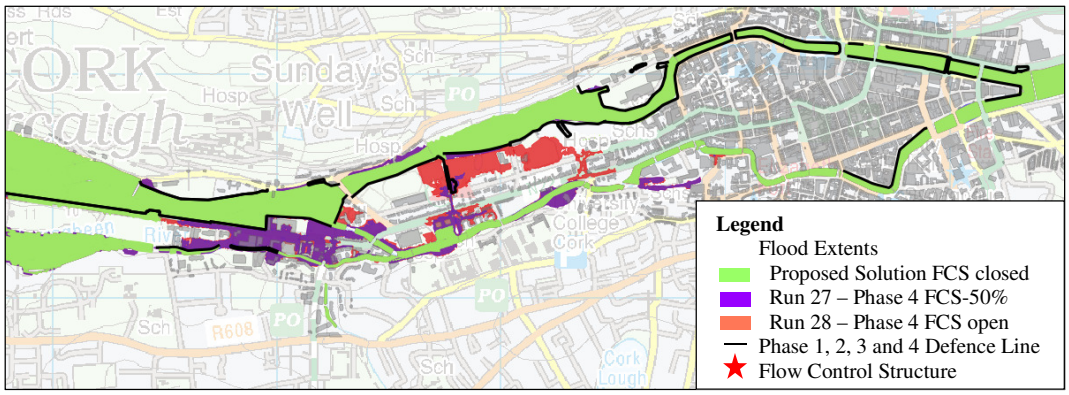
5 Further Considerations

5.1 Operation of Flow Control Structure

The operation of the flow control structure (FCS) plays a significant role in the Lower Lee FRS as it controls inflow from the Lower Lee into the South Channel and thereby affects water levels along the lower section of the Curragheen as well as the upper to middle section of the South Channel.

A number of modelling runs were set-up, in order to test the effect of the flow control structure during the phasing of works. Figure 37 presents modelling results comparing three different openings of the FCS for a fluvially dominated event and defences up to Phase 4 in place. Figure 38 presents the corresponding water surface profile plot along the Curragheen and Figure 39 presents the channel chainage.

Figure 37: Maximum flood extents showing baseline and interim condition (Phase 4) for Run 27 and Run 29 (Q500MHWS) in comparison to the Proposed Solution (FCS closed)



Modelling results shows extensive flooding along the lower section of the Curragheen for both opening stages of the FCS (namely FCS open and FCS 50% (half open)). Flooding in this area is eliminated once the FCS is closed.

Modelling results also show extensive flooding in the area of University College Cork for the modelling run with the FCS open. This flooding originates from the South Channel and is reduced significantly once the opening of the FCS is decreased by 50% or more (see Figure 37).

It is also important to note that closing the FCS will not always be a preferred operation, i.e. in a situation when flows in the Curragheen and Glasheen are low, some flow from the Lower Lee would be allowed to enter the South Channel. It is therefore intended for the FCS to be actively managed to maximise flows in the system while minimising flooding.

Figure 38: Water surface profile plots showing a comparison of different openings of the flow control structure (please refer to Figure 39 for chainage of the Curragheen)

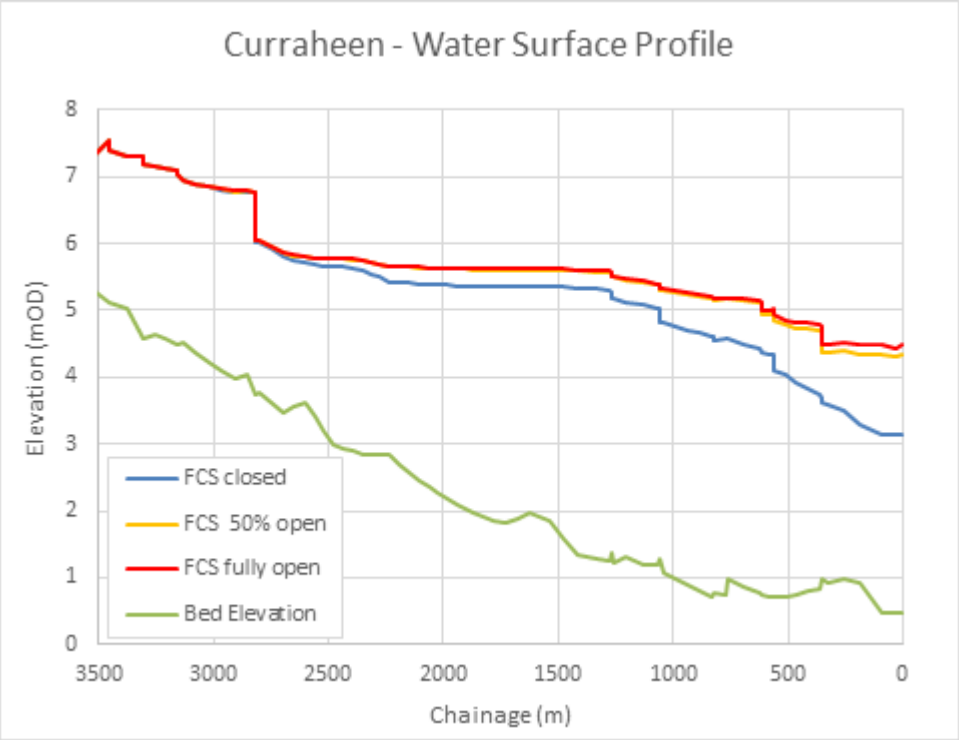
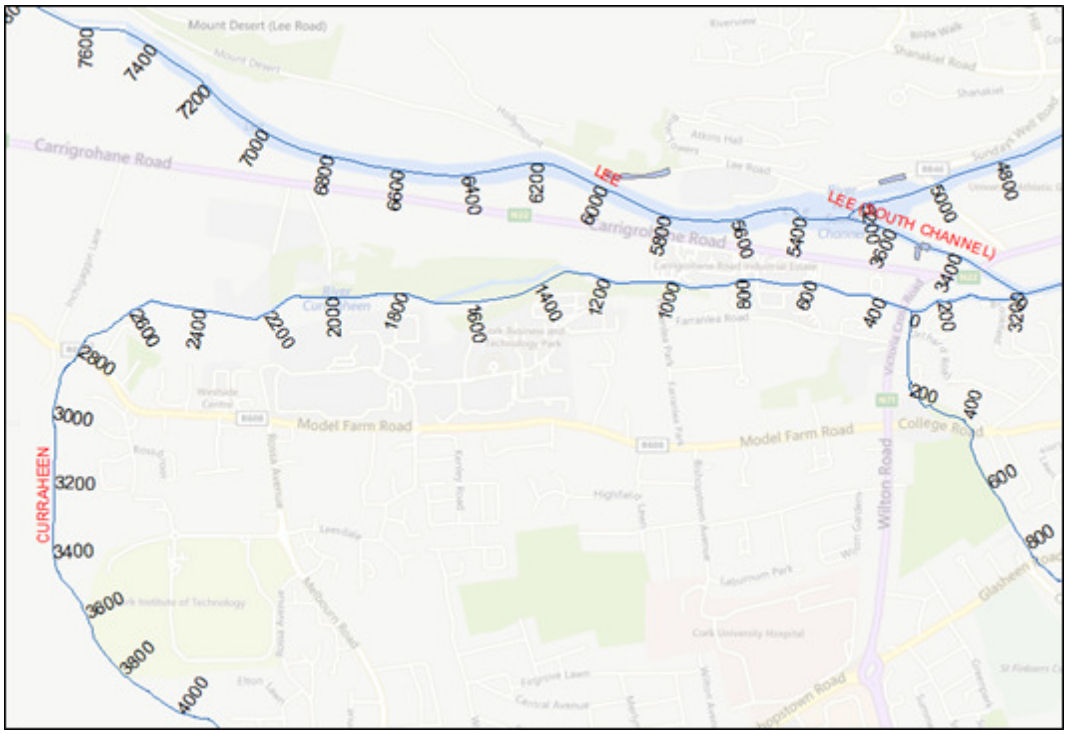


Figure 39: River chainage for Curragheen



5.1.1 Flow Distribution between North and South Channel

The initial assessment of providing the flow control structure (FCS) as part of Phase 1 assumed that flows into the South Channel would be reduced to a minimum. Findings showed that flood defences along the North Channel would be required for this scenario (4.2.3).

However as previously mentioned, providing the FCS as part of Phase 1 would add flexibility to the scheme during the phasing of works, as it would allow active management and distribution of flows between the North and South Channel, depending on the tide conditions and inflows from tributaries. A number of modelling runs were therefore set-up to assess the operation of the FCS.

From the initial assessment, the following was established:

- Flooding occurs on the South Channel at a flow of approximately 70m^3/s.
- Flooding typically starts regardless of what tide is used, as the channel is fluvially dominated in the effected reach and upstream of a number of weirs. However the peak flooding and extent depends on the final level of tide.
- The flow control structure is modelled as a sluice type structure, 15m in width and having a total opening height of 1m (25%), 2m (50%) and 3m (75%).

The assessment of the FCS used a flow rate of 350m^3/s at Waterworks Weir and a range of tide levels from 2.47m (2-year tide), 1.97m (MHWS), 1.50m and 1.0m, the latter two representing two relatively low tide conditions.

Figure 40 presents the river chainage for Cork Central Island and Figure 41 presents the flow hydrographs for the North and South Channel and the three different openings of the FCS.

Figure 40: River chainage for Cork Central Island

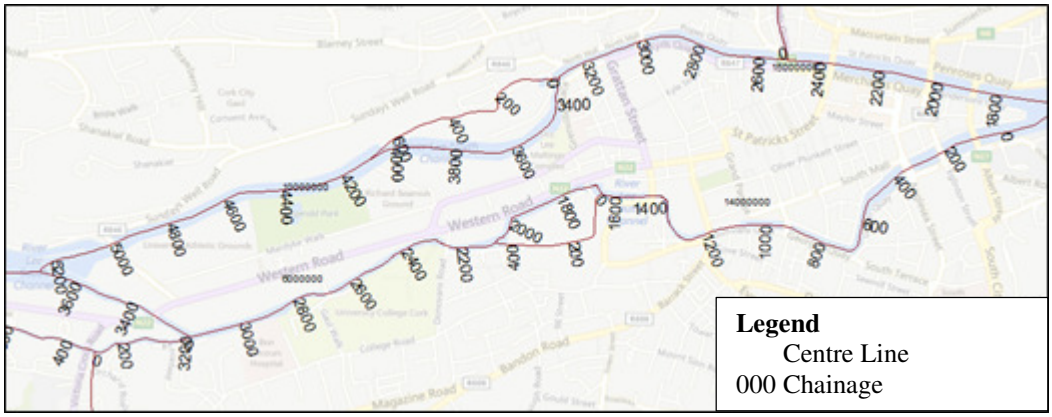
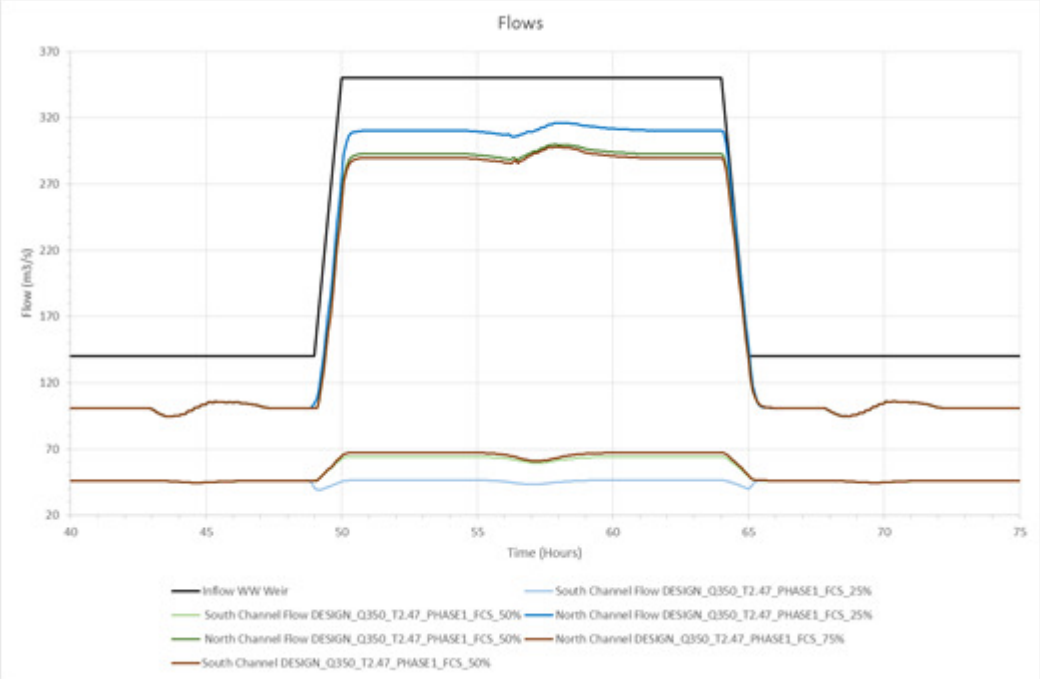


Figure 41: Flow distribution between North and South Channel (Phase1 includes Phases 1 and 2)



Testing the system for the MHWS shows no flooding along the South Channel for any of three openings. There is a minor reduction in flood extents along the North Channel for both of the two larger opening of the FCS and Figure 42 presents results.

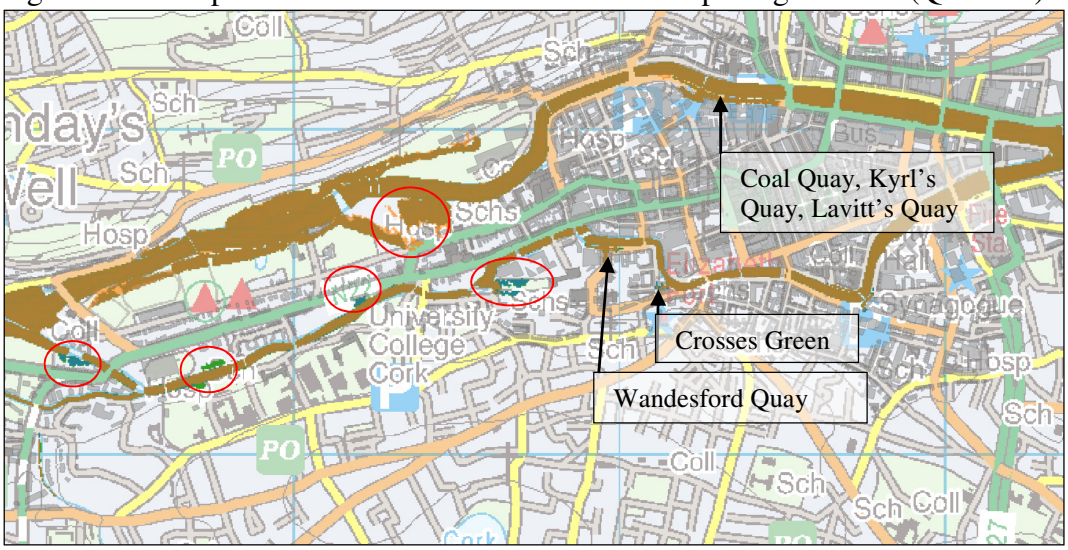
Figure 42: Comparison of flood extents for different openings of FCS (Q350 MHWS)

Modelling results show no flooding along the South Channel for any tide below the MHWS, regardless of the scale of the opening.

Flood extents along the North Channel vary slightly depending on the tide level and opening of the FCS and the 25% opening in combination with the MHWS tide results in the largest flood extent and there are a small number of properties at flood risk at Fitzgerald Park.

Figure 43 presents a comparison of modelling results for the combination of the 2-year tide with a flow rate of 350m^3/s at Waterworks Weir.

Figure 43: Comparison of flood extents for different openings of FCS (Q350 T2)

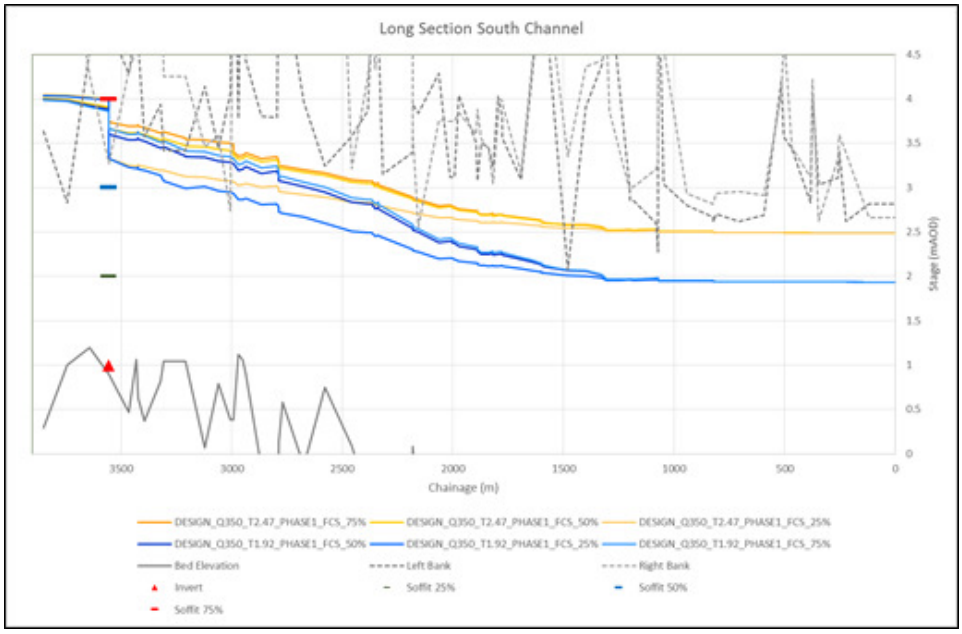


Results show some local flooding along the North and South Channel. The areas of Coal Quay, Kyrl's Quay and Lavitt's Quay (North Channel), as well as the areas of Wandesford Quay and Crosses Green (South Channel) are located in tidally dominant areas and as a result there is no significant difference in flood extents between the FCS being 25%, 50% or 75% open.

There is a small reduction in flood risk in the area of UCC associated with the FCS being 25% open in comparison to the FCS being 50% or 75% open. However there is a similar increase in flood risk along the North Channel at Fitzgerald Park associated with FCS being 25% open (see circled areas in Figure 43).

Figure 44 presents a long section of the South Channel for the MHWS tide and the 2-year tide for the three opening conditions of the FCS.

Figure 44: Long-section showing opening of FCS and modelled water surface profile for various runs (Phase1 includes Phases 1 and 2)



Results show that there is little difference between the two larger opening conditions of 50% and 75%. The reason being that water levels for 50% opening height are close to the soffit of the structure and increasing the opening height further only results in a small increase in flow.

Reducing the opening height of the FCS however, reduces water levels by up to 0.5m along the fluvially dominated reach of the South Channel, from chainage 3500m and 1300m.

5.2 Interface with Potential Infrastructure (Roads) Projects

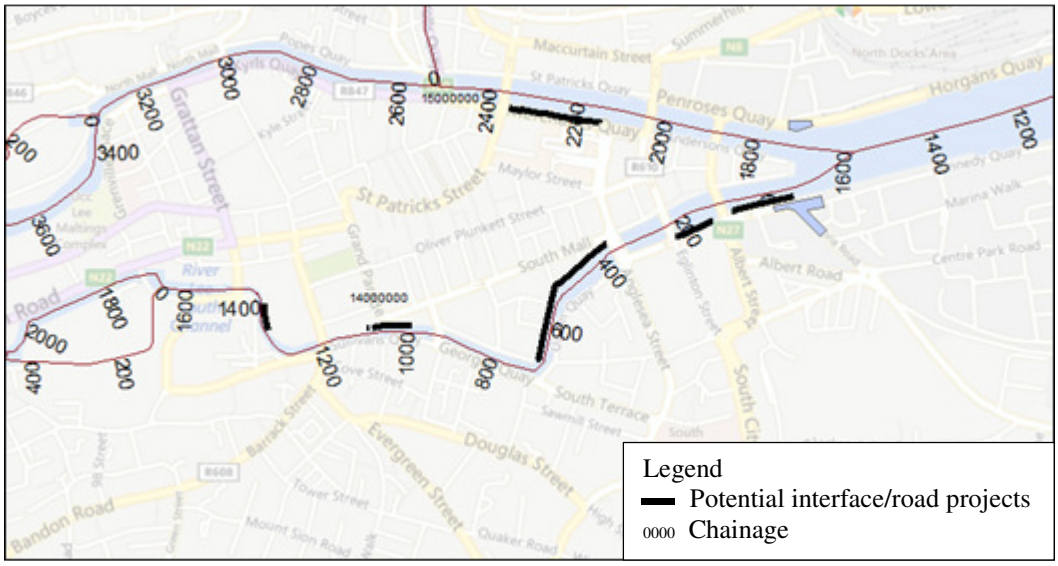
There are a number of proposed road projects at Cork Central Island, some of which may have a common interface with the proposed flood relief works and combining these with the flood relief works could minimise traffic disruption and provide cost savings.

The proposed road project are outlined as follows:

- Patrick's Quay/Merchants Quay: Proposed Pedestrian bridge at Hanley Street (incl cycle lane)
- Albert Quay East: Proposed contra-flow bus lane
- Beamish and Crawford Site: Proposed Cork Events Centre
- Grand Parade Quay: Proposed WWI memorial
- Morrison's Quay: Proposed public realm improvement works
- Lee Road Waterworks: Proposed extension to water treatment

The location of these elements are presented in the Figure 45 together with the channel chainage.

Figure 45: Location of potential interface between road projects.



5.3 Traffic Management

The phasing of the proposed Lower Lee FRS is likely to affect the phasing of the City Centre Movement Strategy (CCMS). Consideration of the phasing of works in terms of traffic management is detailed in this section.

It is recommended however that extensive high level consultation is carried out with the Roads and Transportation Division of Cork City Council and that the phasing of the CCMS and Lower Lee FRS are cognisant of each other.

5.3.1 Morrison's Island (Phase 0)

Works at Morrison's Island is unlikely to affect the flow of traffic, as the existing parking along the quays will provide sufficient space to carry out the works. The reduction in parking spaces will have to be taken into consideration however and in particular any reduction in disabled parking spaces should be replaced elsewhere.

Further consideration has to be given to the public bike docking station, which may have to be removed temporarily.

Consideration should also be given to aligning the proposed works with the proposed public realm along Morrison's Quay.

5.3.2 Phase 1 and 2

The majority of works associated with Phase 1 and 2 are located outside of Cork Central Island and as a result there is only localised impact expected in terms of traffic.

5.3.3 Phase 3

Phase 3 consists of works along a number of quays at Cork Central Island and each of these is considered hereunder from a traffic management perspective.

The area of Coal Quay contains a wide footpath, which would assist in carrying out the works. There are also two traffic lanes eastbound on Coal Quay and Lavitt's Quay and it may be possible to reduce these to one lane to allow works to be carried out here.

The area of Crosses Green to Crawford Hall contains car parking areas, which would be sufficient to accommodate works. There is a relatively narrow one way system exiting at Forde's Funeral Home that may require diversion via Deans Hall. The section from St. Finbarre's Bridge to Sharman Crawford Street may not be able to accommodate works without a diversion for east or west bound traffic. One option could be to divert west bound traffic via Clarke's Bridge, Hanover Place and Hanover Street/Washington Street.

The area at George's Quay contains two lanes as well as a bus lane westbound, which would provide sufficient space to accommodate works.

The area of Union Quay from Copley Street to Anglesea Street contains car parking on both sides which would provide sufficient space to accommodate works. Between Copley Street and South Terrace there are two opposing lanes and no car parking. An option would be to divert northbound traffic and to maintain inbound traffic (east to west). One example would be to divert this traffic earlier on South Terrace via Cotters Street, as there is no traffic from George's Quay side of junction.

At the area of Lapp's Quay, there is relatively little through traffic and it contains a wide car parking area. Recently, this area was used to accommodate a works compound area for repair works to Clontarf Bridge. Consideration will need to be given to the Public Bike Docking Station, which may have to be removed temporarily.

Works in the area of Lee Distillery Branch would have little impact on traffic.

The area of Bachelor's Quay (West) contains car parking as far as Pat McDonnell Paints. There is a pinch point from Pat McDonnell Paint to Grenville Place. One option would be to divert traffic via Henry Street, Grattan Street/South Parish. Similar diversions were required for quay wall repair works on Grenville Place. Works in this area will need to tie in with the phasing of the CCMS. It is likely that the lane layout on Bachelor's Quay and Grenville Place would be revised under the scheme.

5.3.4 Phase 4

Phase 4 consists of works along the North Channel of Cork Central Island on both the northern and southern banks of the channel.

While each area/quay is considered individually hereunder, works along both banks at the same time should be avoided. This is to allow for at least one of the quays to be unaffected by traffic disruption.

Furthermore, works on subsequent/adjacent bridges at the same time should also be avoided.

Works in the area of Port of Cork is considered to have little impact on traffic.

The area of Anderson's Quay contains a relatively wide green area between the quay and the road, which would be able to accommodate works. There are however, plans for coach parking facilities to be provided and Cork City Council Transportation division should be notified.

The area of Merchant's Quay contains one eastbound lane and two westbound lanes as well as a bus lane. Works in this area will need to tie in with the phasing of the CCMS. It is likely that the lane layout on Merchant's Quay would be revised under the scheme.

The area of Christy Ring Bridge contains five lanes as well as adjacent footpaths. Works in this area may require one lane on either side to be removed separately.

The area of Camden Quay contains two westbound lanes and one eastbound bus lane.

Works in this area may require the bus lane to be removed to maintain two lanes westbound. Works in this area will need to tie in with the phasing of the CCMS. It is likely that the lane layout on Camden Quay would be revised under the scheme.

The area of St. Patrick's Quay (West) contains two lanes westbound as well as a 30m right turn lane and a bus parking area. One option would be to utilise the car parking on the right hand side to accommodate works. An alternative would be to utilise the car parking for the Bus Station.

The area of St. Patricks Quay (East)/Penrose Quay (West) contains three westbound lanes as well as a wide car parking area. The car parking area would be sufficient to accommodate works.

The area of Penrose Quay (East) contains two westbound lanes as well as a bus lane and a wide footpath/quay. The footpath/quay area would be sufficient to accommodate works.

The area of Knapp's Square contains a wide footpath and bicycle lane as well as one traffic lane each way. Works could be accommodated in conjunction with closing the left turn northbound lane on Christy Ring Bridge. This would require reducing traffic to a single lane in each direction.

The area of Pope's Quay contains a wide footpath as well as parking area and cycle lanes. Generally there is sufficient space to accommodate works, apart from some pinch points e.g. at Farren's Quay as well as Shandon Pedestrian Bridge, which will require traffic to be diverted onto the two-way cycle track.

The area of Griffith Bridge contains two lanes each way. In order to accommodate works, these would require closing one lane at a time.

The area of North Mall would generally contain sufficient space to accommodate works, as there is car parking on most of the north side lane.

In areas where there is no car parking, traffic lanes would be reduced to one lane east bound and diverted west bound up Blarney Street via Shandon Street. This diversion could be carried out in conjunction with closing the left lane northbound on Griffith Bridge, if required.

The area of Bachelor's Quay (East) contains two lanes of traffic each way. Temporary closure of one lane would be required to accommodate works.

5.3.5 Phase 5

Phase 5 consists of works along numerous quays along the South Channel of Cork Central Island and each of these is considered from a traffic management perspective hereunder.

The area of Albert Quay East contains two wide traffic lanes with car parking as well as a wide quay. There is sufficient space to accommodate the works.

The area of Albert Quay contains three lanes as well as relatively wide quays, which would be sufficient to accommodate works.

The area of Terence McSweeny Quay contains three traffic lanes and a bus lane westbound, which would be sufficient to accommodate works.

The area of Clontarf Bridge contains three traffic lanes. One option would be to close one lane at a time. This bridge has been completely closed in the recent past during the summer, which may also be an option to accommodate works.

The area of Sullivan's Quay is likely to contain a pinch point at the Sober Lane bar and Flying Enterprise Complex. Diversion via South Mall, Grand Parade, Tuckey Street and South Main Street or a localised diversion onto Cobh Street would be considered if works cannot be contained within the contra-flow cycle track.

In the area of French's Quay, liaison with Forde's Funeral Home will be required. This area contains a relatively wide traffic lane, which is considered wide enough to allow traffic pass, but will need to remove car parking/bus stop locally to accommodate works.

Works in the areas opposite Sullivan's Quay, the Beamish and Crawford Site, back of the Hanover St properties, Western Road and at the back of the former Service Station site are considered to have little impact on traffic.

5.4 Demountables for Cork Central Island

There are a number of areas at Cork Central Island where demountable defences are proposed.

In the current phasing this has been identified for works at Morrison's Island as well as various areas of Phase 3, Phase 4 and Phase 5 of the works. It is therefore likely that demountable defences will be constructed by different contractors.

However, the final scheme should contain the same demountable type of defences, so that the same method/ mechanisms are used throughout the various areas.

It is therefore recommended that contracts for the relevant phases provide the relevant level of detail and specify the type of demountables to be used.

6 Conclusion

The phasing of works has been developed based on the following key criteria:

- Phase works in a way that maximises interim benefit in terms of incrementally reducing flood risk.
- Typical annual spend profile and individual contract values of approximately €15 Million.
- Avoidance of any increase in flood risk associated with the interim condition in comparison to the baseline condition.
- Practical consideration and potential combining of other projects.
- Ensuring contract phasing and timescales reasonably minimises disruption to businesses and landowners including Traffic considerations.

The costs and timescales for delivery of the proposed phases is set out in Table 7 below.

Table 7: Summary detail - Proposed phasing

Phase	Planning Route	Cost Estimate	Start	Finish
Morrison's Island	Part 8	€5m	Dec 2017	Dec 2018
Phase 1	ADA	€24.4m	April 2018	Oct 2019
Phase 2	ADA	€17.8m	Mar 2019	Sept 2020
Phase 3	ADA	€10.8m	Sept 2020	Mar 2022
Phase 4	ADA	€15.7m	Mar 2022	Sept 2023
Phase 5	ADA	€16.8m	Sept 2023	Sept 2024
Total		€90.5m		

The phasing of the proposed works is set out in Figure 46 below.

Figure 46: Location plan of proposed phasing of work