OPW
Oifig na nOibreacha Poiblí
The Office of Public Works

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

Supplementary Report on Option of River Diversions

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Lower Lee Flood Relief Scheme

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Executive Summary

The Lower Lee Flood Relief Scheme (LLFRS) was commissioned by the Office of Public Works (OPW) with the objective of delivering a flood relief scheme for Cork City and environs to provide protection against the 1 in 100 year fluvial/1 in 200-year tidal flood events.

The project followed on from the pilot Lee CFRAM Study which identified the preferred Scheme as being a combination of a flood forecasting system, optimised dam operating procedures and direct defences.

Following extensive study and assessment, a proposed Scheme was developed which consisted of a modified version of the above measures together with a flow control structure on the south channel to rebalance flows between the north and south channels.

The proposed Scheme was subsequently brought to Statutory Exhibition stage through the Arterial Drainage Act (as amended) in late 2016/early 2017.

A number of submissions were received which queried the potential for diversion of at least some of the peak flow away from Cork.

Some submissions made reference to a study entitled “Irish Rivers 2040”. This study was undertaken by a group of Dutch architects and landscape architects were invited to share their experiences on potential strategies and solutions to flood protection, and to suggest some concept solutions for Irish river systems. One of the case studies included in the study was Cork City.

A theoretical option suggested was to provide a by-pass or overflow channel for the River Lee flow (or part of the flow) from upstream of the Waterworks Weir, south of the city, eventually discharging into Lough Mahon. This was a concept and no significant details were provided on the possible routes, scale, capacities, levels etc. The purpose appears to be to provide a reduced flow into the city and thus reduced direct defences.

There was also a submission proposing to divert the Curragheen and Glasheen along a similar route tying into the Tramore River in the adjacent valley. The purpose of this proposed route was to remove the Curaheen and Glasheen flow from entering the south channel and thus allowing the south channel to be isolated during a tidal event, therefore avoiding tidal defences on the eastern stretch of the South Channel.

The potential diversions noted above were screened out at Options Stage. However, in response to the submissions received at Exhibition Stage, this supplementary report has been prepared to demonstrate why these suggested alternatives are not viable solutions for Cork.

The assessment established that all of the proposed diversions routes have significant technical, social and environmental constraints due to the location, scale and distances involved.

The concept of a partial diversion of the River Lee as espoused in the Irish Rivers 2040 Report is technically unviable and cost prohibitive.

A number of possible measures for diversions of the Curraheen and Glasheen Rivers was considered to facilitate the Option of isolating the south channel.

A variation of Option 2 as assessed in the Lower Lee FRS Options Report was developed and is considered to be the optimum combination of storage and diversions of tributaries to facilitate isolation of the South Channel. (Referred to as Option 2a in this report). It includes the following measures:

- The majority of works outlined in "option 2" of the Scheme options report (i.e. fluvial defences upstream of Cork, fluvial and tidal defences along the North Channel, and isolation structures at the upstream and downstream ends of the South Channel), excluding defences along the Curraheen and Glasheen, but increased defence heights on the North Channel.
- Upstream Storage on the Curraheen and the flood relief diversion of the residual Curraheen flow into the River Lee at Inchigaggin.
- Diversion of the Glasheen into the Tramore River via the N40 South Ring Road, along with downstream flood defences along the Tramore to mitigate the increased flood risk associated with the additional flows.
- An additional pumping facility at the downstream end of the South Channel to cater for the residual fluvial flows from the tributaries plus pluvial flows from the urban catchment.

Option 2a has a number of considerable drawbacks compared with the exhibited scheme as follows:

- Requires higher defences would be required on the north channel.
- The omission of direct defences at the eastern end of the south channel could be seen as a positive in terms of minimising impact on the existing quay walls. However, the proposed investment in quay wall remedial works along this reach (proposed as part of the exhibited scheme) would not form part of an option to isolate the South Channel. Therefore the condition of the existing quay walls would continue to deteriorate.
- There would be a significant increase in residual flood risk for those people living downstream of the proposed storage area in Curraheen due to the risk of breach.
- There would also be a significant increase in risk and/or considerable disruption in undertaking mitigation works for those people living adjacent to the Tramore valley downstream of the proposed diversion tie-in point.
- The downstream isolation structure on the south channel may increase siltation at the downstream end of the south channel. This would require further assessment and may necessitate the provision of mitigation measures.
- A preliminary cost estimate for option 2a was prepared and it was found to be significantly more expensive than all of the options presented in the Scheme options report.

Therefore, considering all of the above, “option 2a” as developed in this report is considered unlikely to be more preferable to the exhibited Scheme.

Therefore, the findings of this report confirm that all of the suggested diversions have significant technical and environmental constraints due to the location, scale and distances involved in the proposals, meaning that all suggested diversions are unviable, either technically, environmental or economically.

1 Introduction

The Lower Lee Flood Relief Scheme (LLFRS) was commissioned by the Office of Public Works (OPW) with the objective of delivering a flood relief scheme for Cork City and environs to provide protection against the 1 in 100 year fluvial/1 in 200-year tidal flood events.

The project followed on from the pilot Lee CFRAM Study which identified the preferred Scheme as being a combination of a flood forecasting system, optimised dam operating procedures and direct defences.

Following extensive study and assessment, a proposed Scheme was developed which consisted of a modified version of the above measures together with a flow control structure on the south channel to rebalance flows between the north and south channels.

The proposed Scheme was subsequently brought to Statutory Exhibition stage through the Arterial Drainage Act (as amended) in late 2016/early 2017.

A number of submissions were received which queried the potential for diversion of at least some of the peak flow away from Cork.

Some submissions made reference to a study entitled “Irish Rivers 2040”. This study was undertaken by a group of Dutch architects and landscape architects were invited to share their experiences on potential strategies and solutions to flood protection, and to suggest some concept solutions for Irish river systems. One of the case studies included in the study was Cork City.

A theoretical option suggested was to provide a by-pass or overflow channel for the River Lee flow (or part of the flow) from upstream of the Waterworks Weir, south of the city, eventually discharging into Lough Mahon. This was a concept and no significant details were provided on the possible routes, scale, capacities, levels etc. The purpose appears to be to provide a reduced flow into the city and thus reduced direct defences.

There was also a submission proposing to divert the Curragheen and Glasheen along a similar route tying into the Tramore River in the adjacent valley. The purpose of this proposed route was to remove the Curaheen and Glasheen flow from entering the south channel and thus allowing the south channel to be isolated during a tidal event, therefore avoiding tidal defences on the eastern stretch of the South Channel.

It became evident that it would be would be in the public interest to provide the public with further detail and a greater evidence base to explain why these options are not viable alternatives to the exhibited scheme. This report sets out this further evidence base.

The scope of the study is as follows:

- Identification of the major constraints that diversion options would need to address

- Review of River Lee diversion option as presented in the "Irish Rivers 2040" report
- Further review of South Channel isolation option (i.e. "Option 2" in Scheme options report), incorporating suggestions for tributary diversion options, as put forward in some exhibition submissions.

2 Potential for Partial Diversion of the River Lee at Cork

2.1 Suggested River Lee Bypass Route

The "Irish Rivers 2040" Report suggested a concept of providing a bypass to the River Lee.

Figure 1 presents an extract from the Irish River 2040 Report. Figure 2 shows the proposed diversion overlain with aerial photography. The latter indicates the current level of urbanisation along the suggested route.

Figure 1: Extract from Irish Rivers 2040 Report showing possible route of River Lee bypass

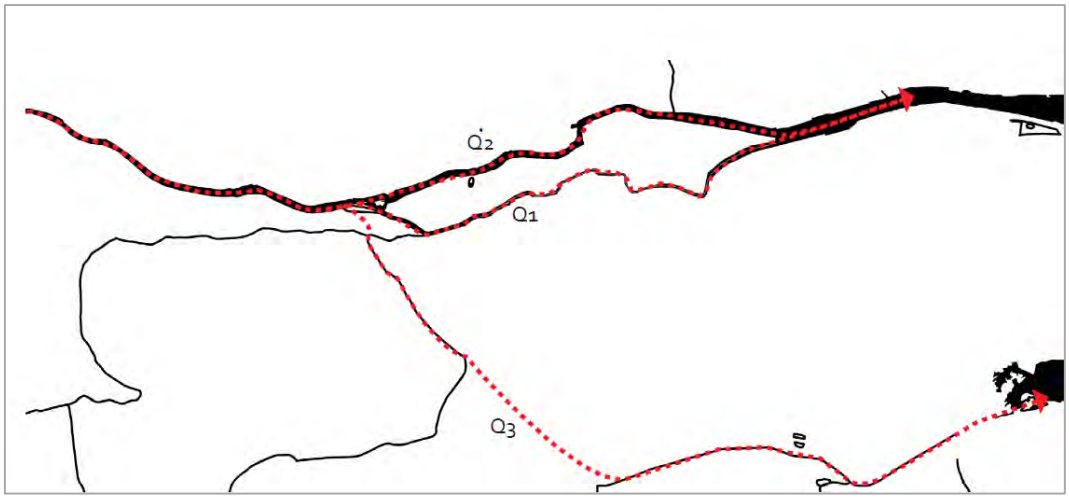


Figure 2: River Lee diversion – Plan View overlain with Aerial Photo (Bing Maps)

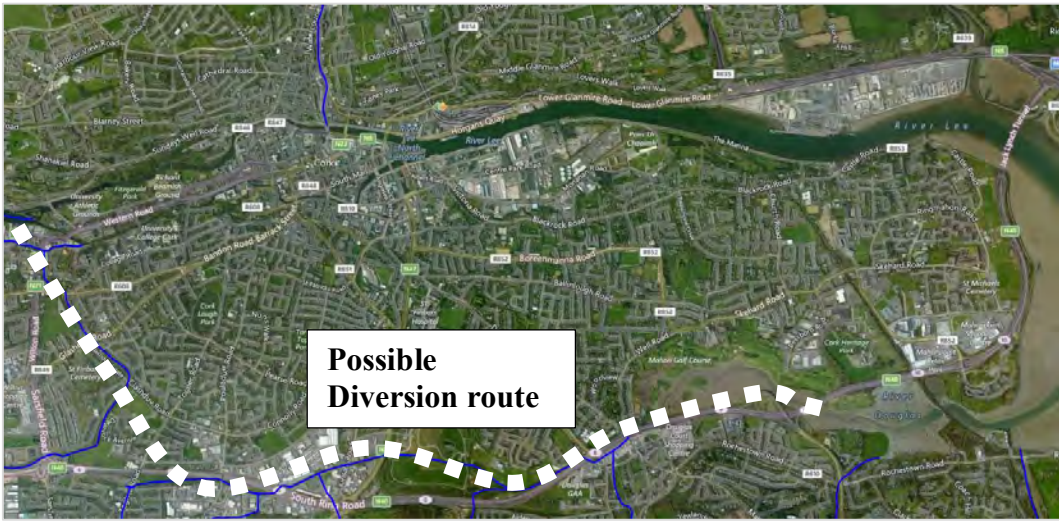


Figure 3 presents the proposed diversion overlain with LiDAR data to provide an indication of the changes in topography along the route. Figure 4 presents a long section profile plot of the proposed diversion route.

Figure 3: River Lee diversion – Plan View overlain with LiDAR

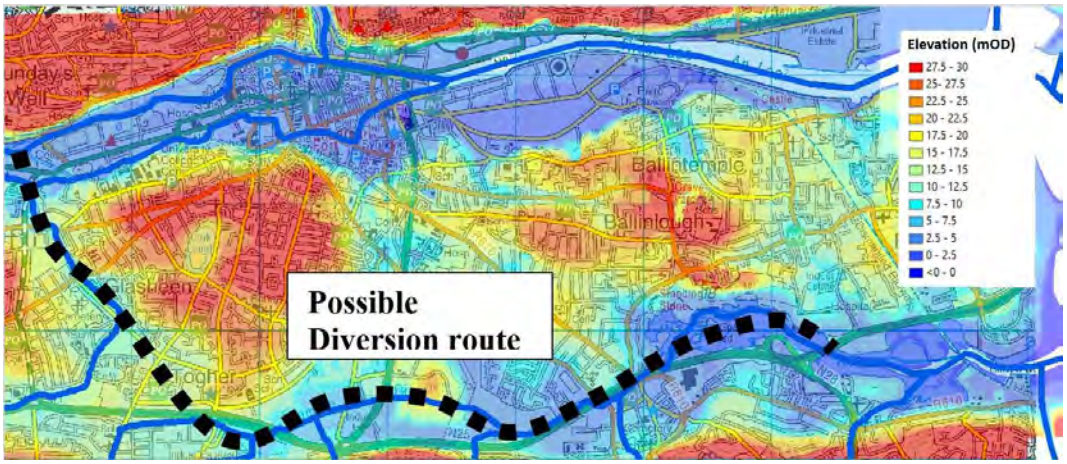


Figure 4: River Lee diversion - Long Section Profile (ground levels)

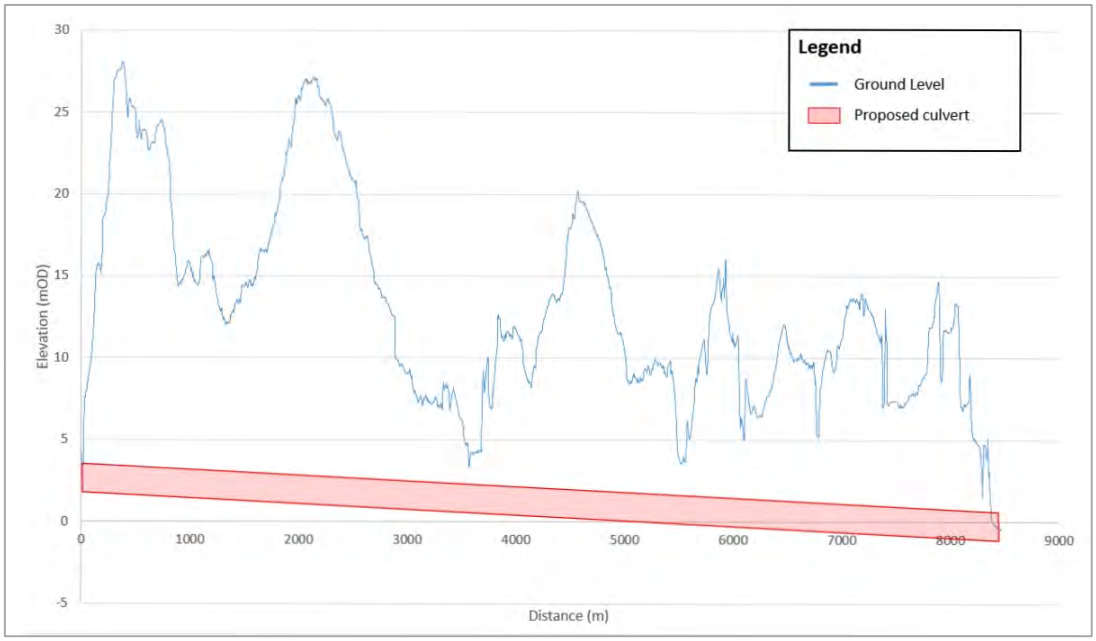


Figure 3 presents the proposed diversion overlain with LiDAR data to provide an indication of the changes in topography along the route. Figure 4 presents a long section profile plot of the proposed diversion route.

Figure 3 and Figure 4 show that the ground elevation at the proposed inlet is circa 4m above the proposed discharge point at Lough Mahon.

The topography along the route of the diversion varies by over 20m, which suggests that significant lengths of tunnelling would be required. It is expected

that the majority of the tunnelling would likely be through bedrock for the following reasons:

- A rock escarpment runs parallel to the River Lee in the vicinity of County Hall/Victoria Cross. Rock can be observed outcropping at several locations in this vicinity.
- Publically available[1] site investigation information suggests that rock has been encountered at shallow depths along the route (e.g. in the vicinity of Deanrock Estate).

2.2 Estimation of Required Conveyance Capacity of Diversion.

The purpose of diverting part of the River Lee flow directly to Lough Mahon is to reduce flood risk in Cork City along the South and North Channel to the extent that direct defences are avoided to defence against major fluvial events.

Therefore, to estimate the magnitude of flow to be diverted, it is necessary to compare the design peak flow against the undefended capacities of the existing north and south channel. Table 1 below shows the indicative capacities of the existing Lee channels close to the western end of the central island (i.e. in the fluvially-dominated reach).

The capacities shown assume that no raised defences are provided. Therefore, flow above these capacities would need to be conveyed in a bypass channel or culvert, in order to remove the need for fluvial defences in the city.

(Tidal defences would still be required as the diversion would not alleviate tidal flood risk.)

Table 1: Indicative Conveyance Capacities

Channel	**Approximate Bankfull Flow Capacity within fluvial reach (m^3/s)**
North Channel only	$350m^3/s$
North Channel & South Channel combined	$390m^3/s$

The design peak flow on the Lee at Waterworks Weir is circa $555m^3/s$, and the predicted Curraheen and Glasheen peak flows are circa $50m^3/s$ combined. Therefore it is apparent that a River Lee bypass would need to be capable of conveying at least $200m^3/s$ to avoid the need for defences.

2.3 Potential for Gravity or Pumped Diversion with $200m^3/s$ Capacity

A simple hydraulic model was prepared for the above scenario in Flood Modeller software. It was found that due to the flat gradient and tidal influence at the outlet, a theoretical culvert at least 150m wide x 2m high would be required to ensure

[1] www.gsi.ie

that flow could be conveyed at all tide levels while maintaining acceptable levels at the inlet.

Such a solution is unlikely to be technically viable. Even if it were, the cost of such a solution would be in the order of several hundred million euro. Tidal flood defences would still be required even if this option could be constructed. Therefore, it is immediately evident that such a solution is not technically viable and extremely cost prohibitive.

An alternative to the gravity solution would be a pumped bypass culvert. Such an option was raised an early PID and thus considered for the North Channel as part of the Lower Lee Options report (Arup, 2017). Findings from that assessment show that a pumped bypass would be prohibitively expensive and flow volumes are impractically large. It can similarly be inferred that a pumped diversion from Waterworks Weir to Lough Mahon would also result in the same findings.

3 Option of Isolating South Channel by Substantially Diverting Curaheen and Glasheen

3.1 Introduction and Background

As discussed in the Options Report, the option of isolation of the South Channel was considered in detail.

One of the primary reasons why this option was ruled out at options assessment stage, was that there is insufficient storage on the South Channel to cater for inflows from the Curraheen and Glasheen Rivers.

Accordingly, the option of diverting the Curraheen and Glasheen Rivers directly into the North Channel was considered in the Options Report. However, it scored poorly in the Multi Criteria Analysis (MCA) as the levels in both watercourses would be significantly increased as a result of the backwater effect from the higher north channel levels. This would mean that a very significant length of very high defences would be required, particularly along the Curaheen. This issue is discussed further in the main Lower Lee Options Report[2].

3.2 Storage Capacity of South Channel

If the South Channel were to be isolated as part of a proposed Scheme, sufficient storage capacity would need to be available in the channel to cater for inflows from these tributaries, along with the inflow from the existing surface water drainage system in the city.

The volume of storage available in the South Channel was calculated using the channel cross sectional survey data from the Lee CFRAMS project, and based on the following assumptions:

- An assumed allowable peak level at the downstream end of the South Channel of 2.5mOD (existing threshold of flooding).
- Assumed that the downstream gate would be closed at a level of 0mOD.
- Storage below the crest level of each existing weir on the South Channel was discounted on the relevant reaches.

Based on the above, a capacity of circa 230,000m^3 was calculated. This equates to an average allowable inflow of circa 8m^3/s over the 8 hour duration of the downstream barrier.

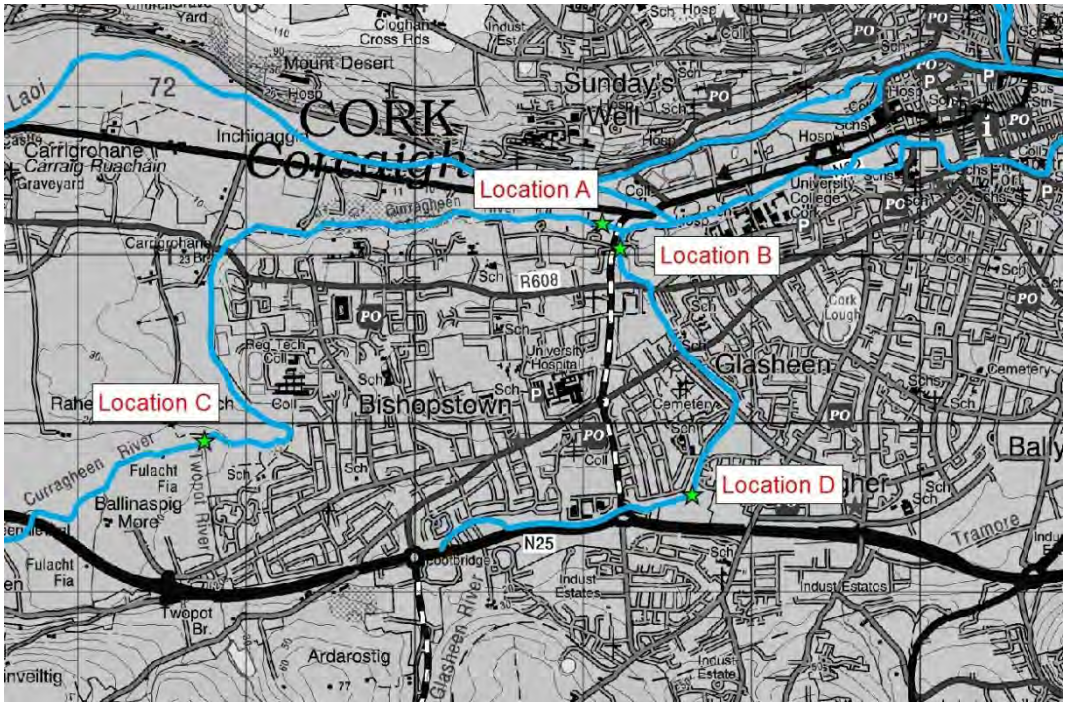
[2] Arup/JBA Consulting (March 2017) Lower Lee (Cork City) Drainage Scheme (Flood Relief Scheme) Options Report

3.3 Estimation of Peak Tributary Flows and Volumes

In order to get an understanding of the quantity of water that would either need to be stored within the South Channel, and/or conveyed in a diversion, it is necessary to undertaken design flow estimates for the Curragheen River and Glasheen River as they enter the south channel and upstream of possible diversion locations on each tributary.

These locations are shown in Figure 5 below.

Figure 5: Indicative range of tributary offtake locations considered potentially feasible



Flow estimates for the confluence with the south channel were undertaken using FSU methodologies and are presented in Table 2 below.

Table 2: Tributary Flow estimates at confluence with South Channel - 1 in 100-year event

Location	Watercourse (location of estimate)	100-year peak flow estimate[3] (m^3/s)	Approximate volume of 100-year flood hydrograph - 8-hour duration (m^3)
A	Curragheen River (County Hall)	47.3	1,000,000
B	Glasheen River (Victoria Cross)	11.1	300,000

A number of potential diversion points were considered on both the Glasheen and Curaheen which would allow a gravity connection to either the Lee (main channel) or the Tramore as relevant.

[3] Office of Public Works (2017), Lower Lee (Cork City) Drainage Scheme Hydrology Report

In order to define the reach in which a gravity offtake would need to be located, the flows and volumes at several points upstream on each tributary were estimated using FSU methods. Flow estimates at the locations considered optimum for diversions are presented in Table 3.

(If offtakes were to be located further upstream of these points, then the flow generated by the remaining downstream proportion of the catchment would likely exceed the volumetric capacity of the South Channel.)

Table 3: Tributary Flow estimates at upstream limit of feasible gravity offtake locations - 1 in 100-year event

Location	Watercourse (location of estimate)	100-year peak flow estimate (m^3/s)	Approximate volume of 100-year flood hydrograph - 8 hours around the peak (m^3)	Approximate Residual Volume entering South Channel (m^3)
C	Curragheen River (North of N40)	43	950,000	50,000
D	Glasheen River (North of N40)	3.9	100,000	200,000
			Total Residual Volume	250,000m^3

For this study, it has been assumed that extreme pluvial events in the urban catchment would not coincide with the peak of an extreme fluvial event on the Curraheen/Glasheen. Therefore inflows from the urban drainage network have not been calculated.

As the residual volume of 250,000m^3 entering the south channel is slightly in excess of the 230,000m^3 calculated earlier, and allowing for the urban drainage inflow, it is likely that a pumping installation may need to be constructed at the downstream end of the south channel to cater for pluvial inflow to the South Channel along with residual fluvial inflow.

Note that "option 2" presented in the Scheme options report did not have a residual fluvial element from the Curraheen and Glasheen inflowing to the South Channel, which allowed the omission of pumping.

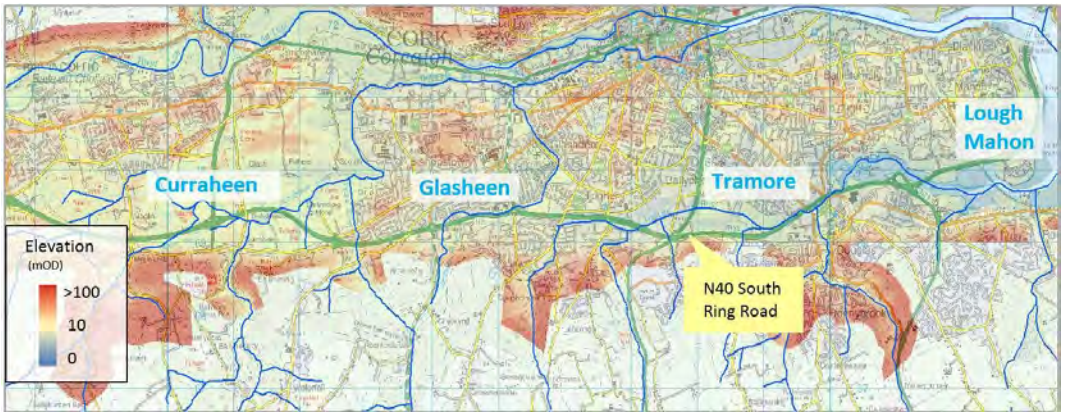
3.4 Isolation of South Channel – Required Reduction in Tributary Inflows

As discussed in earlier sections, it has been suggested that partial diversions of the Curraheen and Glasheen could increase the feasibility of the option of isolating the South Channel, by significantly reducing the inflow. The options for achieving this are reviewed below.

Local constraints in terms of distance, topography and urbanisation have been assessed for the potential partial diversion of flows from the Curragheen River and the Glasheen River as outlined earlier in Figure 1 and Figure 4.

Figure 6 presents a layout plan of the watercourses overlain with the study's LiDAR data.

Figure 6: Location plan and topography (LiDAR) showing Curragheen, Glasheen and Tramore River



Some exhibition submissions suggested that there may be a potential eastward diversion route along the N40 South Ring Road which could pick up both the Curraheen and Glasheen, to allow them to discharge into the Tramore River/Douglas River Estuary.

There is also potential to intercept the Curaheen further west and divert it into the River Lee (main channel) at Inchagaggin.

All diversion options for the Glasheen are discussed in Section 4 below, whilst all Curaheen diversion options are discussed in Section 5.

The optimum alternative option is summarised in Section 6 and costed in Section 7 of this report.

4 Options for Diversion of Glasheen

In order to assess the feasibility of a diversion from the Glasheen River to the Tramore River, topography, urbanisation and the existing flood risk has been reviewed.

The most feasible diversion route for the Glasheen River to the Tramore River appears to be upstream of the Deanrock Residential Estate, discharging at Pouladuff Industrial Estate, as presented in Figure 7.

Figure 7: Glasheen River Diversion (Bing Maps)

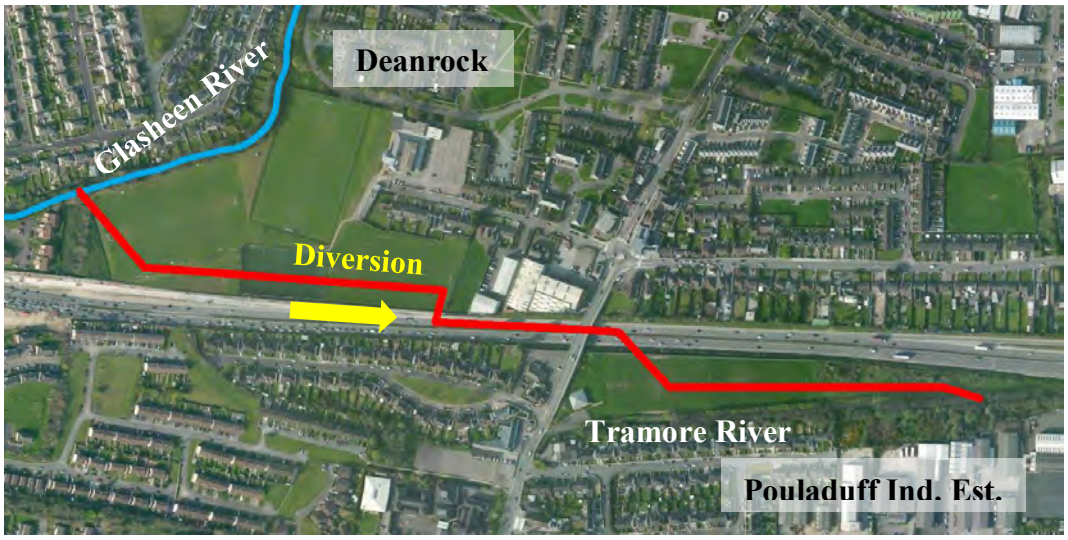


Figure 8 presents the proposed diversion route overlain with LiDAR data and Figure 9 presents a long section profile plot.

Figure 8: Glasheen River Diversion - LiDAR

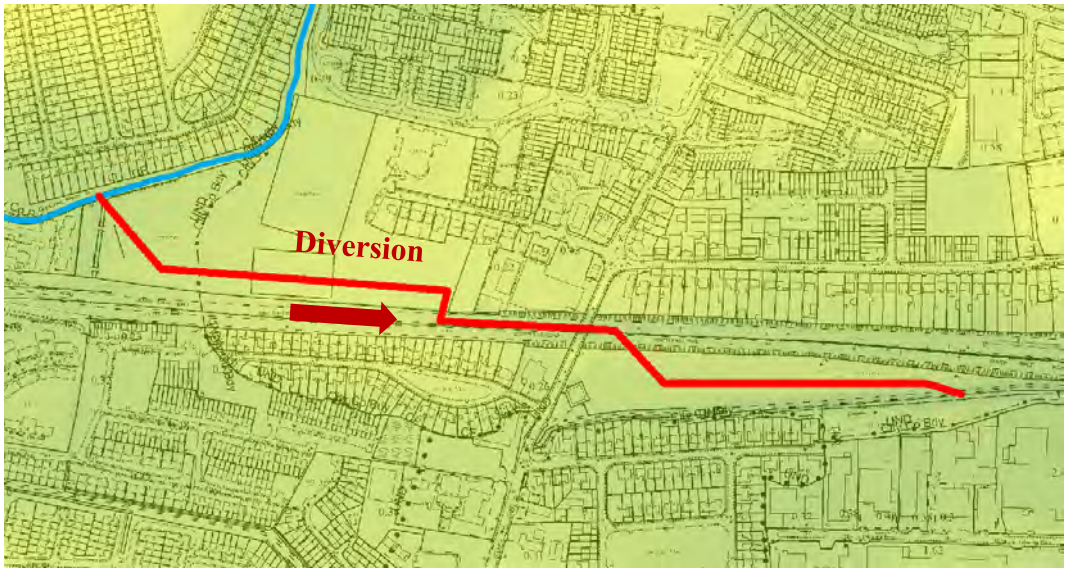
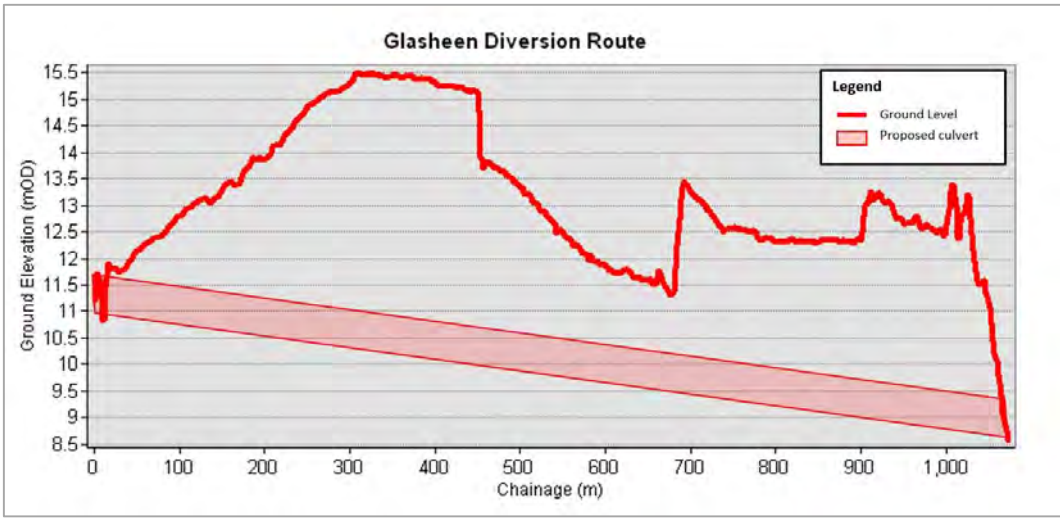


Figure 9: Longitudinal Section of existing ground levels along possible Glasheen diversion



The length of the diversion is circa 1km and would require construction of a new culvert between the Glasheen and Tramore River. The diversion route would go through existing playing fields and require a length to be constructed under the busy N40 south ring road.

Based on the topographic information available, it appears that flow by gravity may be possible.

However, it is worth noting that even if flows could be diverted to the Tramore River/Douglas estuary, then this would increase the existing flood risk in the Douglas/Togher areas, which are already at considerable risk.

This existing flood risk is illustrated on the Lee CFRAMS flood maps presented in Appendix A.

This shows that the existing channel capacity of both watercourses would be exceeded during design flood events.

A number of significant bridges on the Tramore river, downstream of the diversion outfall shown in Figures 7 & 10 have been newly constructed or replaced (on the south ring road and Kinsale road) in recent years based on the existing design flows. The substantial diversion flows would add significantly to the design flow at these structures and would increase flows beyond the design capacity of these new structures and so would increase flood risk.

As increased flood risk on the Tramore would not be acceptable, the further increase in flow from the diversion would necessitate substantial improvement works.

5 Options for Diversion of Curraheen

5.1 Option for Diversion of Curraheen into Tramore River

A submission suggested a diversion of the Curraheen north of the N40. However, once the Curraheen has passed north of the N40, its low elevation relative to the Tramore, means that a gravity diversion would not be possible. A diversion from north of the N40 would also need to traverse heavily urbanised areas. Therefore, a potential route along the south side of the N40 was assessed as an alternative. It should be noted that the residual flow from the Curraheen catchment downstream of this point, is higher than the capacity of the isolated south channel and so greater pumping would be required at the downstream end of the South Channel.

Figure 10 presents this possible diversion route overlain with LiDAR data and Figure 11 presents a long section profile of the diversion route.

Figure 10: Possible Curraheen Diversion – N40 Route

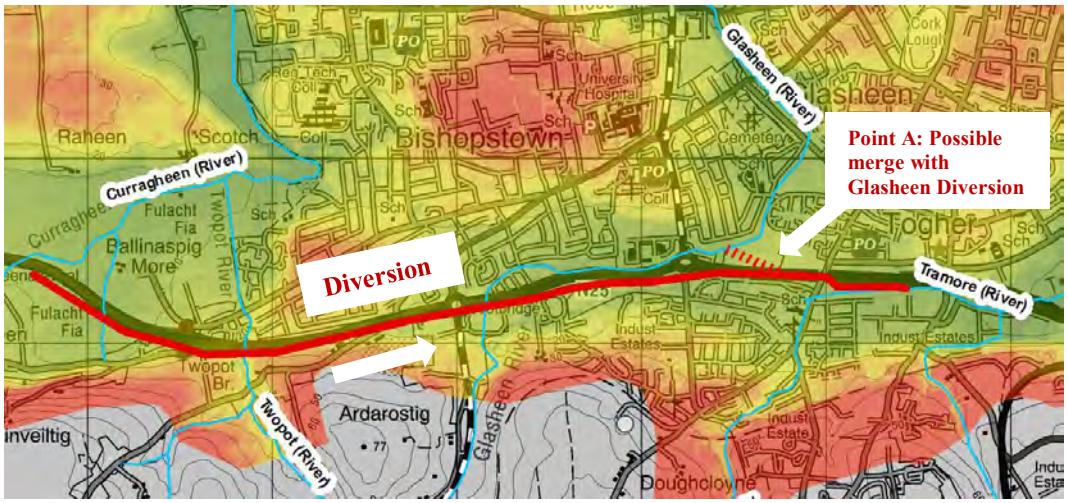
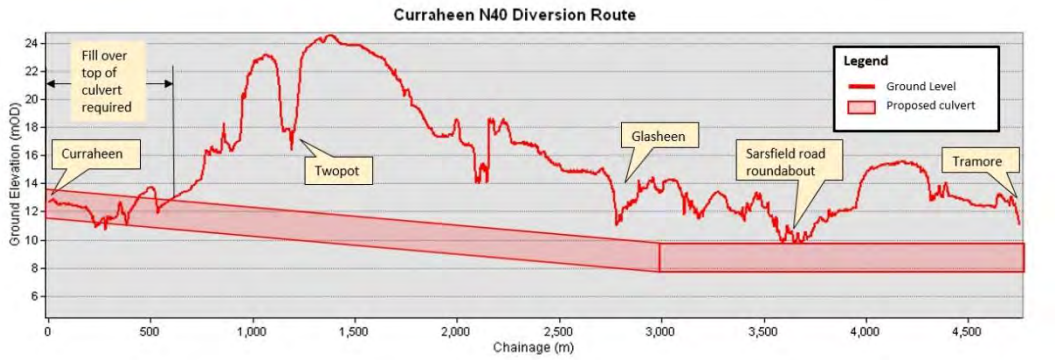


Figure 11: Longitudinal Section of existing ground levels along possible Curraheen diversion (N40 route)



The length of the diversion is circa 5km and the intake point is circa 3.5m above the outlet into the Tramore River (i.e. a gradient of circa 1 in 1400)[4].

The topography along this route also rises by circa 10m in elevation and as a result significant tunnelling would be required. The diversion culvert would need to pass under both the Twopot River and the Glasheen River due to the relatively high elevations of those channels at the crossing points. The route would also need to run under the N40 carriageway for approximately 600m. The possibility could also exist for an offtake from the Glasheen (as described in section 4 above) to be merged to the Curaheen diversion (see Point A on Figure 10 below)

A simple hydraulic model was prepared for the above scenario in FloodModeller software. It was found that due to the flat gradient, a culvert at least 150m wide x 2m high would be required to ensure that flow could be conveyed while maintaining acceptable water levels at the inlet.

For context, the N40 South Ring Road is only circa 40m wide in the vicinity of Point A on Figure 10. It is difficult to see how such a culvert could be practically constructed, considering that it would be considerably deep in comparison to ground level.

The previous comments regarding increased flood risk along the Tramore (refer to Section 4) are even more relevant in the case of this route. The Curraheen flow would more than double the existing flow in the Tramore. Therefore, it is expected that major flood defence works, including construction of new flood defence walls, embankments and reconstruction of bridges and culverts would be required in the downstream reach to mitigate the increased flood risk.

It is also important to note that the bridges on the Tramore river downstream of the diversion outfalls in Figure 7 and Figure 10 have been newly constructed or replaced (on the south ring road and Kinsale road) in recent years based on the existing regime design flows. Such substantial diversion flows would add significantly to the design flow at these structures and would be very likely to increase flows beyond the design capacity of these new structures and so increase flood risk.

Considering the enormous scale, cost and disruption that would arise with this option, it is not considered technically and/or economically viable.

5.2 Potential for Diversion of Curraheen to River Lee at Inchigaggin

In addition to considering the option of diverting the Curaheen into the Tramore, we have also considered other possible options to reduce the contribution to the South Channel from the Curaheen.

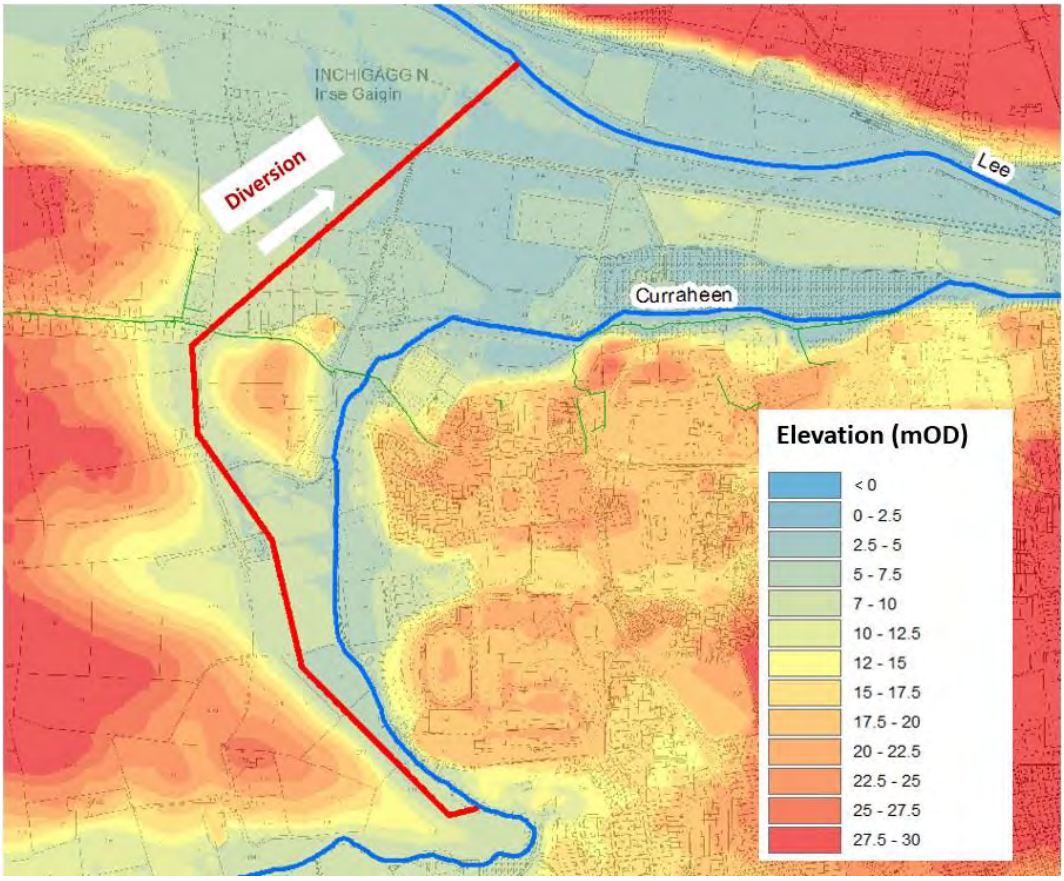
[4] The bed level of the Tramore continues to fall downstream of the proposed discharge point, before the channel becomes tidally-influenced. However even if the Curraheen diversion culvert were to be lengthened to take advantage of this fall, the maximum culvert gradient which could be achieved is approximately 1 in 1000. This is not expected to change the conclusions of this analysis.

A possible alternative diversion of the Curraheen to the main Lee channel appears to exist as shown Figure 12 below.

The length of this diversion is circa 2.5km and would require construction of a new culvert between the Curraheen and River Lee at Inchigaggin. The intake point is circa 3m above the outlet into the River Lee (i.e. a gradient of circa 1 in 800). The diversion route would be primarily in agricultural land, with a limited length beneath rural roads. Based on the topographic information available, it appears that flow could be diverted by gravity.

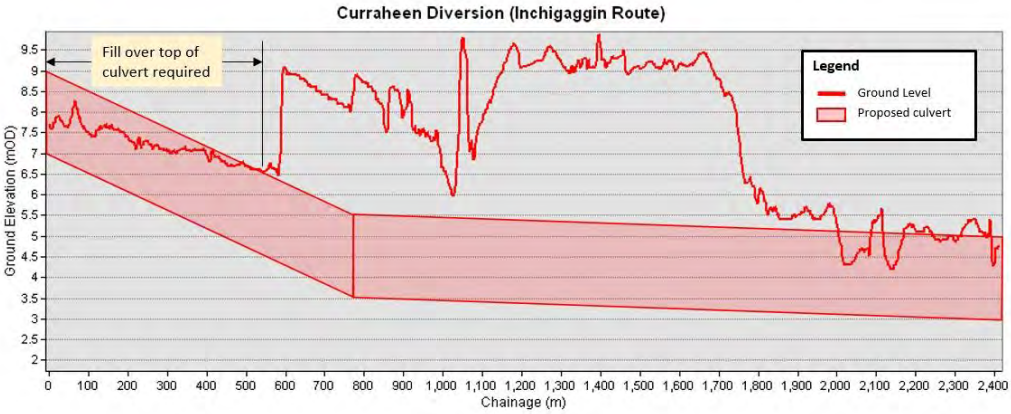
A simple hydraulic model was prepared for the above scenario in FloodModeller software. It was found that, a culvert at least 15m wide x 2m high would be required to ensure that flow could be conveyed while maintaining acceptable water levels at the inlet.

Figure 12: Possible Curraheen Diversion – Inchigaggin Route



It is imperative to note that none of the above flow diversions would address tidal flood risk on the North Channel and substantial flood defences works would be required to address tidal flooding on that reach. The increased flow from the Curraheen would also result in higher defence levels on the North Channel, compared to the exhibited Scheme.

Figure 13: Longitudinal Section of existing ground levels along possible Curraheen diversion (Inchigaggin route)



5.3 Curraheen Storage Option

The option of providing storage on the Curraheen was also assessed as a potential alternative to diversion. A potential storage area just upstream of Cork Institute of Technology was identified. The location and extent of the storage area is shown on Figure 14 below.

Figure 14: Curraheen potential storage area

While the storage area is severely constrained by existing development in the area, there is the potential for approximately 550,000m3 of storage to be created up to the 11mOD contour. This would involve the construction of a new dam (incorporating a flow control structure) with a maximum height of approximately 2m.

Construction of circa 1m high levees would also be required along the length of channel in the storage area, in order to prevent inundation of the floodplain too early during a flood event.

A preliminary review indicated that the peak flow in the 100 year event could be reduced from 43m3/s to approximately 13m3/s, assuming that the period of attenuation required is limited to 8 hours. This equates to a residual volume passed downstream of approximately 400,000m3. Therefore, as the storage area does not have the volume available to attenuate the Curraheen flow sufficiently to prevent exceedance of the South Channel capacity, it was ruled out as a standalone option.

5.4 Curraheen - Combination of Options

A combination of the Curraheen storage and diversion measures outlined in Section 5.2 and Section 5.3 was also considered. This would potentially have the following advantages over each of the measures in isolation:

- The flow to be conveyed in the diversion culvert could be reduced to approximately 13m^3/s due to the attenuation in the new storage area.
- The available head at the inlet would be increased, which would increase the conveyance capacity of the diversion culvert.
- As a result of the above, the cross section of the diversion culvert could be reduced to approximately 3m wide x 2m high.

This option appears to be technically feasible, therefore it was subjected to further review as outlined hereafter.

6 Summary of Alternative Solution Incorporating Optimum Curraheen/Glasheen Solution

Based on the preceding analysis, we can conclude the following:

- A diversion of the Curraheen via the N40 is not viable, due to excessive cost and disruption to residential areas and traffic flow on the N40 during construction. Also, the limited hydraulic gradient available would make the culvert impractically large to pass the design flow, and would significantly increase downstream flood risk.
- An option of providing storage on the Curraheen is not considered viable as a standalone measure, as insufficient storage volume is available.

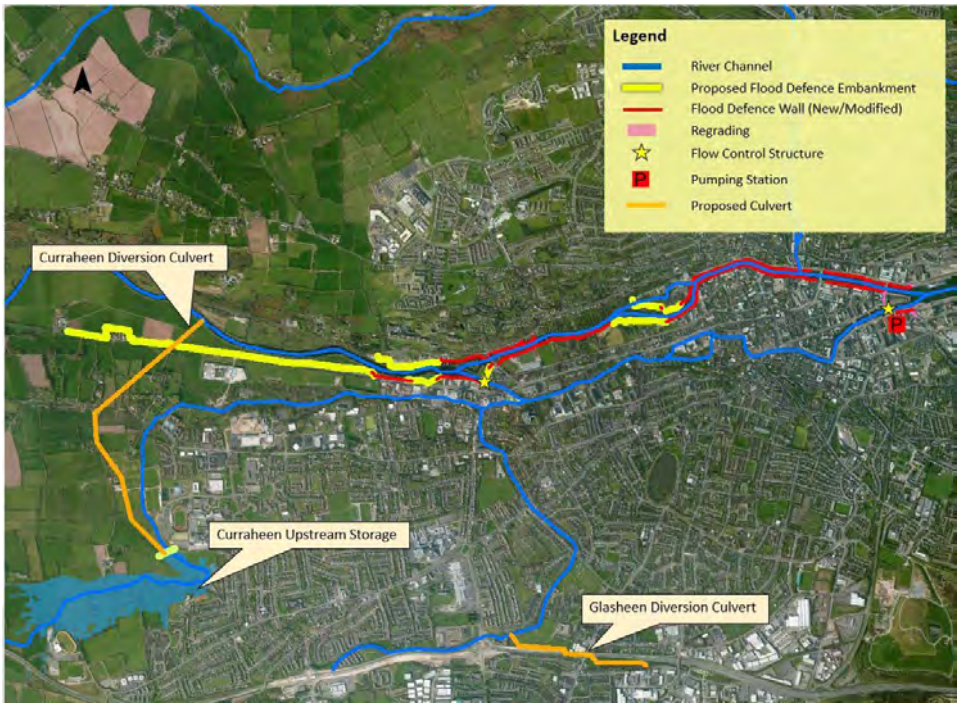
The only measures which cannot immediately be ruled out are:

- Storage on the Curaheen with flood relief diversion to the Lee at Inchigaggin route
- Diversion of the Glasheen into the Tramore via the N40

Therefore, in order to carry out a "like for like" comparison with the other scheme options, the above two measures were combined with other measures required to deliver the design standard of protection in Cork. This option is hereafter referred to as "option 2a" as it is a variation of Option 2 (Isolation of the South Channel) in the Lower Lee FRS Options Report.

These measures required for Option 2a are illustrated in Figure 15.

Figure 15: Combination of measures at Cork City



The measures can be summarised as follows:

- Isolation structures at each end of the South Channel
- Surface water pumping station at the downstream end of the South Channel to cater for the residual fluvial flows from the tributaries plus pluvial flows from the urban catchment
- Increased height fluvial and tidal direct defences along the North Channel
- Flood forecasting & warning system,
- Revised dam operating procedures,
- Upstream washlands
- Storage Area on the Curaheen with flood relief diversion of the Curraheen to the Lee at Inchigaggin
- Diversion of the Glasheen into the Tramore via the N40, including ancillary downstream flood mitigation works.

It is important to note that none of the above mentioned flow diversions would address tidal flood risk on the North Channel and substantial flood defences works would be required to address tidal flooding on that reach. The increased flow from the Curraheen would also result in increased defence levels on the North Channel, compared with the exhibited Scheme.

7 Preliminary Cost Estimate

A preliminary cost estimate was prepared for "Option 2a" as outlined above. The cost estimation methodology utilised was as outlined in the Lower Lee Options Report, Section 13.

A full build-up of costs for option 2a is included in Appendix B.

Table 4 below compares the total costs for option 2 and option 2a.

Table 4: Summary of Costs

	Option 2 – Isolation of South Channel and Direct Defences	**Option 2a – Isolation of South Channel and Direct Defences (tributary diversions)**
	€	€
Measured Items	46,303,494	60,000,000
Prelims (17.5%)	8,103,111	10,500,000
Unmeasured Items (20%)	9,260,699	12,000,000
Subtotal	**63,667,304**	**82,500,000**
Archaeology & Environmental (10%)	6,366,730	8,250,000
Baseline Construction Cost Total	**70,034,035**	**90,750,000**
Contingency / Optimism Bias (20%)	14,006,807	18,150,000
Construction Cost Total	**84,040,842**	**108,900,000**
Fees and Supervision (9%)	7,563,676	9,801,000
Construction & Fees Total	**91,604,518**	**118,701,000**
Land Acquisition (10%)	8,404,084	10,890,000
Art (1% or Cap at €64,000)	64,000	64,000
Site Investigation & Surveys	1,200,000	1,200,000
Capital Cost Total	**101,272,602**	**130,855,000**
Maintenance Costs	18,051,973	23,391,720
Project Cost Total	**119,324,575**	**154,246,720**

8 Conclusion

All of the proposed diversions routes have significant technical, social and environmental constraints due to the location, scale and distances involved.

Having reviewed each of the proposed diversion routes in detail, we have concluded the following:

River Lee Diversion

A partial diversion of the River Lee as outlined in the Irish Rivers 2040 Report is technically unviable and cost prohibitive.

South Channel Isolation

Of the possible measures assessed in this report, a potentially feasible combination of measures ("option 2a") appears to be:

- The majority of works outlined in "option 2" of the Scheme options report (i.e. fluvial defences upstream of Cork, fluvial and tidal defences along the North Channel, and isolation structures at the upstream and downstream ends of the South Channel), excluding defences along the Curraheen and Glasheen, but increased defence heights on the North Channel.
- Upstream Storage on the Curraheen and the flood relief diversion of the residual Curraheen flow into the River Lee at Inchigaggin.
- Diversion of the Glasheen into the Tramore River via the N40 South Ring Road, along with downstream flood defences along the Tramore to mitigate the increased flood risk associated with the additional flows.
- An additional pumping facility at the downstream end of the South Channel to cater for the residual fluvial flows from the tributaries plus pluvial flows from the urban catchment.

This option has a number of considerable drawbacks compared with the exhibited scheme as follows:

- Higher defences would be required on the north channel.
- The omission of direct defences at the eastern end of the south channel could be seen as a positive in terms of minimising impact on the existing quay walls. However, the proposed investment in quay wall remedial works along this reach (proposed as part of the exhibited scheme) would not form part of an option to isolate the South Channel. Therefore the condition of the existing quay walls would continue to deteriorate.
- There would be a significant increase in residual flood risk for those people living downstream of the proposed storage area in Curraheen due to the risk of breach.
- There would also be a significant increase in risk and/or considerable disruption in undertaking mitigation works for those people living adjacent to the Tramore valley downstream of the proposed diversion tie-in point.

- The downstream isolation structure on the south channel may increase siltation at the downstream end of the south channel. This would require further assessment and may necessitate the provision of mitigation measures.
- A preliminary cost estimate for option 2a was prepared and it was found to be significantly more expensive than all of the options presented in the Scheme options report.

Therefore, considering all of the above, "option 2a" developed in this report is considered unlikely to be more preferable to the exhibited Scheme.

In conclusion, the findings of this report confirm that all of the suggested diversions have significant technical and environmental constraints due to the location, scale and distances involved in the proposals, meaning that all suggested diversions are unfeasible, either technically, environmental or economically.

Appendix A

Flood Risk Mapping

A1 Extracts from Lee CFRAM Flood Maps

Figure 16: Extract from CFRAM flood maps showing Curragheen and Glasheen River

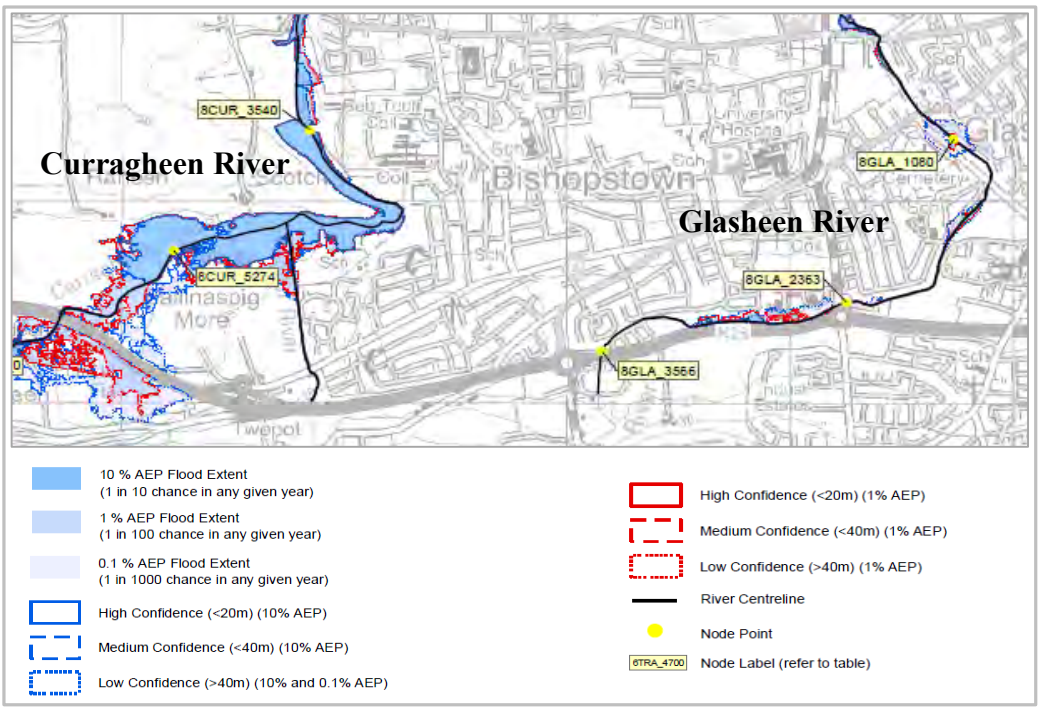


Figure 17: Extract from CFRAM flood maps showing upstream reach of Tramore River – Fluvial Flooding

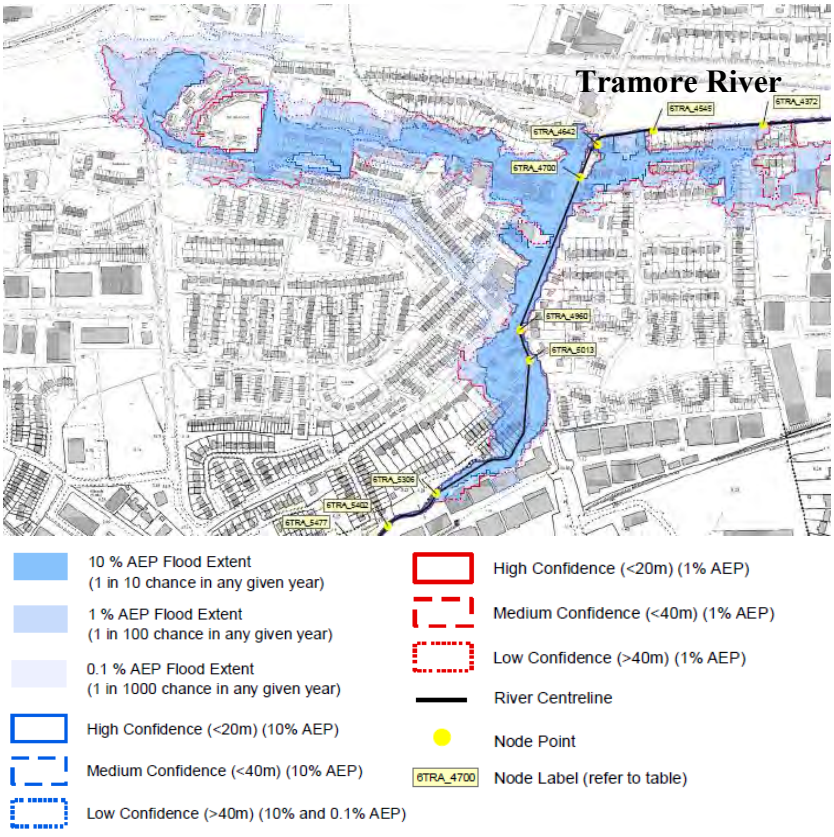
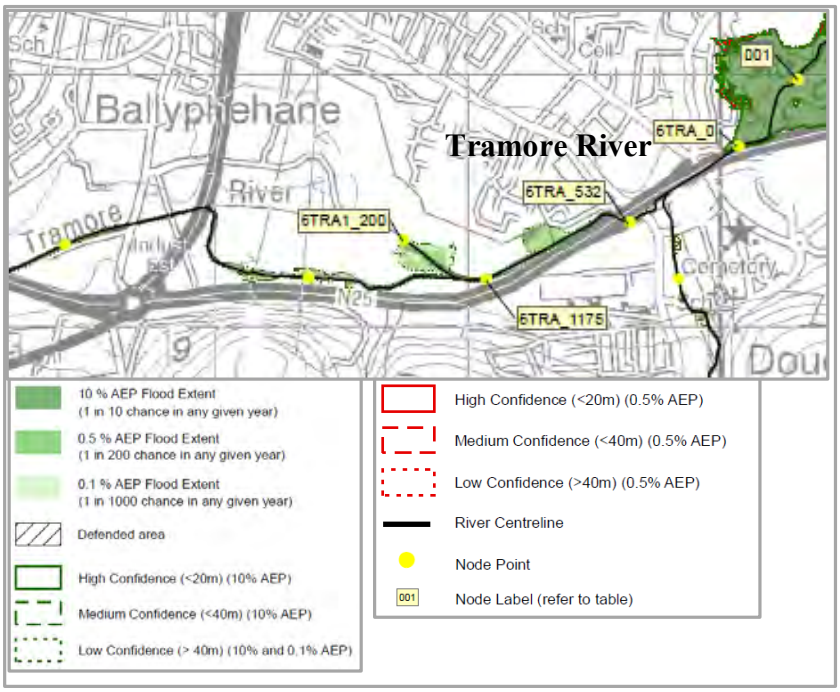


Figure 18: Extract from CFRAM flood maps showing Tramore River – Tidal Flooding



Appendix B

Preliminary Cost Estimate

Cost Estimate			Job No:		230436-00
			Sheet No:		1
Project Title	Lower Lee Flood Relief Scheme		Date:		November 2017
Number	Item Description	Unit	Quantity	Rate €	Total €
	Measured Items Cost for Option 2a - Isolation of South Channel (with Curaheen and Glasheen Diversions)				
1.1	Curaheen Diversion culvert (2km)	m	2000	3500	7,000,000
1.2	Curaheen upstream storage (including flow control structure and embankments)	Prov Sum			2,500,000
1.3	South Channel pumping station	Prov Sum			3,000,000
1.4	Glasheen diversion culvert (incl N40 roadworks)	m	1000	5000	5,000,000
1.5	Allowance for flood mitigation works downstream on the Tramore River	Prov Sum			4,000,000
1.6	Remainder of works as per "option 2", (excluding Curraheen and Glasheen direct defences)	Prov Sum			36,700,000
1.7	Cost of increased defence heights on North Channel	Prov Sum			2,000,000
	Total				**60,200,000**