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N8-N25 Dunkettle Interchange
Flood Risk Assessment Report

Detailed Assessment of Flood Risk

Report Date: July 2012
Report Reference: 2012-07-05_32102600_Rep_FRAReport_D02_V05.doc

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Document Control Sheet

BPP 04 F8
Version 7 April 2011

Client: National Roads Authority   Project No: 32102600
Project: N8-N25 Dunkettle Interchange Flood Risk Assessment
Document Title: N8-N25 Dunkettle Interchange Flood Risk Assessment Report
Ref. No: 2012-07-05_32102600_Rep_FRAReport_D02_V05.doc

	Originated by	Checked by	Reviewed by	Approved by
ORIGINAL D01	NAME [signature]	NAME [signature]	NAME [signature]	NAME [signature]
DATE	INITIALS EDR	INITIALS DRD	INITIALS ACD	INITIALS ACD
September 11	Document Status	Issue (D01)		
REVISION D02	NAME [signature]	NAME [signature]	NAME [signature]	NAME AMG
DATE	INITIALS DRD	INITIALS ACD	INITIALS ACD	INITIALS AM
July 2012	Document Status			
REVISION	NAME	NAME	NAME	NAME
DATE	INITIALS	INITIALS	INITIALS	INITIALS
	Document Status			
REVISION	NAME	NAME	NAME	NAME
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1 Introduction

1.1 The Dunkettle Interchange

The Dunkettle Interchange is situated to the East of Cork, immediately North of the River Lee Estuary (see Figure 1-A). The existing interchange is the junction of a number of key routes including the N8, M8, and N25 as it passes through the Jack Lynch Tunnel beneath the River Lee.

The current interchange is used by approximately 95,000 vehicles a day. This is significantly above capacity, which results in severe traffic congestion. It is proposed that the existing interchange should be improved through engineering works to add capacity and reduce congestion.

The National Roads Authority (NRA) has appointed Jacobs Engineering to progress the proposed improvements, including the development of this Flood Risk Assessment (FRA). The preferred option has been selected after a consideration of a number of potential routes and designs. Flood risk management was a significant factor in the design process.

1.2 Description of the Proposed Site

The existing Dunkettle Interchange is situated above an area of inter-connected tidal wetlands and ponds. The interchange itself is situated in the west of the site area, with the main N25 running east to west and the N8 running south to north. The roads are raised above the wetlands areas on artificial embankments.

The wetlands are interconnected to each other, and to the Cork Harbour Estuary, by a series of culverts, the majority of which are large diameter pipe culverts. The wetland areas act as a series of individual basins, which are filled and emptied sequentially as the tide rises and falls.
Figure 1-B presents a schematic of the wetland areas showing the movement of water. A detailed layout of the site, the wetland areas, and the location of the key structures, is shown in Figure 1-C.

The detailed dynamics of the wetlands and how they fill and empty has been modelled in detail as part of the overall design process. The influence of the existing culverts heavily influence flows in and out of the individual basins.

The topography of the site is predominantly flat due to its proximity to the estuary. The key topographic constraints on the site are the artificial embankments carrying the existing interchange. Immediately to the north of the railway line the ground rises steeply up to Tower Hill. Figure 1-D is a topographic map of the area.

There is little urban development in this area at present. As indicated on Figure 1-C, to the north of the North Esk Mudflats there is a small industrial estate, the North Esk Business Park, and a group of unnamed houses. The Iarnród Éireann Depot in the east of the site constitutes a large area of hard-standing but is predominantly abandoned. To the south of the site the Pfizer works occupies most of the southeast corner of the site.

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1.3 Description of the Proposed Works

The proposed improvements to the Dunkettle Interchange are intended to increase the capacity of the junction by allowing a greater volume of traffic to flow unobstructed through the junction from south to east and vice versa. An overview of the proposed layout can be seen in Figure 1-E.

The proposed scheme was chosen following a 3 stage appraisal process which considered various infrastructural and traffic management alternatives. Alternatives were ultimately assessed in terms of the 5 common appraisal criteria comprising Economy, Safety, Environment, Accessibility and Integration.

The scheme comprises the provision of an improved interchange at the location of the existing Dunkettle Interchange at the intersection of the N8, the N25 and the N40 in County Cork.

The improvement essentially comprises the introduction of free flow traffic links between the existing road arteries served by the existing interchange. Various additional works are required to accommodate these free flow links, most notably several structures to allow the links to pass over and under each other. The proposed scheme includes the following works;

- *A series of direct road links between the N8, the N25 and the N40 and links to the R623 Regional Road in Little Island and Burys Bridge in Dunkettle*
- *1 grade separated junction arrangement at the existing N25 approximately 650m to the east of the existing Dunkettle Interchange*
- *4 roundabouts – 2 at the grade separated junction and 2 at the tie ins with the local road network in Burys Bridge and Wallingstown*
- *43 major structures of various forms comprising:*
  - *1 overbridge and 7 underbridges*
  - *2 railway bridges and 1 footbridge*
  - *modification of the northern approach structure to the Jack Lynch Tunnel*
  - *7 retaining walls and 24 gantries*
- *Several culverts where the scheme crosses watercourses or intertidal areas*
- *Pedestrian and cyclist facilities*

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Figure 1-A Dunkettle Interchange Site Location

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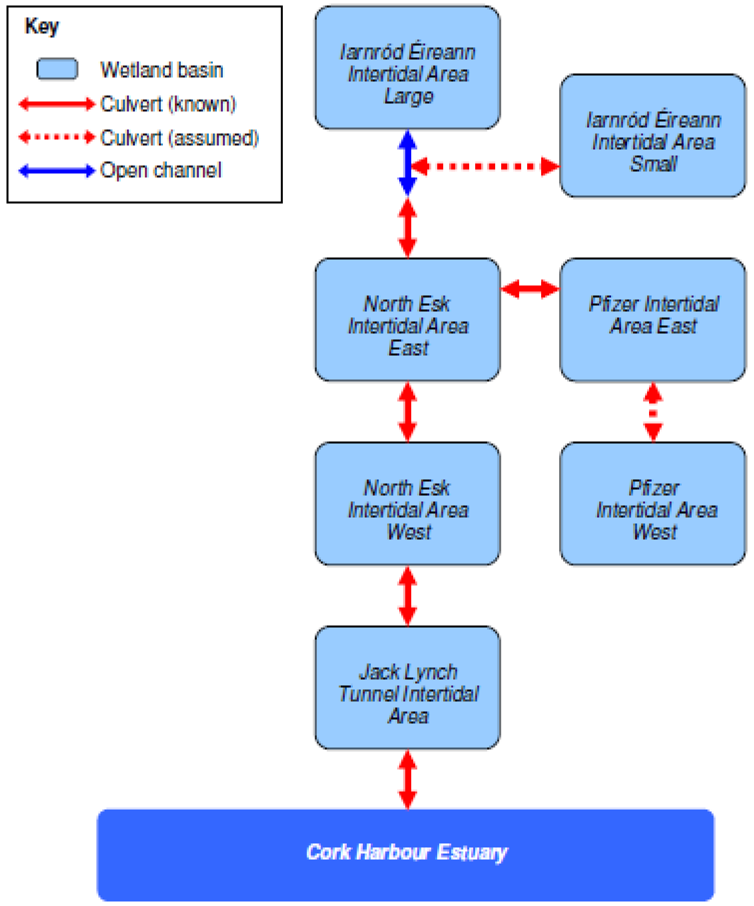

Figure 1-B Schematic Representation of the Existing Wetland Areas

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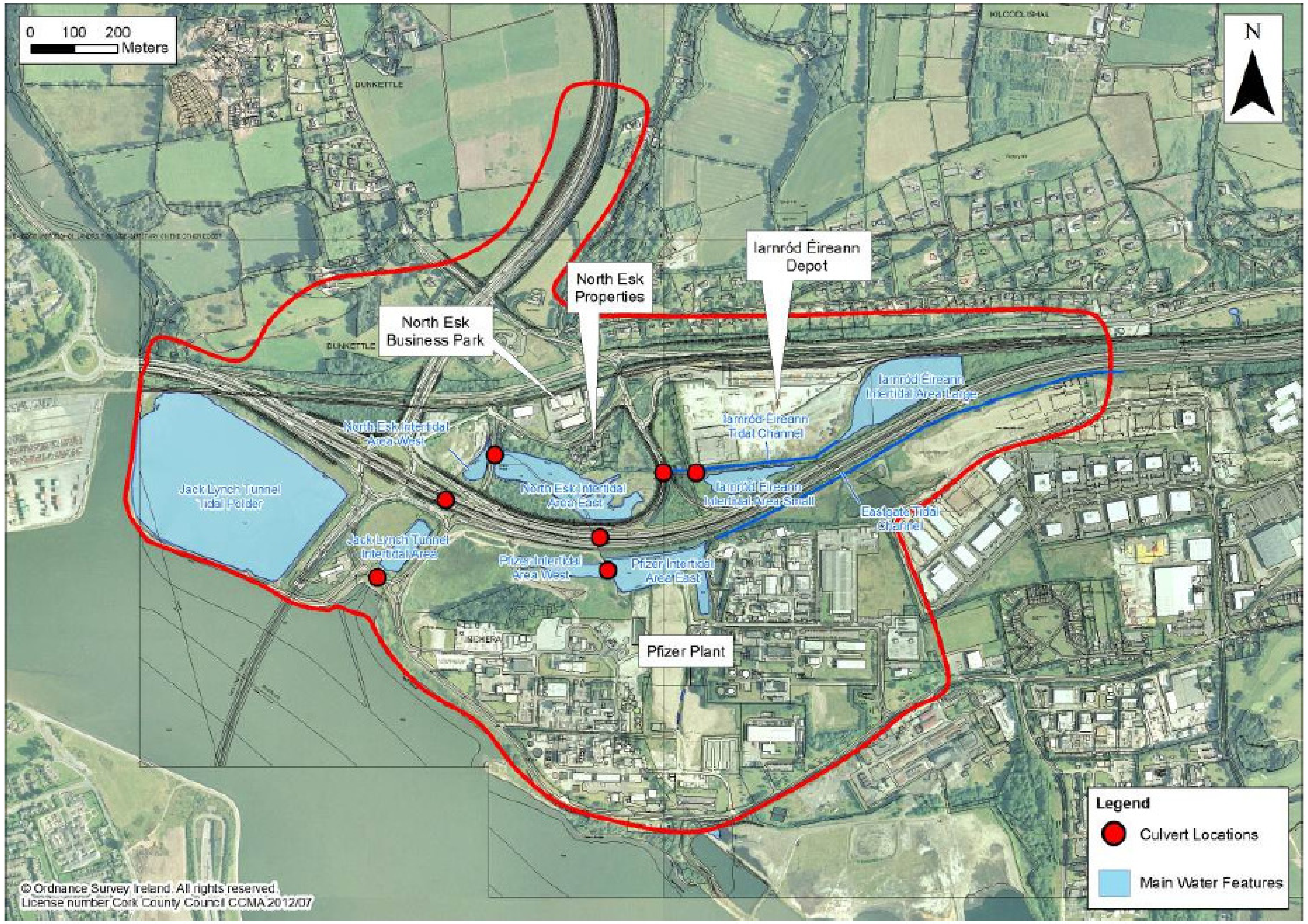

Figure 1-C Site Plan and Key Locations

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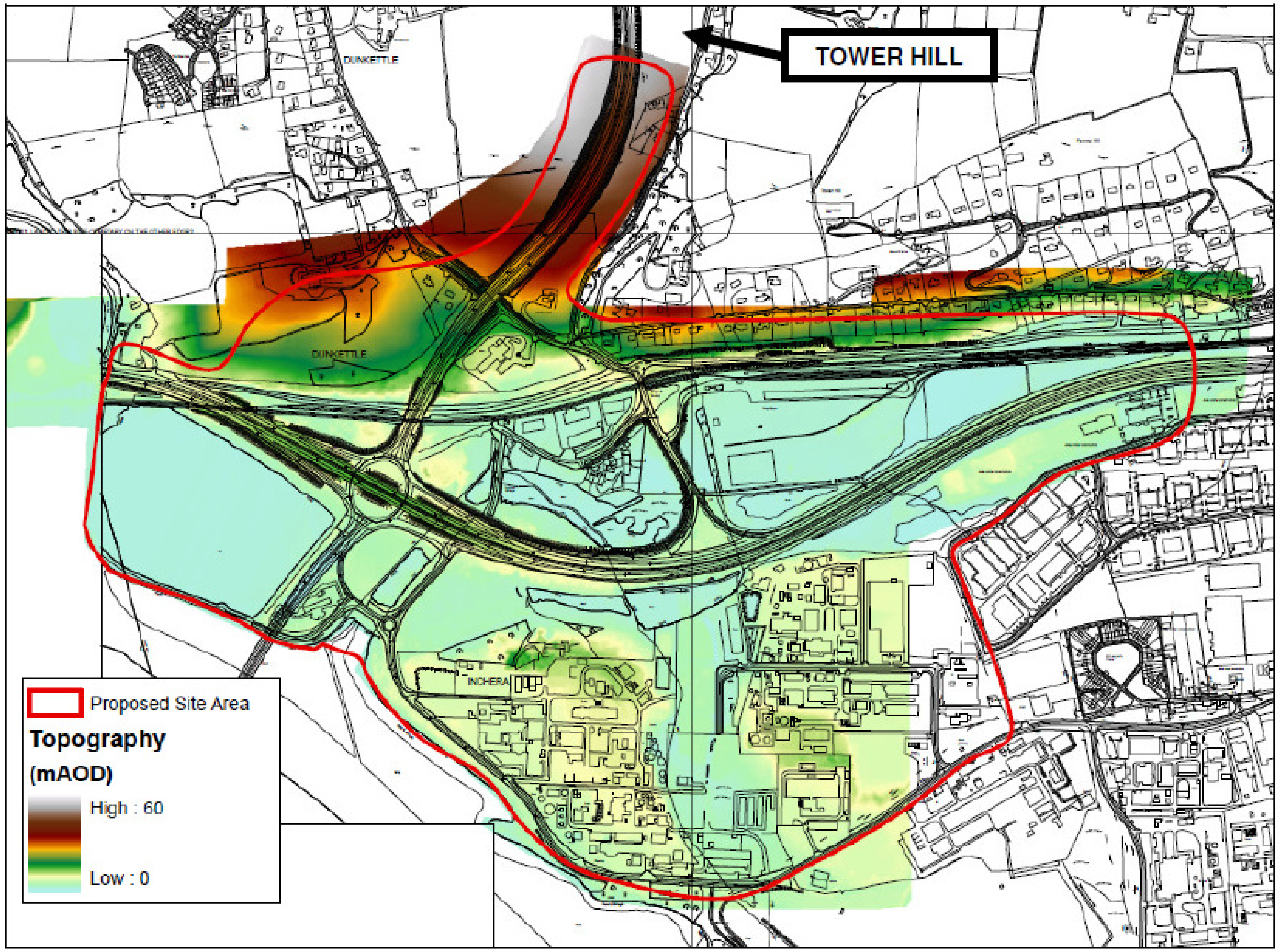

Figure 1-D Topographic Map

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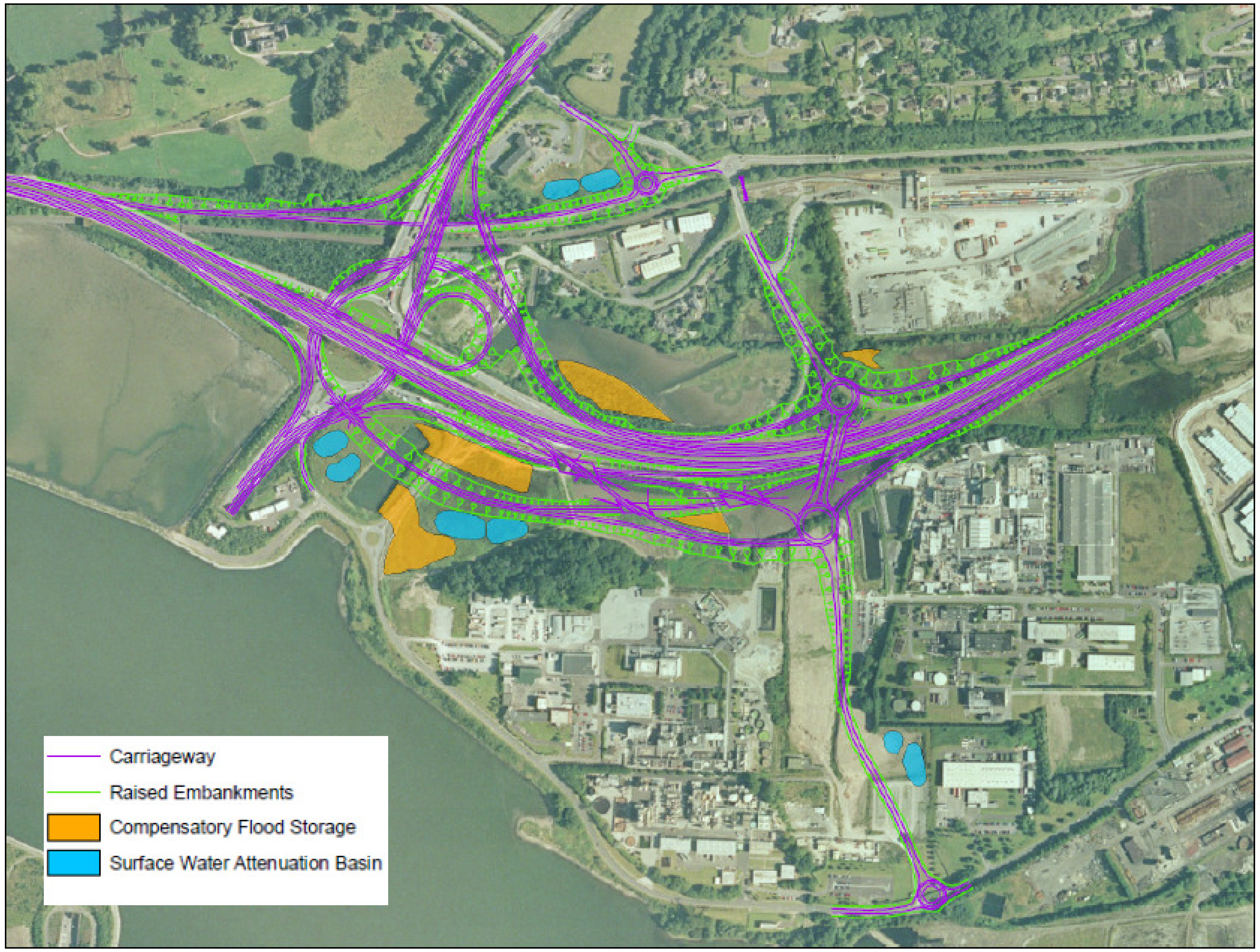

Figure 1-E Proposed Scheme Layout

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2 Background to the Flood Risk Assessment Process

This section provides an overview of the legislative background covering flood risk and development control in Ireland. It is intended to provide a basic understanding of the reasons for, and the objectives of, a Flood Risk Assessment exercise.

For full details of how flood risk is considered by Irish planning legislation, reference should be made to Guidelines for Planning Authorities 20: The Planning System and Flood Risk Management (GPA20).

2.1 The Flooding Problem

Flooding is a natural process that can happen at any time in a wide variety of locations. Flooding can come from rivers or the sea, as well as from prolonged or intense heavy rainfall which can cause sewer, overland flow and groundwater flooding. The frequency, pattern and severity of flooding is likely to increase as a result of climate change.

Flooding has significant impacts on human activities. People who live and work in areas at risk from flooding have to deal with the day to day threat of risk to life, property and belongings. Following a flood event, the clean-up and repairs to rectify the damage can take months or years. The impact in terms of health can be significant, even after the event. Studies have shown that the stress caused by flooding can have serious long-term health consequences.

For business and the economy, the impacts of flooding can be far-reaching. After a flood many businesses fail to reopen or re-locate to other areas.

Flooding to infrastructure often has an immediate risk to life. For example road traffic accidents as a result of flooding to roads can result in death. The disruption caused by damage to infrastructure can be extremely expensive to rectify. Furthermore, the inconvenience and disruption can have long-term impacts on local communities.

In the past, poor planning decisions have increased the level of flood risk by allowing new developments to be constructed in flood-prone areas without the necessary mitigation and resilience measures.

The planning system plays a major role in ensuring development is promoted and guided in a manner that is sustainable in economic, social, and environment terms and at an acceptable risk from flooding. The current guidelines for planning and flood risk are explained below.

2.2 Guidelines for Planning Authorities 20: The Planning System and Flood Risk Management

GPA20 emerged from the 2004 Report of the Flood Policy Review Group. The report highlighted the need to pro-actively manage flood risk and the important role that the planning system plays in avoiding and reducing flood risks to new developments.

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The key principles of flood risk management laid out in GPA20 are:

- ***Avoid** development in areas at risk from flooding, unless there are proven wider **sustainability grounds** that justify development. Where this is the case development must be **appropriate** and flood risks must be effectively **managed** to reduce the level of risk.*
- *Adopt a **Sequential Approach** to flood risk management when assessing the locations for new development based on **avoidance**, **reduction**, and **mitigation** of risk.*
- *Incorporate flood risk assessment into planning application decisions and appeals.*

2.3 The Sequential Approach

GPA20 recommends that a Sequential Approach is taken for flood risk management for new developments. This approach is summarised in Figure 2-A.

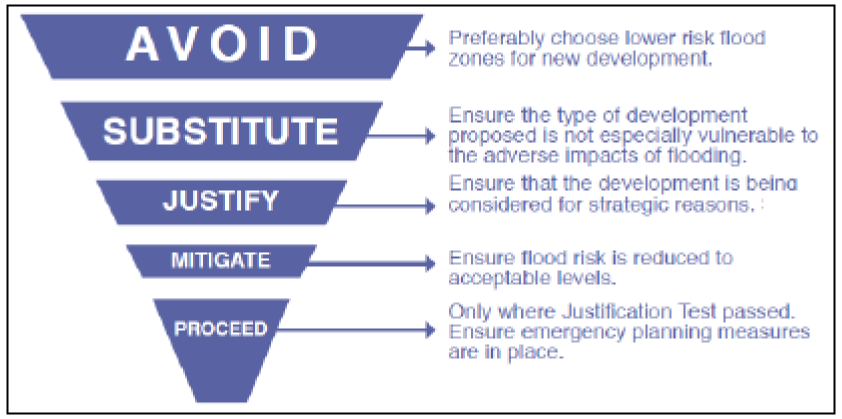

***Figure 2-A** Sequential Approach Principles in Flood Risk Management (GPA20 Section 3 Figure 3.1)*

It is not possible in the case of the proposed Dunkettle Interchange to avoid the flood risks, or substitute the development type at this location, and the proposed development is part of the strategic redevelopment of the road network in this area and therefore meets the requirements of the Justification Test.

Consequently, it is necessary to consider the risk of flooding to the proposed development, the risk that the development will increase risk elsewhere and provide mitigation of these risks as appropriate.

2.4 Assessing Flood Risk

GPA20 outlines the key principles that should be used to assess flood risk to proposed development sites.

It is recommended that a staged approach to flood risk assessment should be used:

- ***Stage 1 Flood Risk Identification** – to identify any flood risks that may warrant further investigation*
- ***Stage 2 Initial Flood Risk Assessment** – to confirm sources of flooding, to appraise the availability of existing information and to assess the potential for mitigation measures*
- ***Stage 3 Detailed Flood Risk Assessment** – to allow design of the proposed development and assess the effectiveness of proposed mitigation measures.*

2.5 Purpose of this Assessment

This FRA has been developed to ensure that the proposed development for the Dunkettle Interchange meet the requirements of GPA20.

The proposed development is potentially at risk from flooding from various sources. Furthermore, its construction could result in changes to flood risk characteristics in other areas. This would be unacceptable in planning terms.

This report represents the findings of a **Detailed Flood Risk Assessment** which has built upon the findings of an Initial Flood Risk Assessment undertaken earlier in the planning and design process.

It provides an overview of the potential flood risks to the proposed site and assesses the potential impact of the proposed option. These impacts, where appropriate, have been quantified through the construction of a detailed hydraulic flood model.

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3 Flood Risk to the Proposed Development Site

Early in the design and selection process for the preferred option of the Dunkettle Interchange it was identified that some elements of the scheme could be at risk of flooding from a range of different sources.

In this section, the flood risks to the site are identified and details on how the scheme has managed these risks, where necessary, are discussed.

3.1 Potential Sources of Flooding

Due to the location of the site and the size of the proposed development, it could be at risk from several sources of flooding, these are listed below:

- ***Coastal*** *- flooding from the sea*
- ***Fluvial*** *- flooding from rivers and watercourses*
- ***Estuarine*** *- flooding from a combination of fluvial and coastal*
- ***Overland Flow*** *– flooding that is caused runoff during high rainfall events*
- ***Artificial Drainage Systems*** *– flooding that occurs as a result of surcharging or blocking of drainage networks*
- ***Groundwater*** *– flooding when water normally stored below the ground rises above surface level or into below ground spaces (such as basements)*

3.2 Assessment of Flood Risks

3.2.1 Coastal Flooding

The Dunkettle Interchange is situated on the north coast of the Cork Harbour Estuary, a major estuary off the Irish Sea. The site is therefore potentially affected by coastal flooding mechanisms.

Coastal flooding is caused by higher sea levels than normal, resulting in the sea overflowing onto the land. Coastal flooding is influenced by three main factors, which often work in combination. These are:

- ***High tide levels*** *– caused by normal, and predictable, astronomical factors.*
- ***Storm surges*** *– where sea levels are artificially raised by areas of low barometric pressure such as depression weather systems.*
- ***Wave action*** *– this is dependant on wind speed and direction, as well as local topography and exposure.*

With regards to wave action, the site's location in Cork Harbour Estuary effectively shelters it from significant wave action. Also, the wetlands that form the majority of the site are separated from the estuary itself by an embankment and are thus further protected. It is considered that wave action is likely to represent a low risk to the development and it has not been considered further within this FRA.

The coastal flood risk from high tides and storm surges has the potential cause significant flooding to the site during major events. In order to identify this risk, further investigations have been undertaken and a detailed hydraulic model has been constructed. The results of this assessment are discussed in Section 3.3.

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3.2.2 Flood Risk from Fluvial Flooding

Flood risk from fluvial sources on the site is limited to three small streams. These are shown in Figure 3-A.

The largest of these, Richmond Park Watercourse, flows off Tower Hill to the north of the site and enters culvert to the north of the North Esk Business Park. This stream flows in culvert beneath the business park and enters the westerly North Esk Wetland at Inchera Bridge.

This watercourse is a minor one, but it has a small, steep catchment and will react rapidly to rainfall on the hills to the north of the site. Should the culvert beneath the North Esk Business Park block there is the potential for overland flows across the site, potentially affecting the railway line, North Esk Business Park and the North Esk Properties.

There are also two small drains associated with the Pfizer and Iarnród Éireann wetlands. These drains are tidally influenced and have small catchments.

The volumes of flow associated to the three watercourses have been assessed using a range of hydrological techniques (detailed in Appendix B). The results from the most conservative estimate, i.e. the technique that produces the highest flows, are given below in Table 3-A. The table provides peak flows for flood events of different annual probabilities (AP).

Watercourse	Peak Flow (m^3/s)						
	50%AP	20%AP	10%AP	4%AP	2%AP	1%AP	0.5%AP
Richmond Park Watercourse	0.95	1.32	1.53	1.93	2.25	2.56	2.93
Iarnród Éireann Drain	0.21	0.27	0.31	0.38	0.45	0.53	0.62
Pfizer Drain	0.30	0.39	0.45	0.54	0.63	0.75	0.88

Table 3-A: Results of Hydrological Investigations (using FSSR16)

Following a review of the flows associated with these watercourses, the risk of flooding from them is considered to be low and they are highly unlikely to impact development on the site. This is because the carriageway of the road is raised significantly above the level of the floodplain.

In addition to the minor watercourses within the site, the major Glashabouy River flows into the estuary to the west of the site. This watercourse falls outside the site boundary and it is not considered that this watercourse will have a significant flood risk to work on the proposed site.

In summary, the assessment has determined that fluvial flood risk to the proposed development is low.

3.2.3 Flood Risk from Estuarial Flooding

As previously noted, the proposed site is separated from the main Cork Harbour Estuary by a culvert between the Jack Lynch Tunnel Wetland and the site estuary itself.

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Initial investigations identified that a coastal flooding event that coincided with fluvial event, could cause an increase in flood levels. The increase flood levels may pose a risk to the development.

In order to assess this risk, the contributing flows from the watercourses (shown in Table 3-A) have been included within the hydraulic model. The results of the modelling are contained in Section 3.3.

3.2.4 Flood Risk from Overland Flow

The topography to the north of the site is very steep and there is the potential for overland flow from this area to flow onto the site, potentially resulting in flooding. However, running between the site itself and the foot of Tower Hill is a local road and the railway line. Both of these features represent potential barriers to surface water flows, both topographically and because they will have their own drainage systems for conveying surface water. This is likely to limit overland flow onto the site.

In addition, the majority of proposed development is centred around the existing interchange. This is situated in the centre of the site approximately 500 metres from the base of Tower Hill. It is unlikely that overland flow from Tower Hill would impact upon the Interchange.

The risk of flooding as a result of overland flow significantly impacting on the development is therefore considered to be low.

3.2.5 Flood Risk from Artificial Drainage Systems

The existing road network and urban development on the proposed site is served by surface water drainage systems. Should these systems block, or if a rainfall event occurs that exceeds the discharge and storage capacity of these systems, flooding of the carriageways and surrounding areas could occur.

These drainage systems are maintained by the NRA in order to ensure that they work correctly and do not become blocked. As it has been demonstrated that overland flow from rural areas onto the existing interchange is a low risk, it is unlikely that significant amounts of debris would be washed onto the carriageway that could result in a blockage.

The risk of flooding from artificial drainage systems is therefore considered low.

3.2.6 Flood Risk from Groundwater

The Geological Survey of Ireland Groundwater Aquifer map, presented in Figure 3-B, indicates that the proposed site sits above two different aquifers. The majority of the site including the existing interchange is situated over a Locally Important Aquifer and the southern half of the site over a Regionally Important Aquifer.

Due to the low-lying nature of the site there is the potential for prolonged rainfall to raise the groundwater level within these aquifers above ground surface level, resulting in flooding.

However, the proposed interchange is raised above the ground level onto artificial embankments which will place the road above potential groundwater flooding issues. Therefore, the risk of flooding to the site is considered to be low.

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3.3 Results of Hydraulic Modelling

The initial assessment of the risk to the site and the development indicated that there could be a risk from coastal and estuarine flooding (i.e. the combination of fluvial and coastal sources).

In order to determine the risk with a sufficiently high degree of accuracy, a hydraulic model was constructed. The construction of the model allowed assessment of the different sources of flooding together and to test a number of different scenarios. The full modelling report is contained in Appendix B and the results of the assessment are summarised below.

In a 0.5% (1 in 200) annual probability storm event, several locations within the site would be affected by flooding without the proposed development in place. The areas at risk and peak water levels in key locations are shown in Figure 3-C.

Water levels across the site will vary as water is transferred from one intertidal basin to the other during the event. The peak water level anywhere across the study area in the existing situation is approximately 2.36mOD.

The modelled water levels indicate that the risk to the proposed development is low. The level of the carriage way of the proposed development in the areas vulnerable to the effects of flooding will be a minimum of 3.5mOD. This is 1.14m above peak levels.

3.4 Future Flood Risk

It is widely predicted that the climate in Ireland will change in the future, leading to increases in sea level, storm event magnitude and frequency, and rainfall depths, intensities and patterns[1].

It is therefore necessary to consider what impact this might have on flood risk to the proposed development.

Although climate change is likely to increase the risk from fluvial and surface water, the assessment has indicated that these risks are already low and it is not considered that climate change will significantly increase the risk of flooding.

Increased runoff into drainage systems could significantly increase the risk of flooding from artificial drainage systems, above the high level of risk indicated by the present day assessment. However, the drainage design for the site will be managed through a drainage strategy which, based upon NRA guidance, will include an allowance for climate change. It is therefore considered that the impacts of climate change on site drainage will be suitably managed without specific mitigation measures being required.

3.4.1 Tidal Flooding

Tidal flood risk will be significantly increased by climate change as this will lead to increases in sea level, and consequently tide level. The OPW Guidance includes two potential climate change scenarios; the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario HEFS.

[1] Office of Public Works, Assessment of Potential Future Scenarios for Flood Risk Management Draft Guidance

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Scenario	Description	Mean Sea Level Rise
MRFS	Intended to represent a likely future scenario, based on the wide range of predictions available and with the allowances for increased sea level within the bounds of widely accepted projections.	+500 mm
HEFS	A more extreme potential future scenario, but one that is nonetheless not significantly outside the range of accepted predictions available, and with allowances for increased sea level at the upper bounds of widely accepted projections.	+1,000 mm

Table 3-B OPW Climate Change Scenarios

Due to the nature of this assessment it has been decided that a precautionary approach will be taken, and the HEF Scenario has been used to determine potential future tidal flood risk.

The modelling of the existing flood risk situation indicates that the maximum water levels within the site are 2.36mOD 0.5% (1 in 200) annual probability flood event. Therefore, with climate change, levels of 3.36mOD have been assumed. Assuming that all levels will propagate into the site with no drop in water levels is a conservative approach.

With a minimum carriageway level of 3.5mOD, this assessment indicates that both the proposed road and the existing elements of the road are significantly above the level and would not be affected by flooding. The risk to the proposed development from climate change has been assessed as low.

3.5 Summary of Flood Risks to Proposed Development

Flood Risk	Summary of Risk to Development	Notes
Coastal	Low	*Results confirmed by modelling.*
River	Low	*Results confirmed by hydrological study.*
Estuarial	Low	*Results confirmed by modelling.*
Overland Flow	Low	*Limited connectivity between high ground to the north and main site area.*
Artificial Drainage Systems	Low	*Highway drainage systems managed by the NRA.*
Groundwater	Low	*Carriageway situated high above surrounding ground level.*
Climate Change	Low	*Increased sea levels likely to significantly increase tidal flood risk but not to the development*

Table 3-C Summary of Flood Risks to Proposed Development Site

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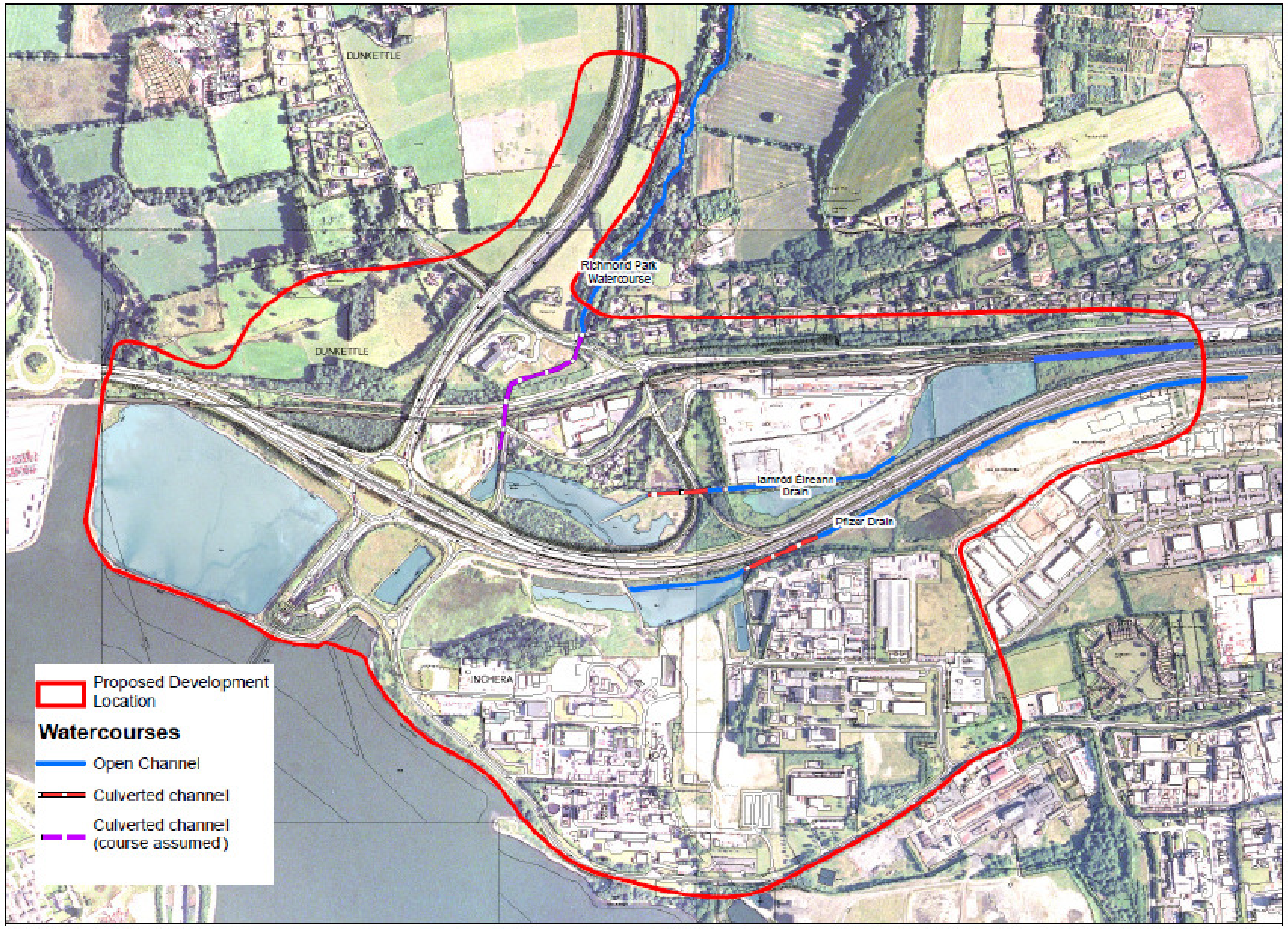

Figure 3-A Watercourses within the study area

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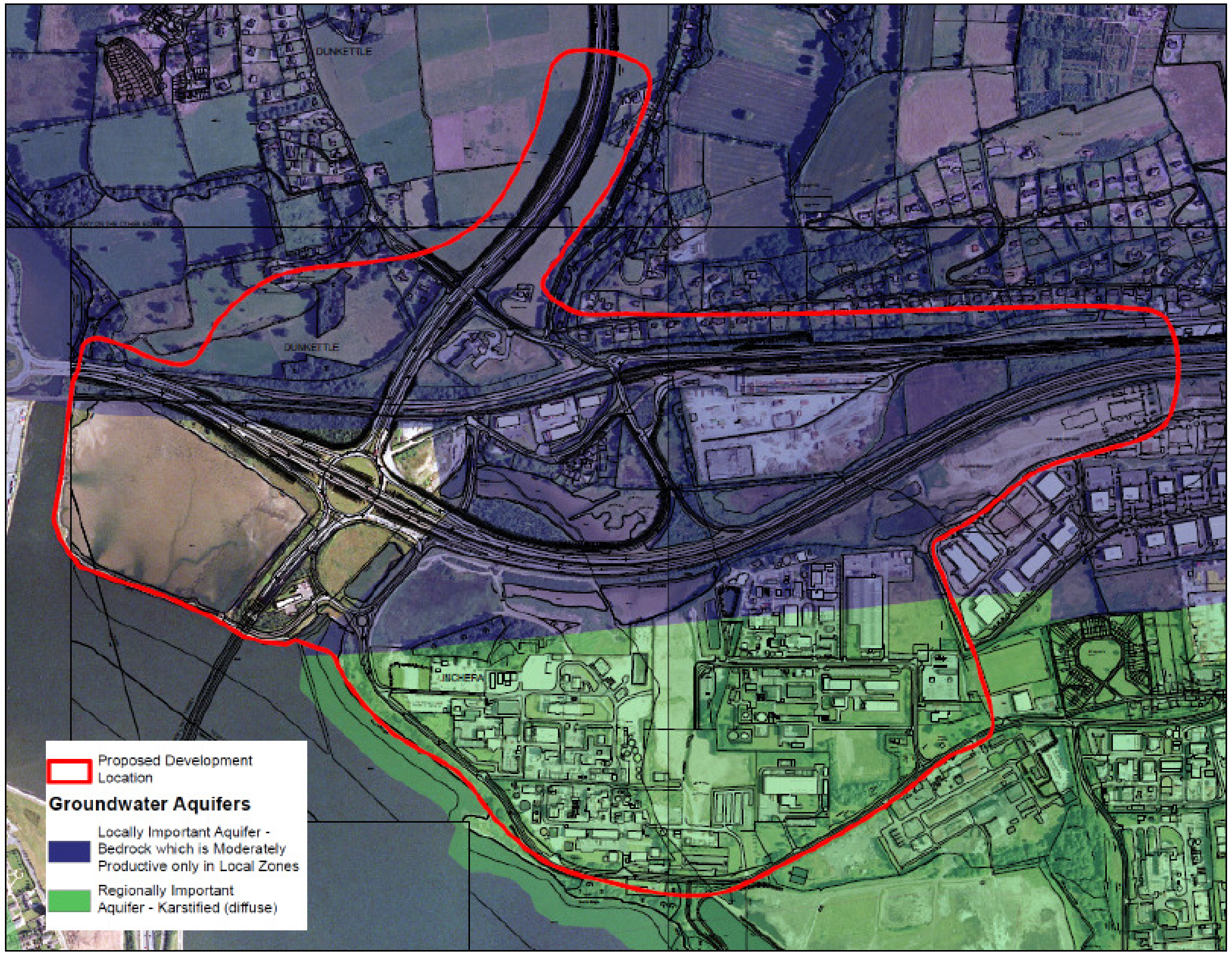

Figure 3-B Major Groundwater Aquifers

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Figure 3-C Extents of flooding in a 0.5% (1 in 200) annual probability flood event

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4 Potential Flood Risk Impacts from Development on the Proposed Site and Elsewhere

Whilst development sites, and the proposed development, can be at risk from flooding it is also possible for development to cause changes to wider flooding patterns and mechanisms, which can increase flooding in other areas. This section examines the potential impacts the development has in other areas in more detail.

4.1 Impacts on Coastal, Fluvial and Estuarine Flooding

The proposed development is highly unlikely to affect the risk of coastal flooding elsewhere (outside of the site). The impact of any potential coastal floodplain loss would be so low, that the in the context of the volume of the sea and Cork Harbour, the difference could not be measured.

Within the development site itself however, flood risk to vulnerable receptors could be increased through several mechanisms. These are:

- ***loss of floodplain*** *– by the construction of embankments in areas at risk of flooding thereby reducing the volume of storage available*
- ***altered flow dynamics*** *- through removal and replacement of channels and culverts*
- ***increased surface water discharge*** *– as a result of additional runoff from the new sections of highway which increase the total area of impermeable surfaces*

The impacts of these mechanisms have been investigated in more detail and the findings are discussed below.

4.1.1 Impact of Floodplain Loss and Altered Flow Dynamics

These potential impacts have been identified through hydraulic modelling of the proposed scheme. The additions to the model include:

- *proposed raised embankments*
- *amendments to culvert locations and sizes*
- *compensatory flood storage areas*

Figure 4-A shows the area of floodplain lost and the location where compensatory storage will be placed to reinstate this floodplain.

Figure 4-B shows the impact of the proposed development on water levels during a 0.5% (1 in 200) annual probability flood event.

From these results, a small 100mm increase in water levels in the Pfizer Intertidal Areas can be identified. However, this is an area where there are no receptors vulnerable to the effects. Conversely, there is a small decrease in water levels in the intertidal areas north of this location. In these areas, there are receptors that are vulnerable to flooding and the flood risk to them has decreased slightly.

The results show that the proposed changes to the site layout will have negligible impact on flood risk from coastal, fluvial and estuarine sources.

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4.1.2 Impact of Additional Surface Water

The new sections of road will add approximately 5ha of impermeable area within the site to approximately 9ha of impermeable area in total. The addition of these sections has the potential to increase the volume and rate of surface water entering local watercourses, water bodies and existing drainage systems.

However, discharges from the existing road infrastructure are currently uncontrolled. This means that they enter the local environment without any attenuation and without any treatment to improve water quality.

The proposed scheme will include provisions to intercept this runoff and manage it through a new SUDS based system which includes treatment and attenuation in several surface water basins.

The majority of runoff from the proposed scheme and the existing road will also be managed within the new SUDS based drainage system. The effect will be an overall reduction in discharges from the present day scenario. Currently, in a 2% (1 in 50) annual probability rainfall event, the discharge into the surrounding water bodies is approximately 662l/s from the existing impermeable area alone. This will fall to 140l/s for the entire site (existing and proposed) following the construction of the scheme.

There will be a small section of the scheme which will discharge to a pipe network in Jack Lynch Tunnel. There is no increase in flows or contributing area to this network. Consequently, there will be no impact on the capacity of this network.

By providing a significant overall reduction in the volume and rate of flows from the present day. The proposed scheme will fully mitigate any potential impacts on flood risk.

4.2 Impacts on Overland Flow

New development can alter existing flow-paths and drainage routes, potentially causing overland flow to flood areas that are not currently susceptible to flooding. However, there are no identified significant overland flow routes on the site.

It is therefore unlikely that proposed development on this site would have a significant impact on the risk of flooding as a result of overland flow.

4.2.1 Flooding from Artificial Drainage Systems

Additional development on this site will increase the number of artificial drainage systems in operation. This could potentially increase the risk of flooding as a result of a failure of one of these systems. However, the fact that the proposed scheme is adding attenuation and reducing the overall volume of flows being discharged, means that there is a low probability of the development increasing flood risk from this source.

It is also worth noting that the proposed drainage design has been developed in consultation with the following bodies:

- *National Parks and Wildlife Services (NPWS)*
- *Inland Fisheries Ireland (IFI)*

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4.2.2 Groundwater Flooding

Although parts of the proposed site are at risk of groundwater flooding, it is unlikely that proposed development on this site would significantly impact on the risk of flooding from groundwater in other areas.

Minor surface works do not significantly impact on groundwater aquifers and the proposed works on this site do not require significant excavations or large areas where below-ground works are proposed. It is considered that the potential for development to increase the risk of groundwater flooding is low.

4.3 Summary of Impacts on Flood Risk

Flood Risk	Summary of Risk	Notes
Coastal	Low	*Minimal change in peak water levels (overall reduction in risk to vulnerable receptors)*
Fluvial	Low	
Estuarial	Low	
Overland Flow	Low	*Flat topography unlikely to result in wider increase in flood risk.*
Artificial Drainage Systems	Low	*No increase in discharge to existing systems*
Groundwater	Low	*Unlikely to significantly impact on existing aquifers.*

Table 4-A Summary of Potential Impacts on Flood Risk

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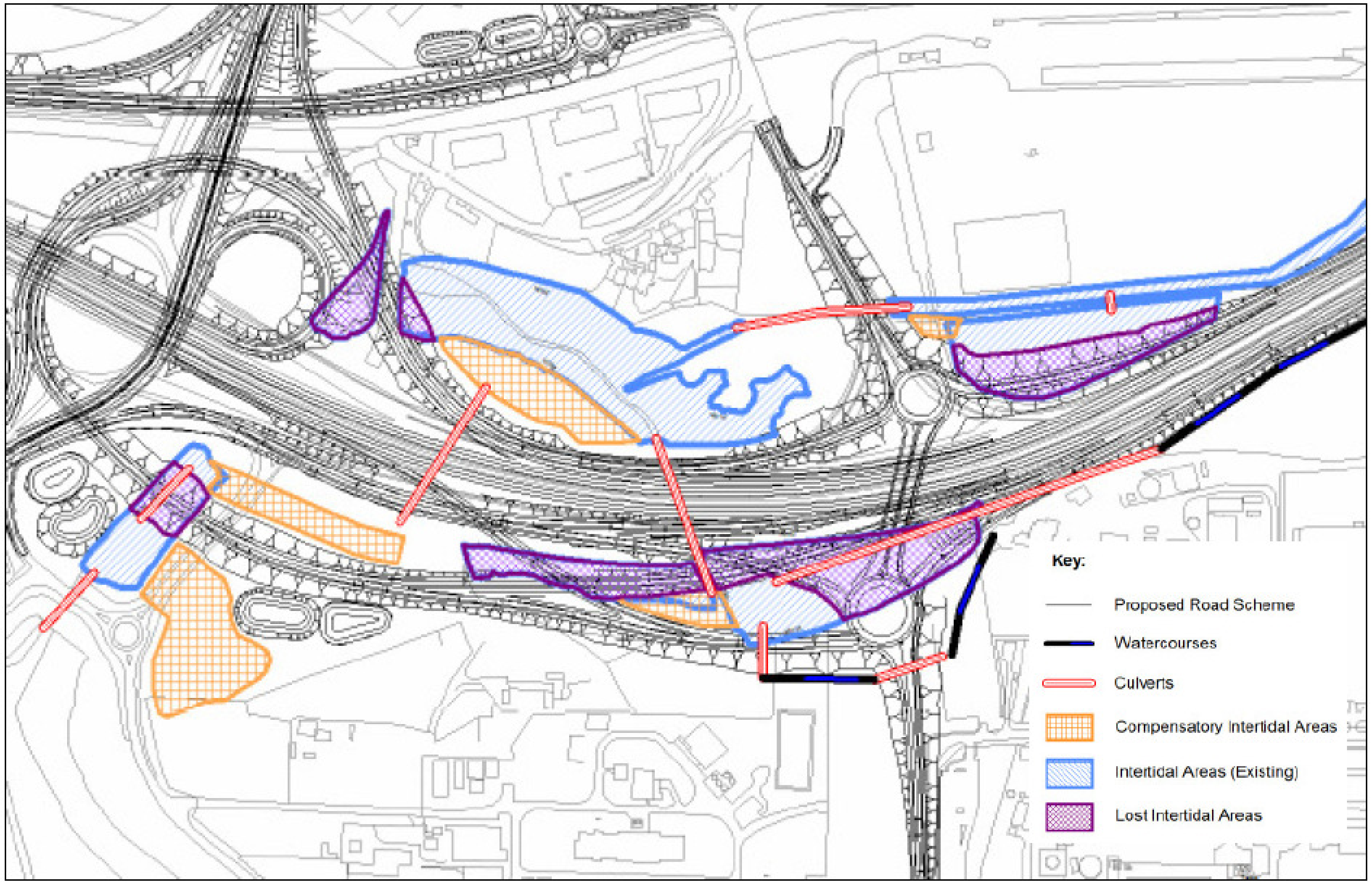

Figure 4-A – Proposed compensatory storage areas and lost intertidal areas

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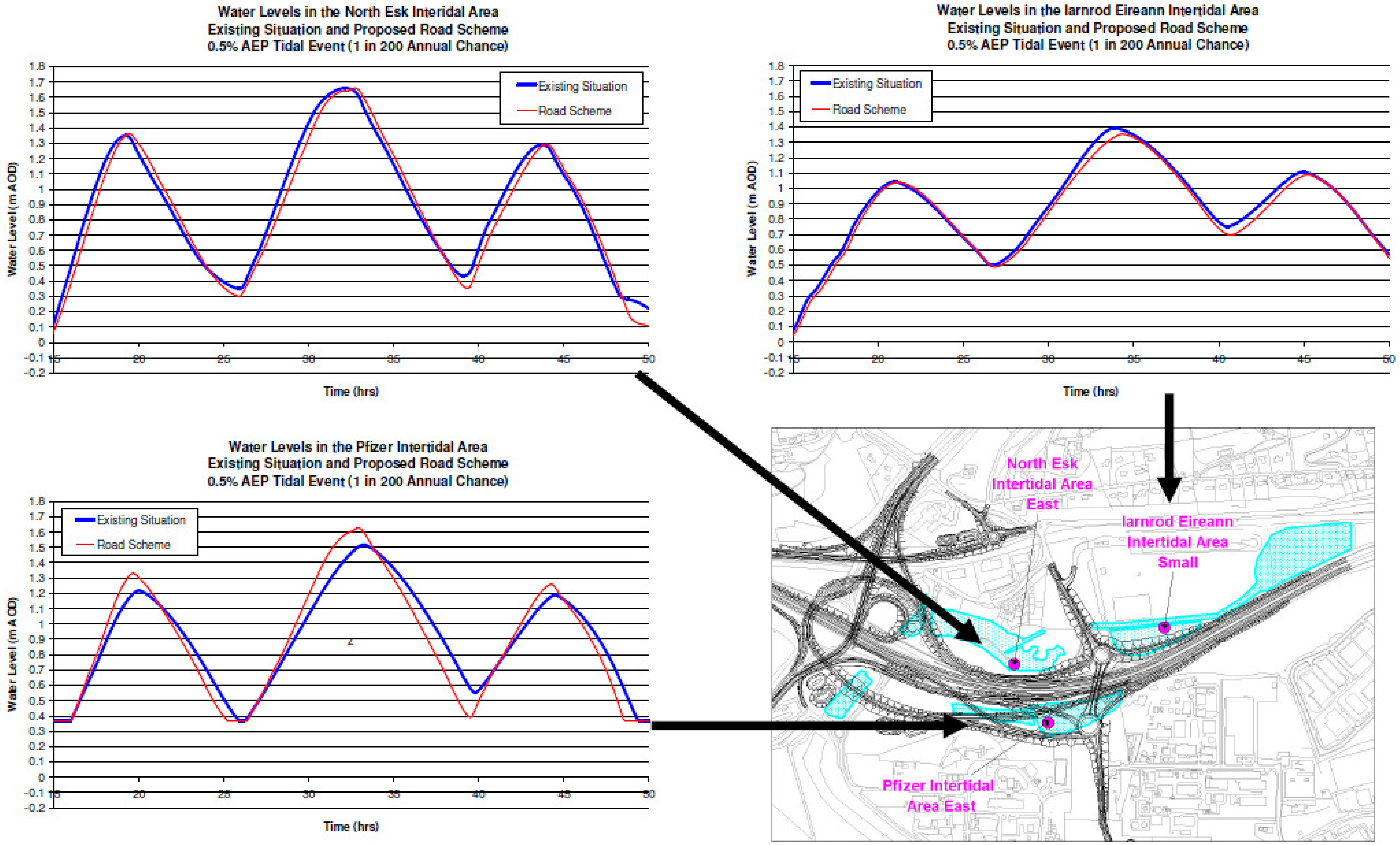

Figure 4-B – 0.5% AEP tidal event time series plots

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5 Conclusions

This report provides a detailed assessment of the flood risk issues that could affect the proposed improvements to the Dunkettle Interchange. The assessment has included investigations into the potential flood risks that could affect development on the site and also what impacts the development could have on flood risk in the surrounding area.

The assessment has found that the flood risk to the development is low from all potential sources. In order to determine this, detailed hydraulic modelling has been undertaken to assess the risk from coastal and estuarine sources. The investigations also included a detailed analysis of the potential flows from local watercourses.

Preliminary investigations into the proposed development indicated that it had the potential to increase flooding within the site and within the surrounding area. Following, the early investigations, the scheme was designed to provide compensatory storage for floodplains that would be lost through the construction of the interchange. In addition, a number of surface water attenuation basins have been included as part of the scheme.

The proposed basins would manage flows from both the existing and proposed scheme. The result is a SUDS based approach that will significantly reduce the existing volume of runoff from the area.

Due to the provision of SUDS and compensatory flood storage areas, the impact of the development on flood risk elsewhere is low.

Climate change may represent a significant future risk to the low areas within the development site by increasing sea levels, resulting in an increased risk of tidal flooding. However, the risk to the proposed road and existing infrastructure is low.

In conclusion, the proposed Dunkettle Interchange is at low risk of flooding and will not significantly increase the risk of flooding elsewhere.

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Appendix A Modelling Report

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N8-N25 Dunkettle Interchange Flood Risk Assessment

Hydraulic Modelling Report

May 2012

32102600/D01

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Document Control Sheet

BPP 04 F8
Version 7 April 2011

Client:	National Roads Authority	Project No:	32102600
Project:	N8-N25 Dunkettle Interchange Flood Risk Assessment		
Document Title:	Hydraulic Modelling Report		
Ref. No:	32102600/D01		

	Originator	Checked by	Reviewed by	Approved by
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DATE May 2012	SIGNATURE	SIGNATURE	SIGNATURE	AMG SIGNATURE
Document Status:				

REVISION	NAME	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE
Document Status				

REVISION	NAME	NAME	NAME	NAME
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Contents

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1 Introduction

1.1 Background

The Dunkettle Interchange is situated to the East of Cork, immediately North of the River Lee Estuary. The existing interchange is the junction of a number of key routes including the N8, M8, and N25 through the Jack Lynch Tunnel beneath the River Lee. The current interchange is used by approximately 95,000 vehicles a day. This is significantly above capacity, which results in severe traffic congestion. It is proposed that the existing interchange should be improved through engineering works to add capacity and reduce congestion.

The National Roads Authority (NRA) has appointed Jacobs Engineering to progress the proposed improvements. A number of options have been considered and a preferred option has now been identified,

The existing Dunkettle Interchange is situated above an area of connected intertidal wetlands and ponds. The interchange itself is situated in the west of the site area, with the main N25 running east to west and the N8 running south to north. The roads are raised above the intertidal areas on artificial embankments.

The intertidal areas are connected together and to the River Lee Estuary by a series of culverts the majority of which are large diameter, pipe culverts. The wetland and pond areas act as a series of individual basins, which are filled and emptied sequentially as the tide rises and falls.

1.2 Aim and Objectives of the Study

The aim of this study was to carry out hydraulic modelling investigations to support a flood risk assessment associated with the proposed engineering works.

The primary objective of the study was to construct a hydraulic model of the Dunkettle interchange and intertidal areas to assess the flood risk in the existing situation and with the proposed road scheme in place; both situations were to be assessed for an extreme tidal event (0.5% Annual Exceedance Probability).

A secondary objective of study was to use the hydraulic model to gain a better understanding of the water levels and flow exchanges between the intertidal areas at high and low tide (Spring and Neap) with a view to preserve the ecological character of the intertidal areas that would be affected by the proposed road scheme.

1.3 Modelling Approach and Software Used

The modelling approach has been based on the development of a two dimensional (2D) hydraulic model to simulate tidal inundation across the study area. The hydraulic model uses a 2D grid comprising individual square cells of 5m side. Each cell is given characteristics relating to the topography such as ground elevation using LiDAR data and bed resistance value (hydraulic friction).

The hydraulic model takes as main input a level hydrograph representing the tide cycle within the River Lee estuary and computes the ingress and egress motion of the tide across the intertidal areas by a set of rules that determines when grid cells may be wet and dry.

A hydrological study was also conducted to estimate design peak flows associated with fresh water catchments that feed into the intertidal areas.

The hydraulic model was constructed using TUFLOW modelling software (TUFLOW build 2011-09-AE iSP) provided by BMT WBM.

1.4 Modelled Area

The hydraulic model of the Dunkettle interchange and intertidal ponds covers an area of approximately 1.3km^2. On the western extent of the model, is the River Lee and to the east is the Eastgate Business Park. The 2D model coverage is shown on Figure 1 along with the proposed road scheme.

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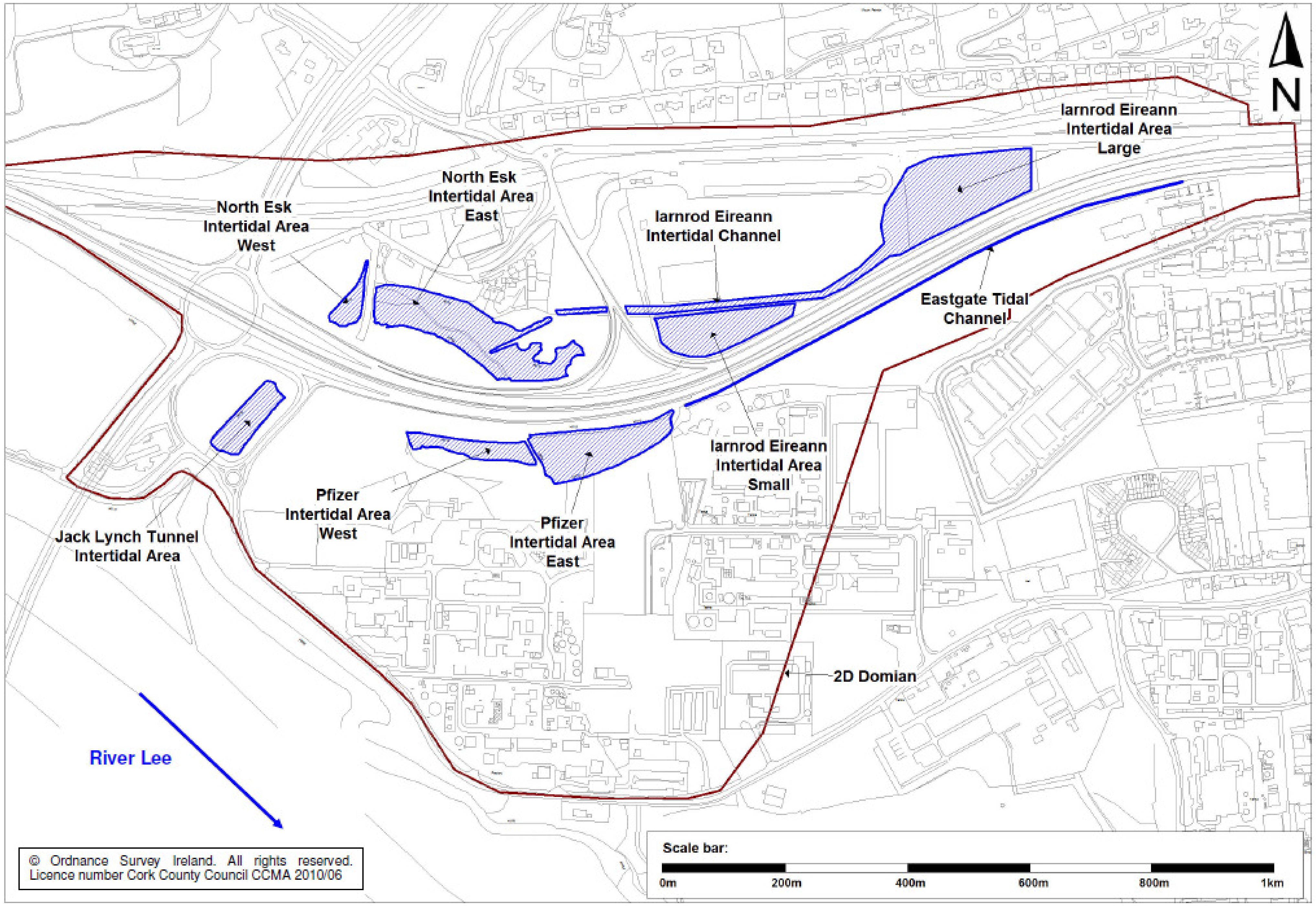

Figure 1 – Model extent

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2 Hydrology

2.1 Introduction

A hydrological study has been carried out to estimate design peak flows associated with fresh water catchments that feed into the modelled area.

The hydrological assessment of watercourses was used for the assessment of flood risk from the fluvial sources. This section details the work undertaken and provides peak flow estimates for a range of AEP (Annual Exceedance Probability) events.

2.2 Hydrology Methodology

The Dunkettle Interchange is located at the mouth of the Jack Lynch Tunnel on the north bank of the River Lee (Figure 2). The N25 follows the natural contour of the land and separates the higher ground to the north from the reclaimed land to the south.

Three watercourses were identified in the vicinity of the interchange, based on the information available on a 1:50,000 scale Ordnance Survey plan of the area (Figure 2). The larger northern catchment is predominantly rural, whilst the two smaller catchments located on both sides of the N25 are largely urban due to the presence of commercial and industrial activities concentrated on the flatter reclaimed land. The sub-catchment areas were determined using the limited OS contour and spot level information.

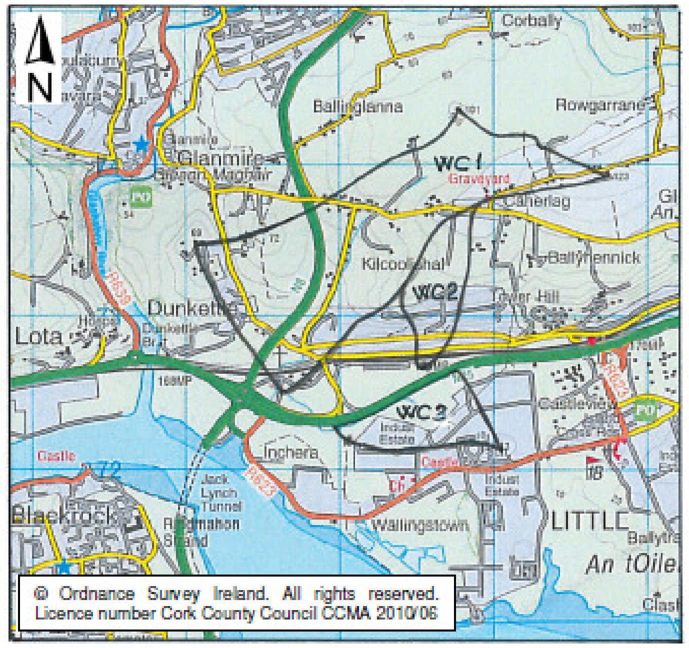

Figure 2 – Locations of Sub-catchments

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Table 1 shows the catchment characteristics of the three sub-catchments. The catchment characteristics were extracted from the information available in the Flood Studies Report maps for Ireland and the relevant OS plan.

Table 1 – Catchment characteristics

Sub-catchment	Area (km^2)	URBAN	SOIL	RSMD	SAAR	r	S1085	MSL (km)
WC1	1.6	0.06	0.3	50	1100	25	40	2
WC2	0.26	0.3	0.3	50	1100	25	10	0.4
WC3	0.28	0.6	0.3	50	1100	25	5	0.2

It is to be noted that the smaller the catchment, the greater the problems in accurately estimating its catchment characteristics. For example if urban development straddles the catchment boundary then particular care is needed when defining its area[1]; almost always the true position of catchment boundary will vary from the topographical divide as shown on the plans.

In addition, the calculation of MSL (mean stream length) and S1085 (channel gradient) can be awkward in very small catchments. Similarly the estimation of the SOIL (soil type) catchment parameter is challenged for small catchments due to the lack of fine detail on the Flood Studies Report (FSR) soil maps. The estimation of peak flows for very small catchments are also affected by the methodology used in the estimation. As the methodologies are derived using observed information from a number of catchments; the number and type of catchments used in the analysis are also likely to affect the applicability of the methodology for that particular catchment. These issues are pertinent for this assessment.

In this assessment several methodologies were used to gain design peak flow estimates. The variability in the estimates helped sample some of the above mentioned uncertainty and allowed the project to select magnitudes that may be considered as being on the higher end of what is likely. A conservative approach to the consideration of fluvial flows was followed as this helped insulate the analysis from the possible underestimation of flows.

The following statistical based approaches developed for use on small catchments have been used. These rely on the estimation of an index flood [Qbar] which is then factored up via the use of the Irish Growth Curve to gain estimates of the T-year flood.

Poots & Cochrane 1 $QBAR=0.0136*AREA^{0.866} * RSMD^{1.413} * SOIL^{1.521}$

Poots & Cochrane 2 $QBAR=0.0150*AREA^{0.882} * RSMD^{1.462} * SOIL^{1.904}$
IH3 $QBAR=0.00066*AREA^{0.92} * SAAR^{1.22} * SOIL^{2.0}$
IH124 Rural $QBAR=0.00108*AREA^{0.89} * SAAR^{1.17} * SOIL^{2.17}$

IH124 Rural is converted to IH124 Urban using QBARUrban/QBARRural ratio. The equations used for this purpose are:-

CIND = 0.124*SOIL+0.28*(CWI -125)
NC = 0.92-0.00024*SAAR
QBARu/QBARr = ((1+URBAN)^(2*NC))*(1+(URBAN*(21/CIND)-0.3)))

[1] Institute of Hydrology, Report No:126 Hydrology of soil types; a hydrologically-based classification of the soils of the United Kingdom., November 1995

where;

AREA : area of each catchment (km^2)
RSMD : Soil Moisture Deficit
SAAR : Seasonally Adjusted Annual Rainfall (mm)
SOIL : Soil classification
URBAN: Urban fraction
CWI : Catchment Wetness Index

In addition to these four “statistical” methods the FSSR16 rainfall-runoff model was also used to both generate a design hydrograph shape as well and an alternative peak flow estimate.

Tables 2 to 4 present the design flow estimates from the various methods.

Table 2 – Estimated Peak Flows for Catchment WC1

Method used	Peak Flow (m^3/s)						
	50%AEP	20%AEP	10%AEP	4%AEP	2%AEP	1%AEP	0.5%AEP
Poots&Cochrane 1	0.78	0.98	1.12	1.31	1.45	1.61	1.75
Poots&Cochrane 2	0.67	0.84	0.96	1.12	1.24	1.37	1.49
IH3	0.45	0.56	0.64	0.75	0.83	0.92	1.00
IH124	0.46	0.59	0.66	0.77	0.86	0.95	1.04
FSSR16	0.95	1.32	1.53	1.93	2.25	2.56	2.93

Table 3 – Estimated Peak Flows for Catchment WC2

Method used	Peak Flow (m^3/s)						
	50%AEP	20%AEP	10%AEP	4%AEP	2%AEP	1%AEP	0.5%AEP
Poots&Cochrane 1	0.16	0.20	0.23	0.27	0.30	0.33	0.36
Poots&Cochrane 2	0.13	0.17	0.19	0.22	0.25	0.27	0.30
IH3	0.09	0.11	0.12	0.14	0.16	0.18	0.19
IH124	0.14	0.17	0.19	0.22	0.25	0.28	0.47
FSSR16	0.21	0.27	0.31	0.38	0.45	0.53	0.62

Table 4 – Estimated Peak Flows for Catchment WC3

Method used	Peak Flow (m^3/s)						
	50%AEP	20%AEP	10%AEP	4%AEP	2%AEP	1%AEP	0.5%AEP
Poots&Cochrane 1	0.17	0.22	0.25	0.29	0.32	0.35	0.38
Poots&Cochrane 2	0.14	0.18	0.21	0.24	0.27	0.29	0.32
IH3	0.09	0.11	0.12	0.14	0.16	0.18	0.19
IH124	0.21	0.25	0.27	0.32	0.37	0.41	0.43
FSSR16	0.30	0.39	0.45	0.54	0.63	0.75	0.88

Given that the FSSR16 rainfall-runoff flow estimates are consistently relatively high these have been used in the modelling analysis. The location of the inflows into the hydraulic model can be seen in Figure 3.

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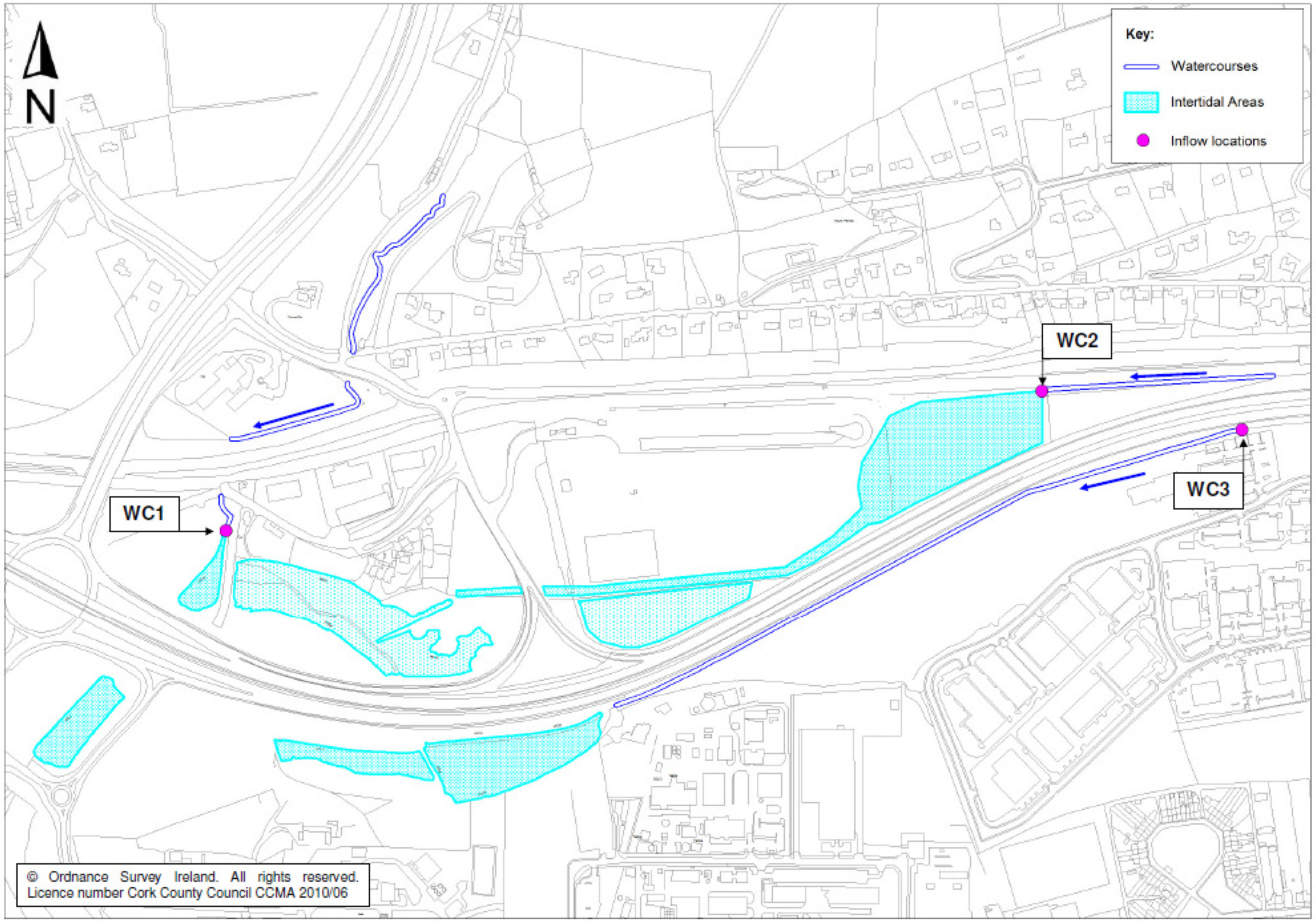

Figure 3 – Hydrological inflow locations to the hydraulic model

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3 Existing Situation Hydraulic Model

3.1 Previous Modelling

There is no known previous modelling specific to the study area.

3.2 Data Collection

A review of the available data used in the construction of the hydraulic model developed for this study is presented below:

3.2.1 Topographic Survey Data

A topographical survey of the intertidal areas was undertaken by Murphy Surveys Ltd in April 2012 in the form of cross-sections taken across of the wetlands and ponds. Murphy Surveys Ltd also conducted a survey of the culverts which connect each individual intertidal area.

3.2.2 Digital Elevation Data

LiDAR data covering the study area was provided by the Office of Public Works (OPW). The LiDAR was principally used to inform the grid of the 2D model with ground elevations.

3.2.3 OS Background Mapping and Site Visit

Mastermap data covering the study area was supplied by the OPW. Jacobs' staff also undertook a visit of the site and took a number of photographs along each of the intertidal areas and surrounding areas.

3.3 Hydraulic Model Schematisation

3.3.1 Model Grid

As previously mentioned, the 2D hydraulic model was based on a grid comprising individual cells of 5m size. This allowed for adequate representation of the natural landscape and also other features such as roads, buildings, whilst not becoming computationally cumbersome.

The maximum area covered by the 2D model is shown on the model extent given in Figure 4 and covers an area of approximately 1,262,000m^2. However the user is given the ability to manually reduce this area by adjusting the number of active cells to accommodate the maximum flood envelope.

Two-metre horizontal resolution filtered LiDAR data was used to inform the grid with accurate ground elevation data.

It should be noted the LiDAR data was found to be of poor quality for the intertidal areas. This is due to the presence of water at the time the LiDAR survey was undertaken which resulted in unrealistic bed elevations being recorded.

Therefore the topographic survey data, collected by Murphy was used to supplement the LiDAR data and ensure an accurate representation in the model of the bed profile and storage capacity of the intertidal areas.

As shown in Figure 4, another area of potentially poor quality LiDAR was found in the vicinity of the properties located north of the North Esk Intertidal Areas. Satellite photograph shows the area is covered with dense vegetation. It is quite common in such a case that the ground elevations surveyed with LiDAR might be inaccurate.

3.3.2 Breaklines

Breaklines were used in the 2D grid to accurately represent any geographical features that have a significant impact on the flood extent. It is particularly useful where the TUFLOW fixed grid discretisation (in our case 5m) does not guarantee that the crest along, for example, a narrow earth embankment, is picked up from the LiDAR data.

The main breaklines included into the 2D model were narrow strips of raised ground between the intertidal areas. In addition, breaklines were also added to ensure the channel like features within the intertidal areas were adequately represented. Ground elevations for these breaklines were extracted from the cross section data collected during the topographical survey.

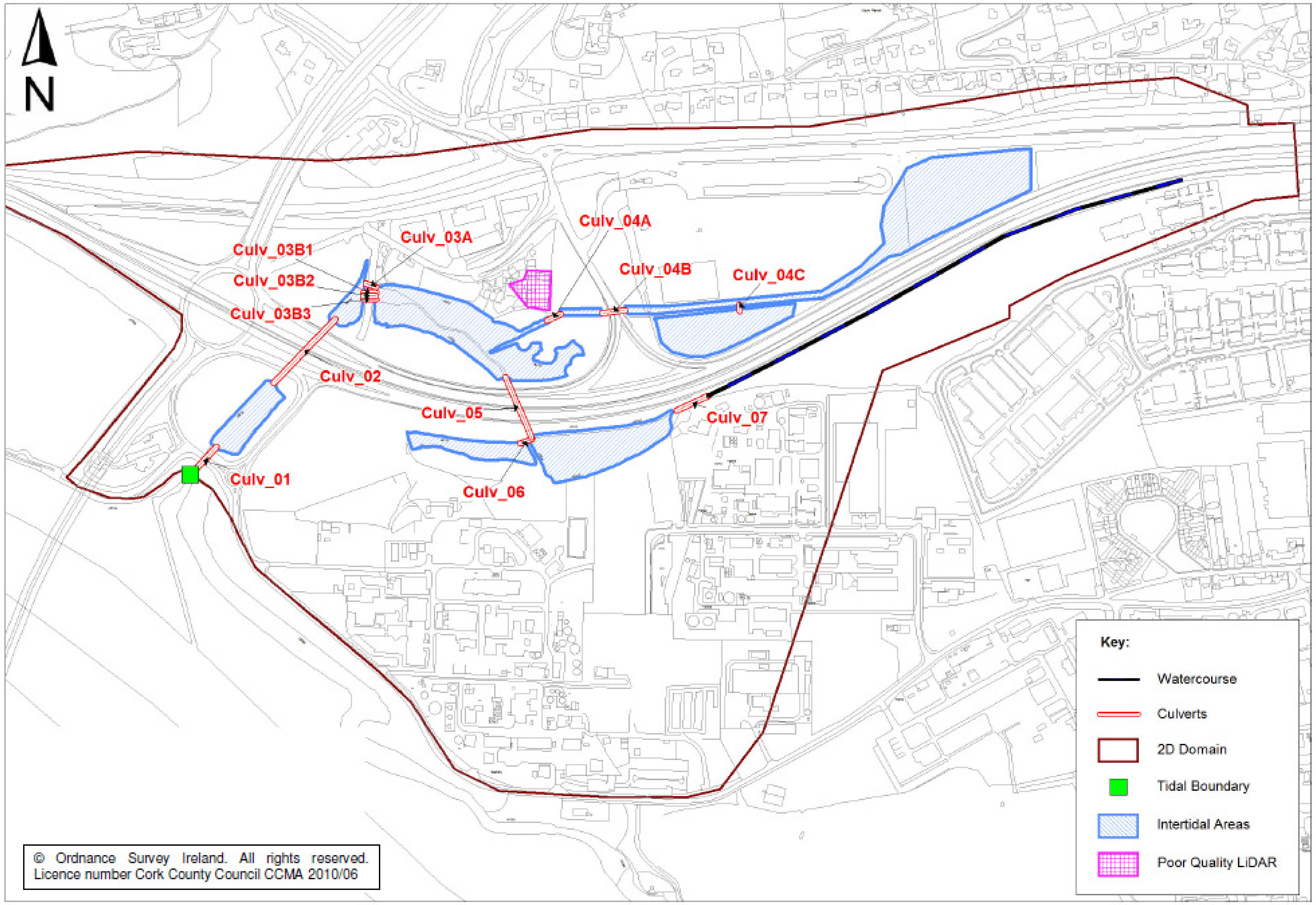

Figure 4 – Existing Situation Model Schematisation

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3.3.3 Hydraulic Friction

Hydraulic roughness, represented by Manning's coefficient "n" in the hydraulic model, is a means of accounting for the effect on the conveyance capacity of bed materials and size, surface irregularities, channel bed forms, erosional and depositional features, channel sinuosity, obstructions and vegetation.

Manning's "n" is a semi-empirical parameter and cannot by directly measured, however a number of established reference literatures such as Chow[2] give advice on the selection of the roughness coefficients for channels and floodplains.

To represent the friction within the 2D model, geographical regions of different land use such as: ponds, wetlands, roads, dense vegetation and buildings have been delineated using OS maps and online sources (aerial maps).

The land use regions were processed as GIS input data into the 2D model grid so that each 2D grid cell carries a land use reference number corresponding to the land use region it falls on. As shown on Table 5, a Manning's "n" value was assigned to each land use reference number.

The values adopted in the intertidal areas range from 0.022n to 0.040n. Higher roughness (0.065n) was applied to densely vegetated areas surrounding some of the intertidal areas.

Table 5 – Roughness definition within the 2D model

Land Use referenc	Manning's "n" value	Land Use description
1	0.035	Pasture (short grass)
2	0.022	Ponds/Mudflats
3	0.040	Wetlands
4	0.025	Roads
5	0.030	Tracks
6	0.300	Buildings
7	0.065	Woodland / Dense vegetation

It should be noted that the use of filtered LiDAR data to inform the 2D model grid means that buildings are not inherently represented in the grid. Given the fact that any building is an obstruction to the flow and would have a major impact on the overland flow routes, a very high roughness value has been attributed to each building/house within the study area to model the effect of the obstruction.

3.3.4 1D Elements

Circular culverts connecting the separate intertidal areas were identified and incorporated into the 2D model as 1D elements. Table 6 outlines the type and dimensions of the 1D elements used within the model. Nearly all culvert inverts and dimensions were taken from the survey data (Section 3.2.1), with the exception of culverts (Culv_04A and Culv_07). For these two culverts, the inverts and dimensions were estimated, based on photographic evidence and surrounding available survey data. The location of these structures can be seen in Figure 4.

[2] Chow, V.T., Open Channel Hydraulics, 1984, McGraw Hill, Singapore

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Table 6 – 1D elements (Existing Situation)

Name of 1D element	Inverts (m AOD)		Diameter (m)
	Upstream	Downstream	
Culv_01	-2.23	-2.48	1.8
Culv_02	-2.04	-2.42	1.8
Culv_03A	-1.59	-1.75	1.8
Culv_3B1	-0.69	-1.12	1.5
Culv_3B2	-0.71	-1.18	1.5
Culv_3B3	-0.71	-1.22	1.5
Culv_04A	-0.95	-0.96	1.2
Culv_04B	-0.93	-0.94	1.2
Culv_04C	-0.23	-0.32	0.6
Culv_05	-0.91	-1.51	1.2
Culv_06	0.00	0.00	1.2
Culv_07	-0.26	-0.77	1.2

3.3.5 Model Boundaries

Tidal boundary
A tidal boundary "Stage vs Time" was applied to the culvert (Culv_01) connecting the Jack Lynch Tunnel Intertidal area to the River Lee. Three different tides were simulated as part of this study:

- *Mean Spring*
- *Mean Neap*
- *0.5% AEP extreme tide event*

Levels and shapes of the Spring and Neap tidal curves were extracted from the Admiralty Tide Tables[3] and can be seen in Figure 5. Peak tide levels associated with these tides correspond respectively to the Mean High Water Spring (MHWS) and the Mean High Water Neap (MHWN) at Cork City Harbour.

A level hydrograph relative to the 0.5% AEP extreme tide event was obtained from the OPW at the confluence of the Glashaboy River with the River Lee (i.e. approximately one hundred metre upstream of the site). The tidal hydrograph was extracted from the outputs of the Cork Harbour Model built as part of the Lee Catchment Flood Risk Assessment and Management Study (CFRAM)[4] in January 2010.

As suggested by OPW, an uplift of 0.1m was made to the extreme peak level of 2.93m AD[5] to adjust for the location of the Dunkettle site. The 0.5% AEP extreme tide hydrograph can be seen in Figure 5.

[3] Admiralty Charts and Publications, Admiralty Tide Tables, United Kingdom and Ireland Vol 1, 2006.
[4] Lee Catchment Flood Risk Assessment and Management Study (CFRAMs), Hydraulic Report, Halcrow, January 2010.
[5] Added to Malin Head Datum

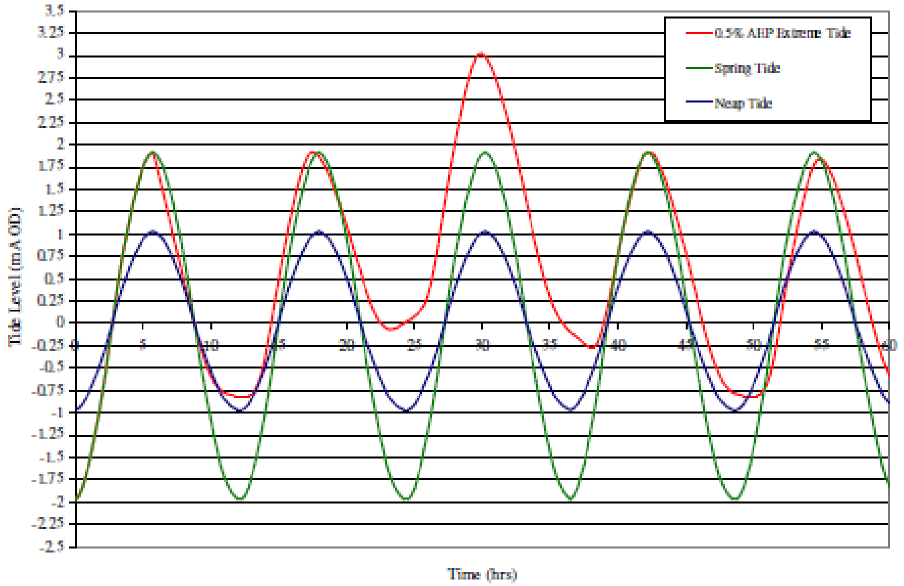

Figure 5 – Tidal Hydrographs

Fresh Water Contributions
As stated previously in Section 2, a hydrological assessment was conducted on the freshwater watercourses that feed into the intertidal areas. It was decided that for the Spring and Neap tide scenarios simulated by the model, no fresh water contributions would be included. The hydrological analysis found that the base-flows associated with the watercourses were insignificant and therefore negligible in comparison with the saline water volumes driven by the tides.

In the case of the 0.5% AEP tide event, three inflows were inserted into the 2D model to represent the fresh water contributions. Considering a joint probability event, a 10% AEP fluvial event was selected to coincide with the tidal peak, for all three watercourses.

Initial Conditions
To obtain the initial water levels within the intertidal area the existing situation model was pre-run for a number of Spring tidal cycles, until a equilibrium was established within the model. The water levels across the 2D domain were extracted at one time step that coincided with the low tide at the model tidal boundary. These initial water levels were then applied in the model at the beginning of the simulations undertaken. The same process was followed for the Neap tide scenario, pre-running a number of Neap tidal cycles.

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4 Proposed Road Scheme Model

4.1 Introduction

The proposed road scheme layout was provided by Jacobs Highways, which included compensatory intertidal areas designated for compensatory flood storage and replacement culverts. Bed elevations for the compensatory areas were originally provided by Jacobs' ecological sub-consultant Scott Cawley Ltd. The proposed road scheme was incorporated into the hydraulic model and the same three tide scenarios described in Section 3 were simulated, so as to allow for a comparative analysis to be performed on the water levels within the intertidal areas.

4.2 Model Schematisation

4.2.1 Model Grid

The hydraulic modelling software, TUFLOW was used to generate the proposed road landforms, which were then superimposed over the existing model grid. The areas designated for compensatory flood storage were lowered from the existing ground level using the bed elevations provided. These were subsequently modified during the model development to avoid exacerbation of the existing flood risk but also to replicate as much as possible during a full tide cycle, the variation of the water levels within the intertidal areas in comparison with the existing situation.

The key features of the proposed road scheme model are illustrated in Figure 6.

4.2.2 Hydraulic Friction

The hydraulic friction values remain unaltered from the existing situation; however the GIS layers have been altered to reflect the geographic changes in land use.

4.2.3 1D Elements

Additional 1D elements were inserted into the 2D model to represent the new culverts (as shown in Figure 6) and the redundant culverts were removed from the model. Table 7 outlines the name and dimensions of the 1D elements used within proposed road scheme model.

Table 7 – 1D elements (Proposed Road Scheme)

Name of 1D element	Inverts (m AOD)		Diameter (m)
	Upstream	Downstream	
Culv_01	-2.23	-2.48	1.8
New_Cul_2	-2.23	-2.30	1.8
New_Cul_3	-1.55	-1.70	Twin 1.5
New_Cul_4	-0.94	-0.93	1.2
Culv_04C	-0.23	-0.32	0.6
New_Cul_5	-0.91	-1.51	1.2
New_Cul_6	-0.70	-0.65	0.6
New_Cul_7	-0.55	-0.60	0.6
New_Cul_8	-0.05	-0.60	0.9

No change from the existing situation

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4.2.4 Model Boundaries

The tidal boundaries remain the same as mentioned in the existing situation (Section 3.3.5). The three tidal cycles; 0.5% AEP, Spring and Neap were applied to the culvert (Culv_01) connecting the Jack Lynch Tunnel Intertidal area to the River Lee.

The initial conditions were derived by the same method as for the existing situation.

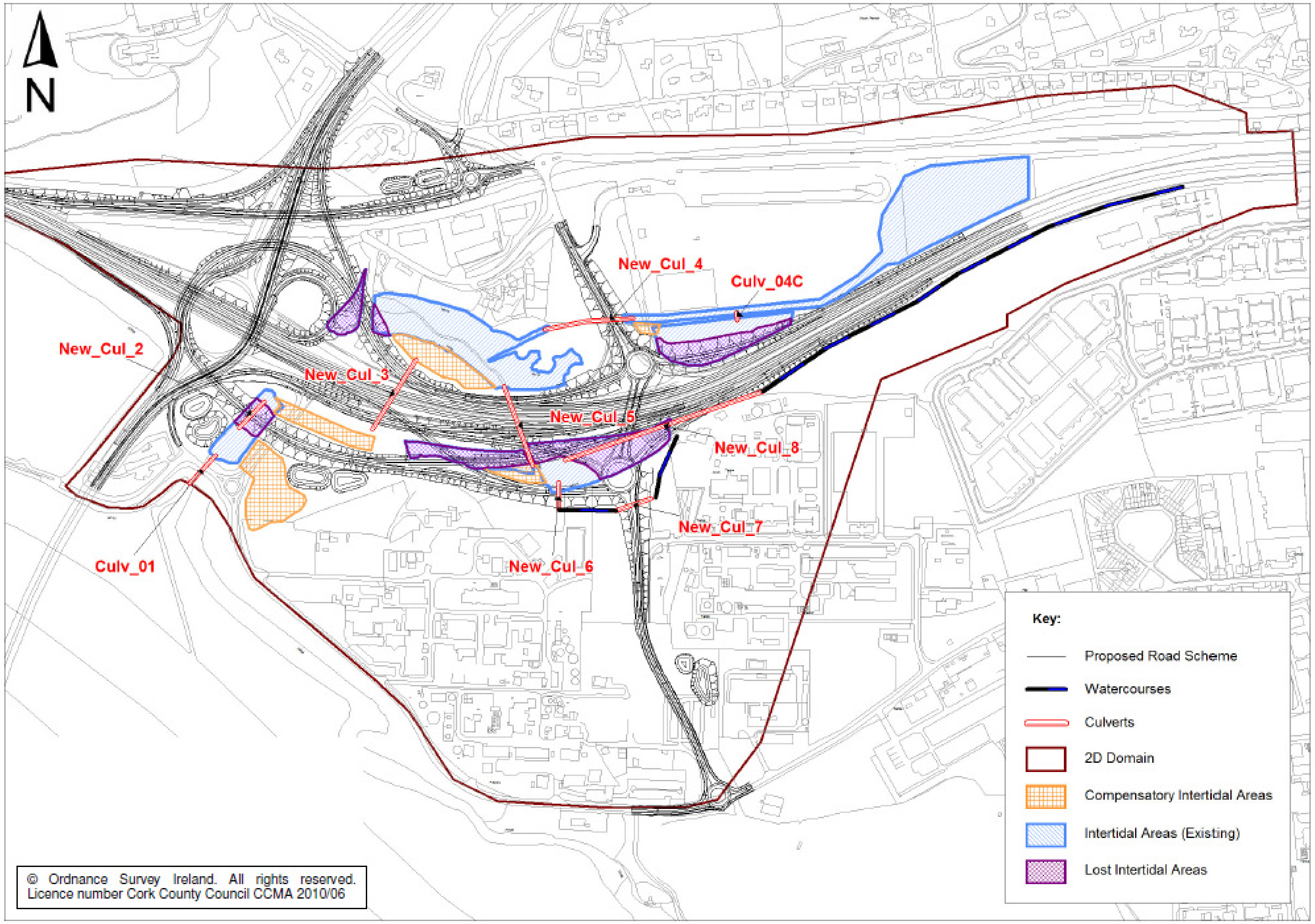

Figure 6 – Proposed Road Scheme Model Schematisation

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5 Model Results

5.1 Flood Risk Mapping

The hydraulic models representing the existing and proposed road scheme scenarios were both run for the three tidal events mentioned previously. Outputs from the hydraulic model were then processed and maximum flood depth maps were produced. These maps are provided in Appendix A.

5.2 Result Analysis

5.2.1 0.5% AEP Extreme Tide Event

The primary objective of the study was to establish the existing flood risk from the intertidal areas for a 0.5% AEP extreme tide event. The maximum flood depth maps provided in Appendix A, shows that one property is at risk of inundation from such event without the proposed development in place. The property is located north of the "North Esk Intertidal Area East", near the Speed Express Logistics warehouse.

However it should be noted that the affected property lies within an area of poor LiDAR quality as detailed in Section 3.3.1 and shown on Figure 4. Therefore this result should be interpreted with caution and for the purposes of this assessment, as the same topographical data is used in modelling both the existing scenario and in the scenario with the proposed development in place, the assessment is still robust in terms of the comparison of both scenarios.

In general, flood mechanisms within the intertidal areas result from a combination of the peak tidal levels, the size / capacity of the culverts and the bed elevations of the intertidal mudflats.

The peak water level varies from one intertidal area to another, due to the flow control effect exerted by the circular culverts and the difference in bed elevations between each of the ponds.

Figure 7 illustrates the maximum water level for a 0.5% AEP event (existing situation) and the direction of the flow for an incoming tide (shown as red direction arrows). The property predicted at risk of flooding is also indicated.

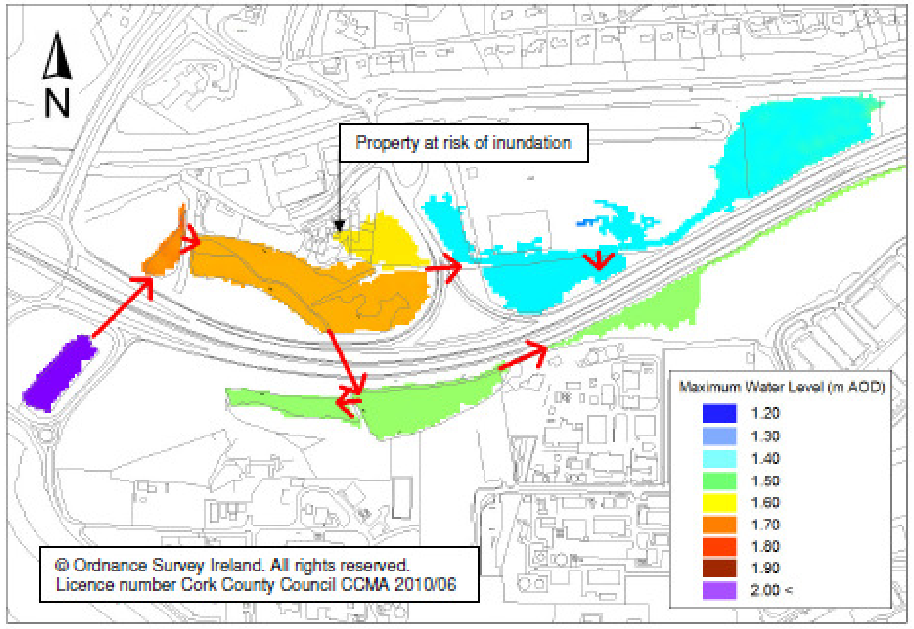

Figure 7 – Maximum Water Levels for the existing situation 0.5% AEP event

Maximum flood depth maps associated with the proposed road scheme situation are also provided in Appendix A and allow for direct comparison with the existing situation. The maps reveal that the maximum depths within the intertidal areas are similar to the existing situation, where in fact the flood extent is slightly reduced in the "North Esk Intertidal Area East". However the property predicted to be inundated under the existing situation remains at risk in the proposed road scheme situation.

To monitor the full tidal cycles (peaks and troughs) within the intertidal areas, time series points were set up to record the water levels for each of the tidal events. This report discusses the data from three locations, which are indicated on Figure 8.

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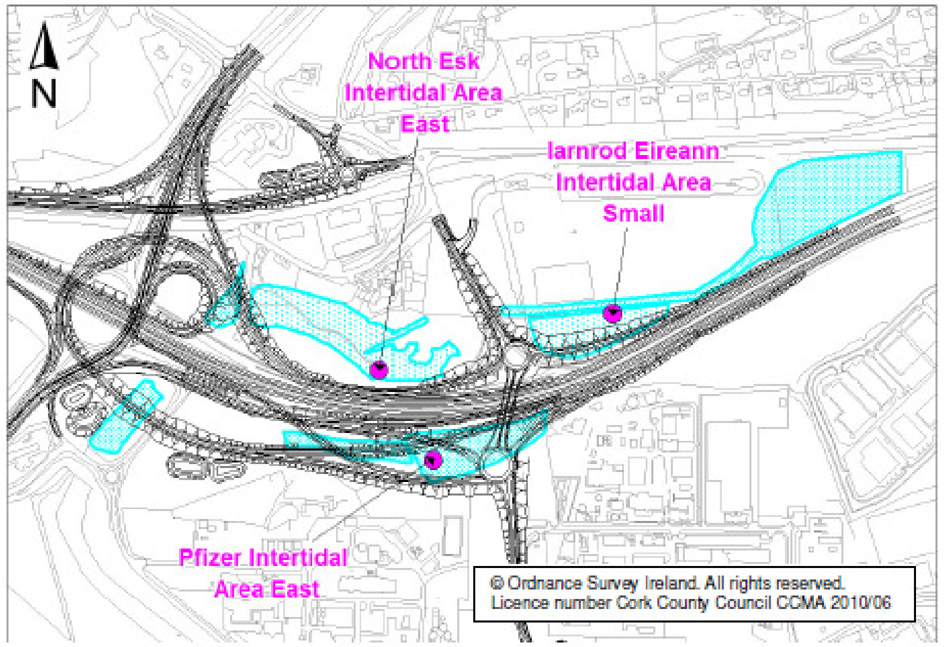

Figure 8 – Time series point location

The time series data for the three points has been plotted in Figure 9. The graphs illustrate that the proposed road scheme reduces the maximum water level in 2 of the 3 intertidal areas for a 0.5% AEP event. Only the water level in the "Pfizer Intertidal Area East" is increased by 100mm, which is due to the significant constraints caused by the road embankments and retaining walls.

The graphs also demonstrate that the bed levels of the compensatory intertidal areas in the proposed scheme model have been successfully set up so that the water level hydrographs remain similar for the two scenarios. The low tide water levels correlate well, with only a 90mm drop in level for the "North Esk Intertidal Area East".

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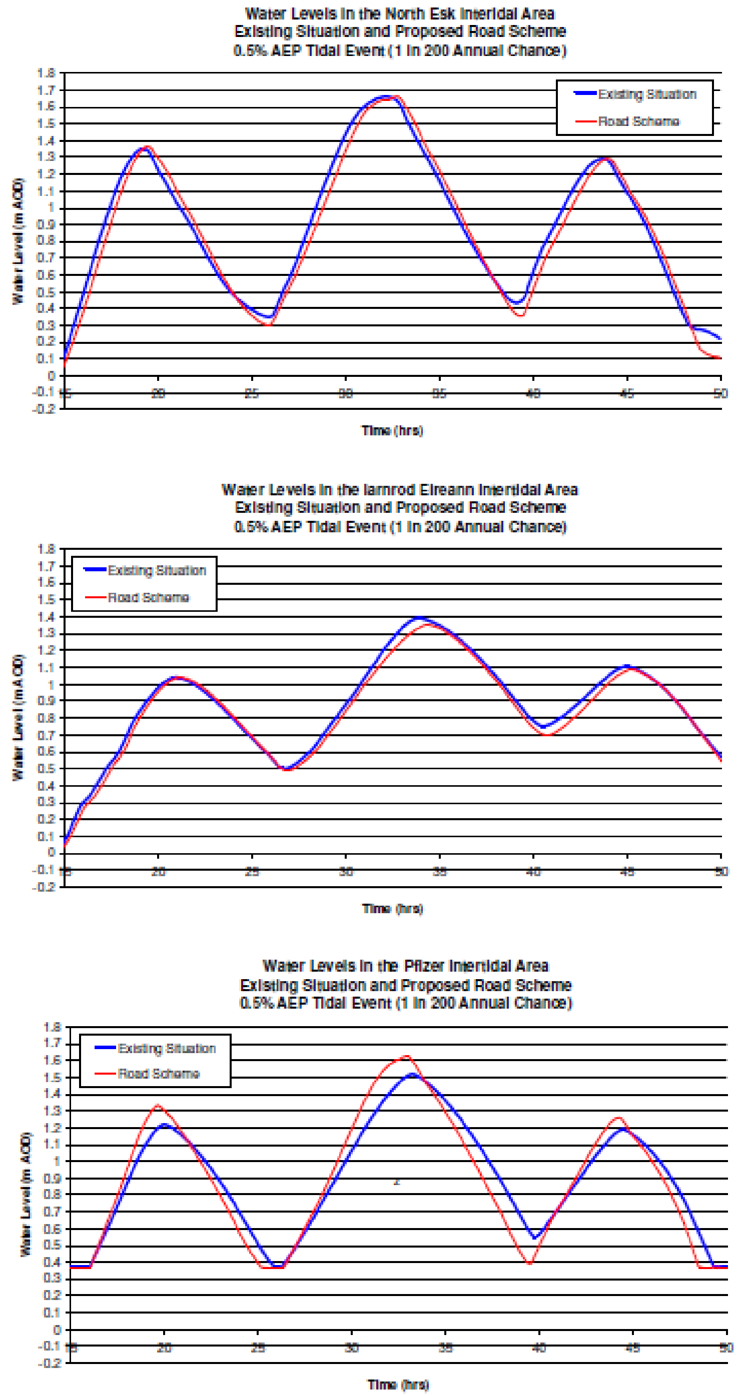

Figure 9 – 0.5% AEP tidal event time series plots

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5.2.2 Spring and Neap Tides

As expected, the model does not predict flooding to any properties within the study area for a Spring and a Neap tide. However, the maximum flood depth maps as provided in Appendix A indicate that shallow flooding (0 – 250mm) would occur to the garden allotments adjacent to the North Esk intertidal Area.

It should be noted the affected allotments lie within the same area of poor LiDAR quality mentioned previously. Therefore, it is re-emphasised here that this result should be interpreted with caution.

The flood mechanisms for both events are similar to the extreme event, with each culvert holding back water at high tide and therefore limiting the water level in the next intertidal area in the sequence.

The same water level time series points as shown on Figure 8 were produced for the Spring and Neap tide scenarios. As shown in Figure 10, the comparison made between the existing and proposed situations confirms the proposed road scheme and associated compensatory intertidal areas set in the hydraulic model do not significantly impact on the water levels during a full spring or neap tide cycle.

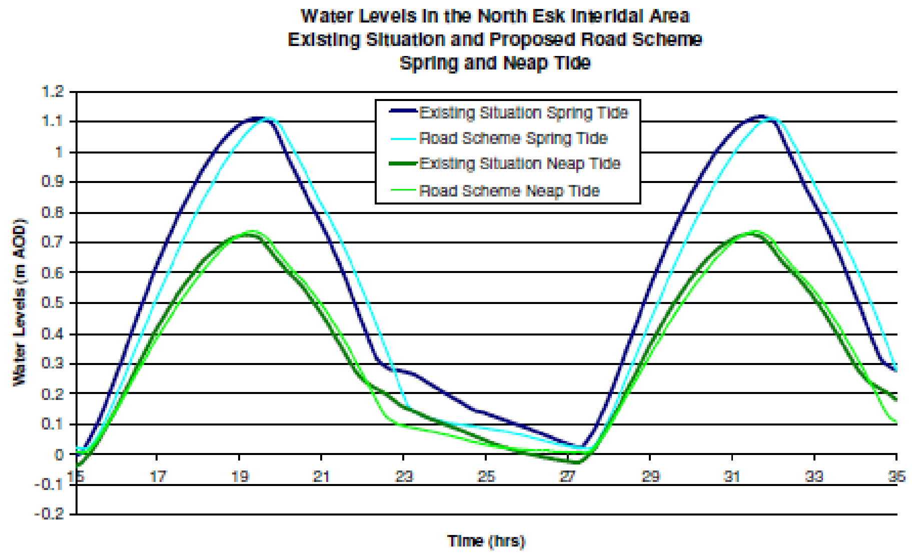

Figure 10 – Spring & Neap Time series plots

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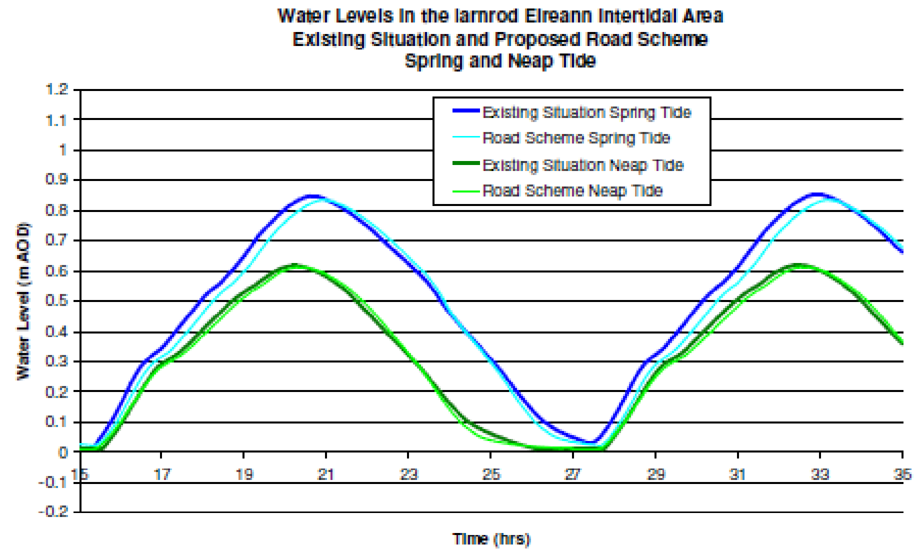

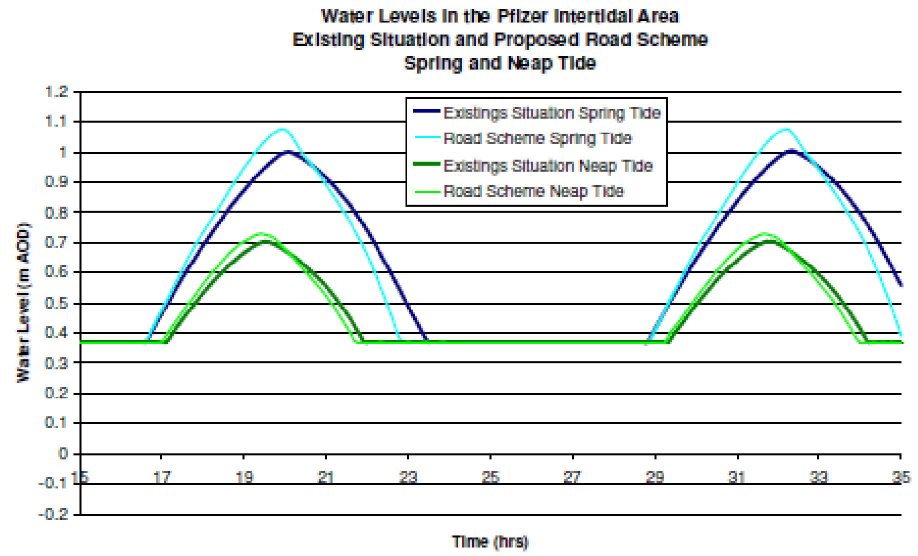

Figure 10 – Spring & Neap Time series plots (continued)

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6 Conclusions

This study has used a new hydraulic model to investigate the flood risk associated with an extreme tidal event at the Dunkettle Interchange for both the existing and the proposed road scheme situations.

The model results have revealed that for a 0.5% AEP extreme tide event, (1 in 200 annual chance) only one property is at risk of inundation in the existing situation. However this result should be interpreted with caution as there is an uncertainty on the ground elevations included in the hydraulic model in the vicinity of the affected property.

All across the study area, comparison of model predictions between the existing and the proposed road scheme situation demonstrate that the proposed works do not increase the flood risk. Peak water levels within the intertidal areas are very similar in both situations. Only a slight increase in the "Pfizer Intertidal Mudflat East" is predicted in the proposed situation but this has no consequence on the flood risk as no properties are located nearby and the area is bounded by reinforced earth retaining walls as part of the proposed development.

Spring and Neap tides were simulated with hydraulic model to aid in the assessment of the ecological impact of the proposed works under normal Spring - Neap tidal regimes. Bed profiles within the intertidal areas were adjusted so that the water levels during the full tidal cycle remain very similar in both existing and proposed situations. This is a first step towards the preservation of the current ecological character of the intertidal areas, should the proposed road scheme be constructed.

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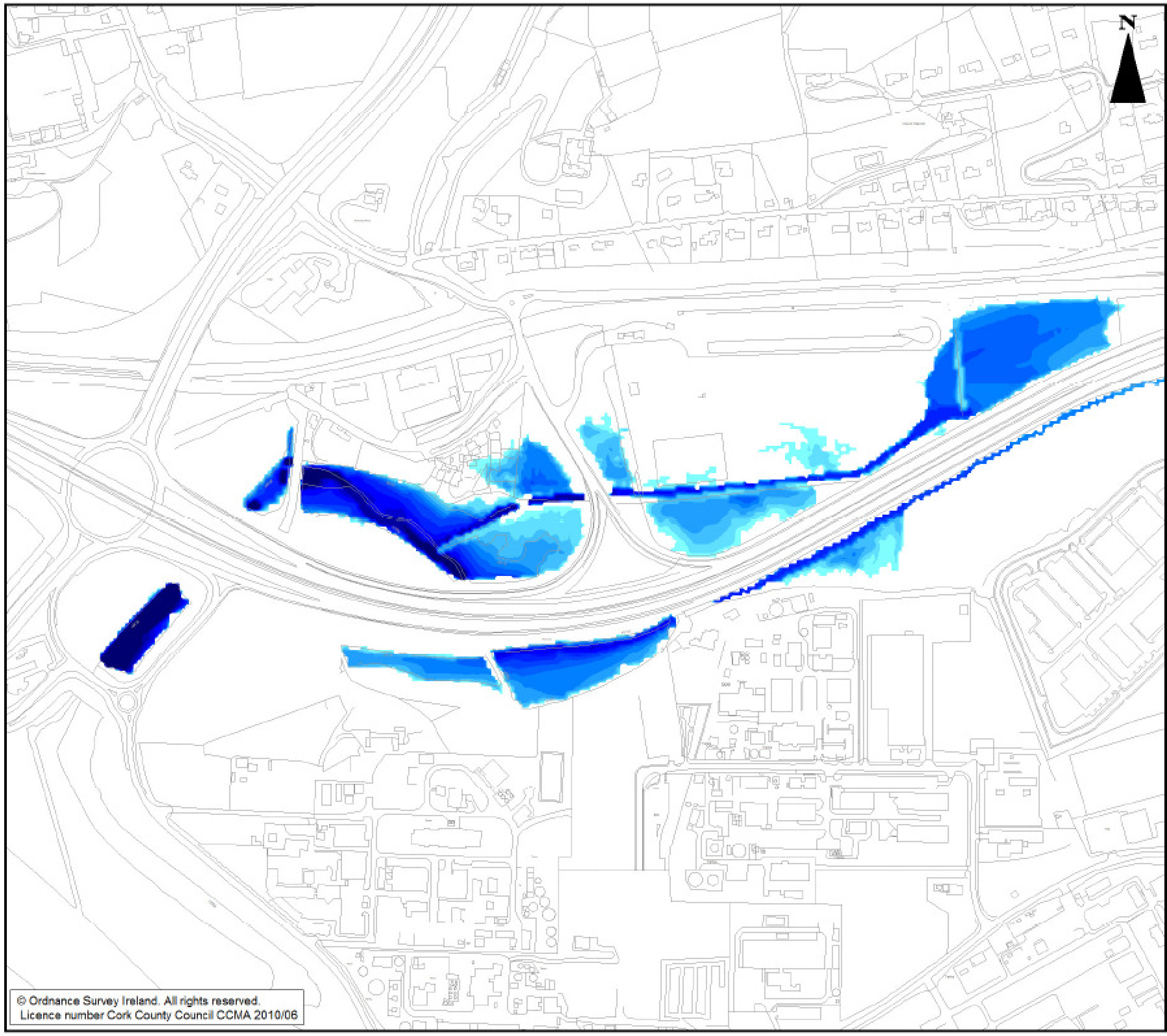
Appendix A



Scale: Not to Scale

Maximum Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- 1.25 - 1.50
- 1.50 - 1.75
- 1.75 - 2.00
- 2.00 - 2.25
- 2.25 - 2.50
- 2.50 - 2.75
- 2.75 - 3.00
- 3.00 <

02	05/12	3210260/D/E03	SR	DD
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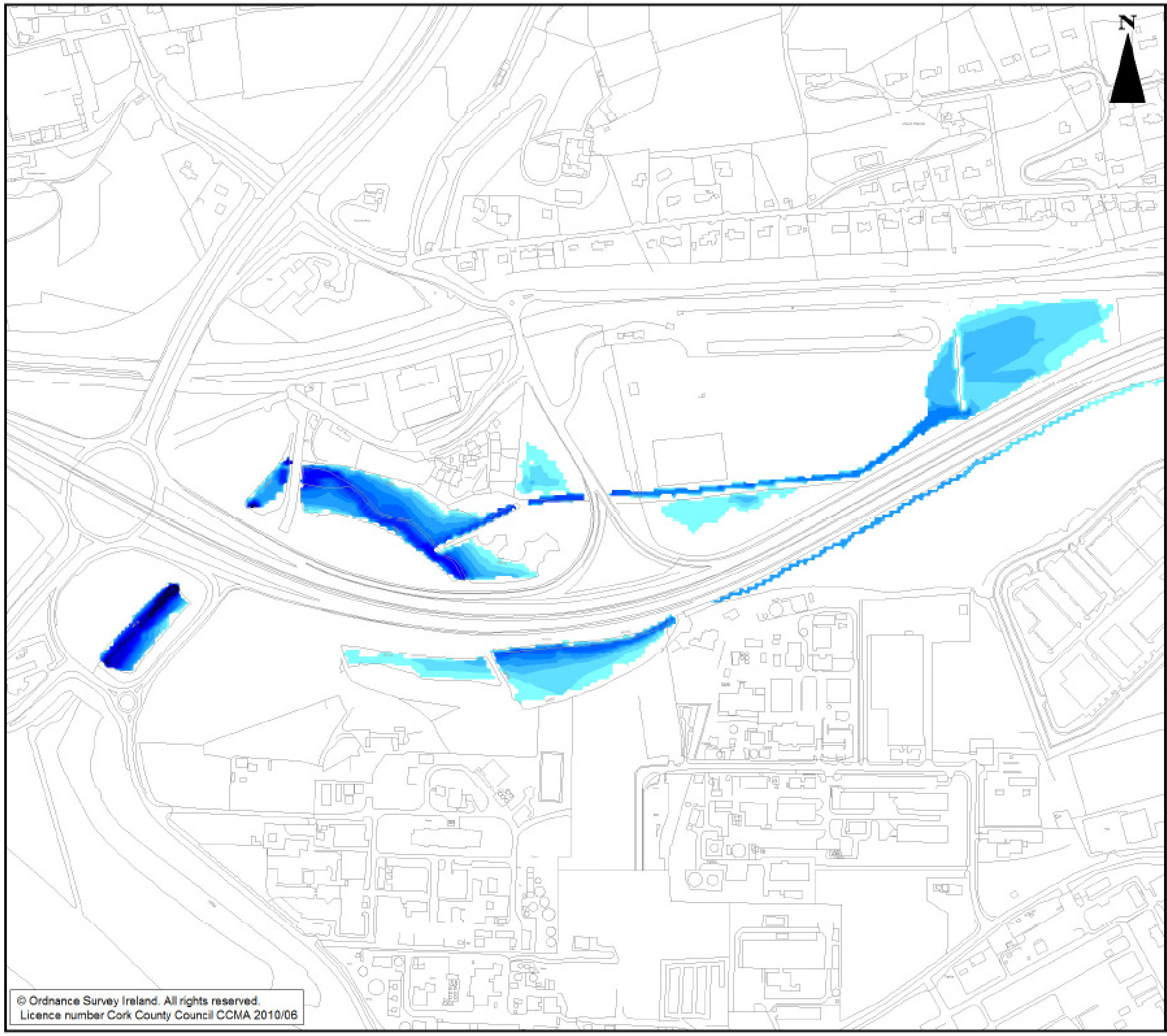
An tÚdarás um Bóithre Náisiúnta

Dunkettle Flood Risk Assessment

0.5% AEP Tidal Event (1 in 200 annual chance)
Maximum Flood Depth
Existing Situation



Scale: Not to Scale

Maximum Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- 1.25 - 1.50
- 1.50 - 1.75
- 1.75 - 2.00
- 2.00 - 2.25
- 2.25 - 2.50
- 2.50 - 2.75
- 2.75 - 3.00
- 3.00 <

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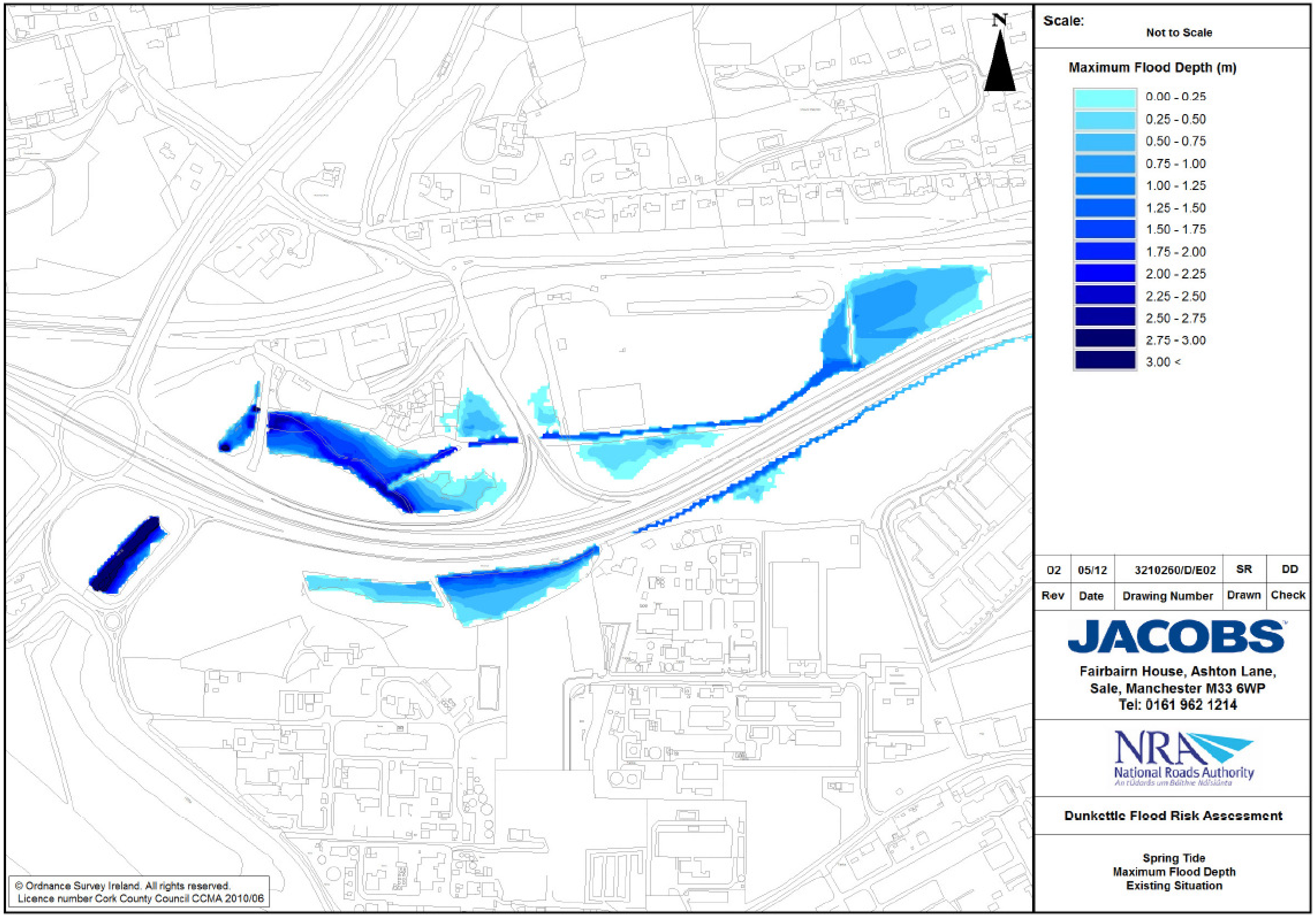
Dunkettle Flood Risk Assessment

Neap Tide
Maximum Flood Depth
Existing Situation


N
Scale:
Not to Scale
Maximum Flood Depth (m)
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.25
1.25 - 1.50
1.50 - 1.75
1.75 - 2.00
2.00 - 2.25
2.25 - 2.50
2.50 - 2.75
2.75 - 3.00
3.00 <
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Dunkettle Flood Risk Assessment
Spring Tide
Maximum Flood Depth
Existing Situation
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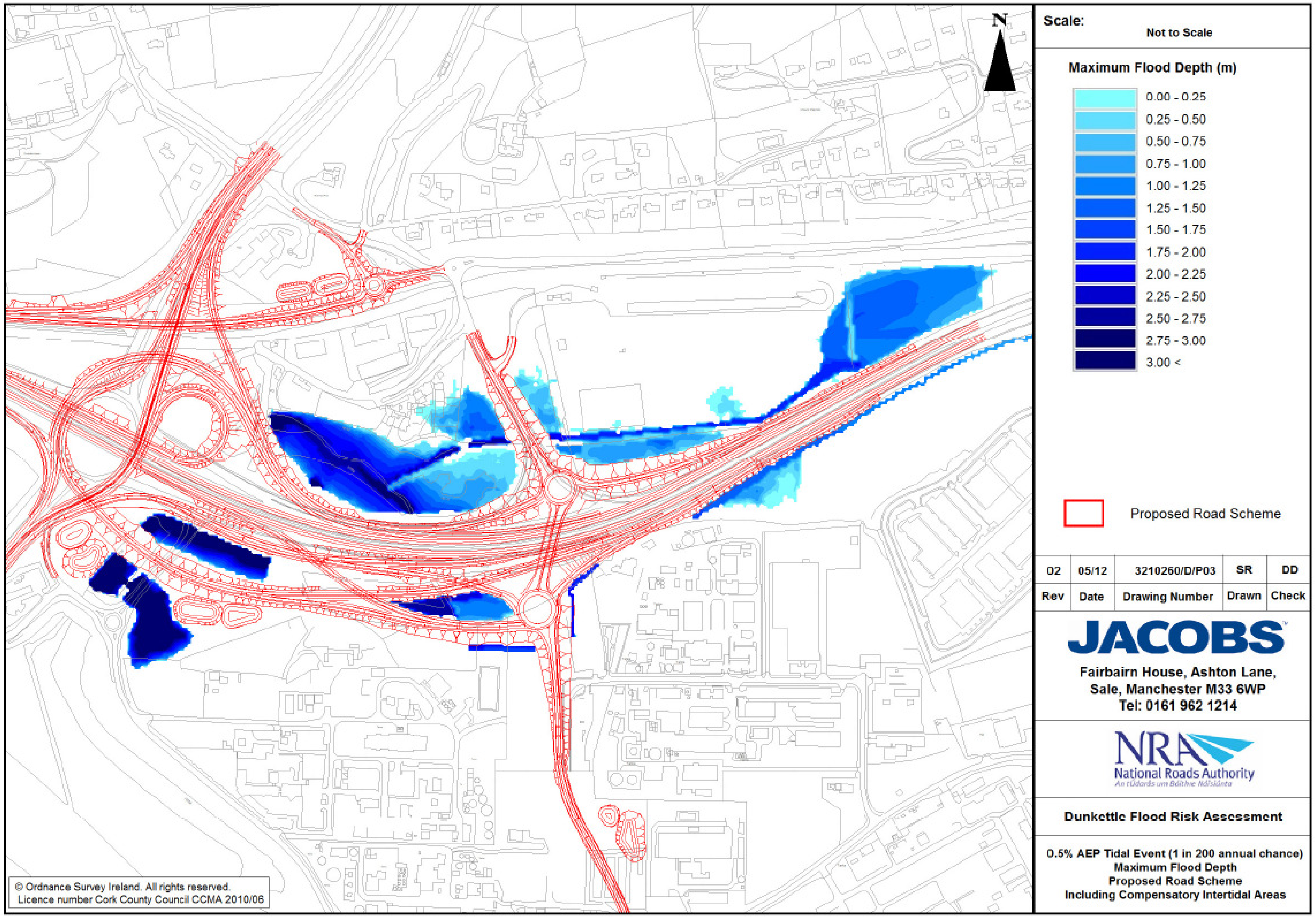
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© Ordnance Survey Ireland. All rights reserved.
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Scale:
Not to Scale
Maximum Flood Depth (m)
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.25
1.25 - 1.50
1.50 - 1.75
1.75 - 2.00
2.00 - 2.25
2.25 - 2.50
2.50 - 2.75
2.75 - 3.00
3.00 <
Proposed Road Scheme
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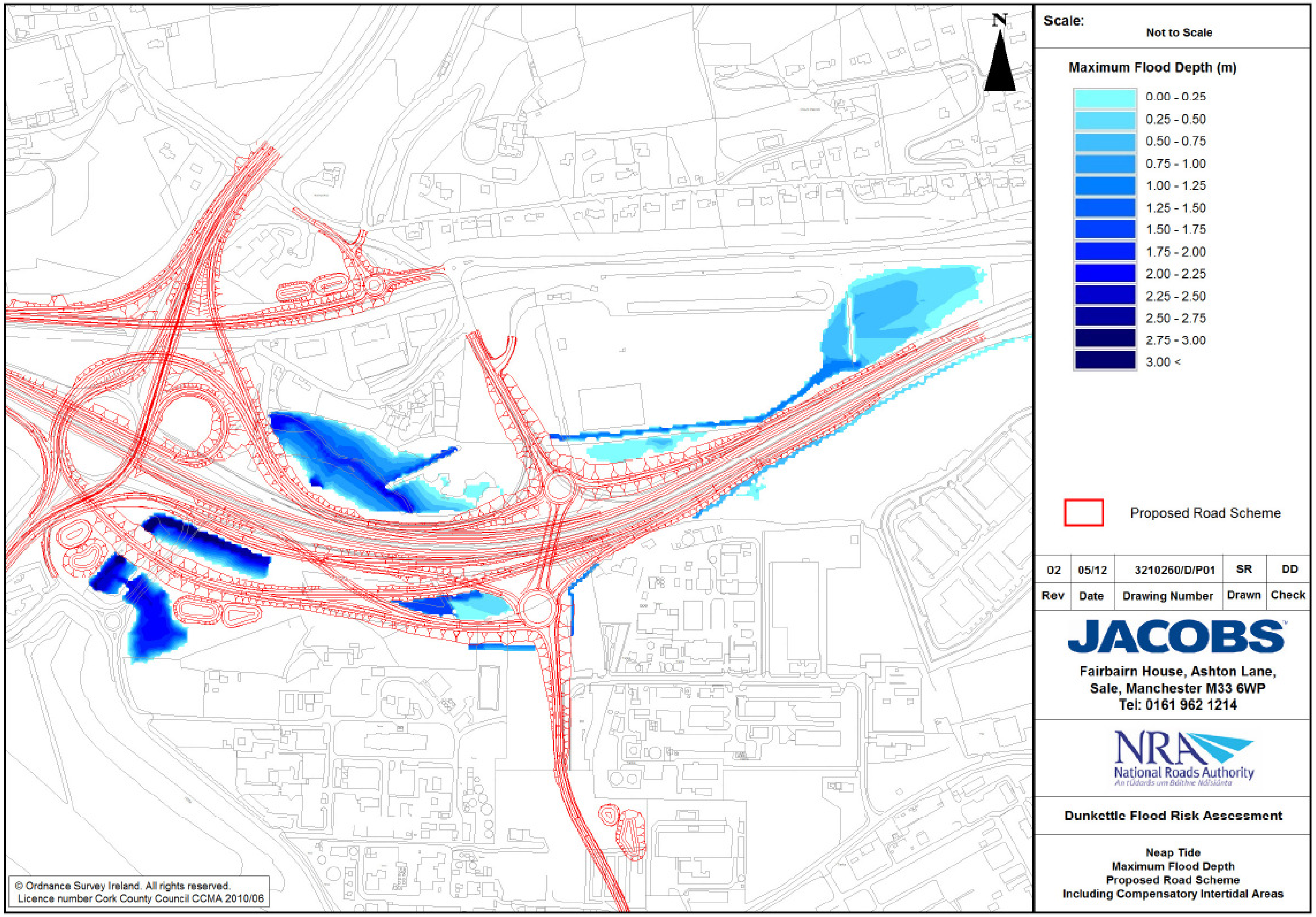
Dunkettle Flood Risk Assessment
0.5% AEP Tidal Event (1 in 200 annual chance)
Maximum Flood Depth
Proposed Road Scheme
Including Compensatory Intertidal Areas


N
Scale:
Not to Scale
Maximum Flood Depth (m)
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.25
1.25 - 1.50
1.50 - 1.75
1.75 - 2.00
2.00 - 2.25
2.25 - 2.50
2.50 - 2.75
2.75 - 3.00
3.00 <
Proposed Road Scheme
02 | 05/12 | 3210260/D/P01 | SR | DD
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Dunkettle Flood Risk Assessment
Neap Tide
Maximum Flood Depth
Proposed Road Scheme
Including Compensatory Intertidal Areas
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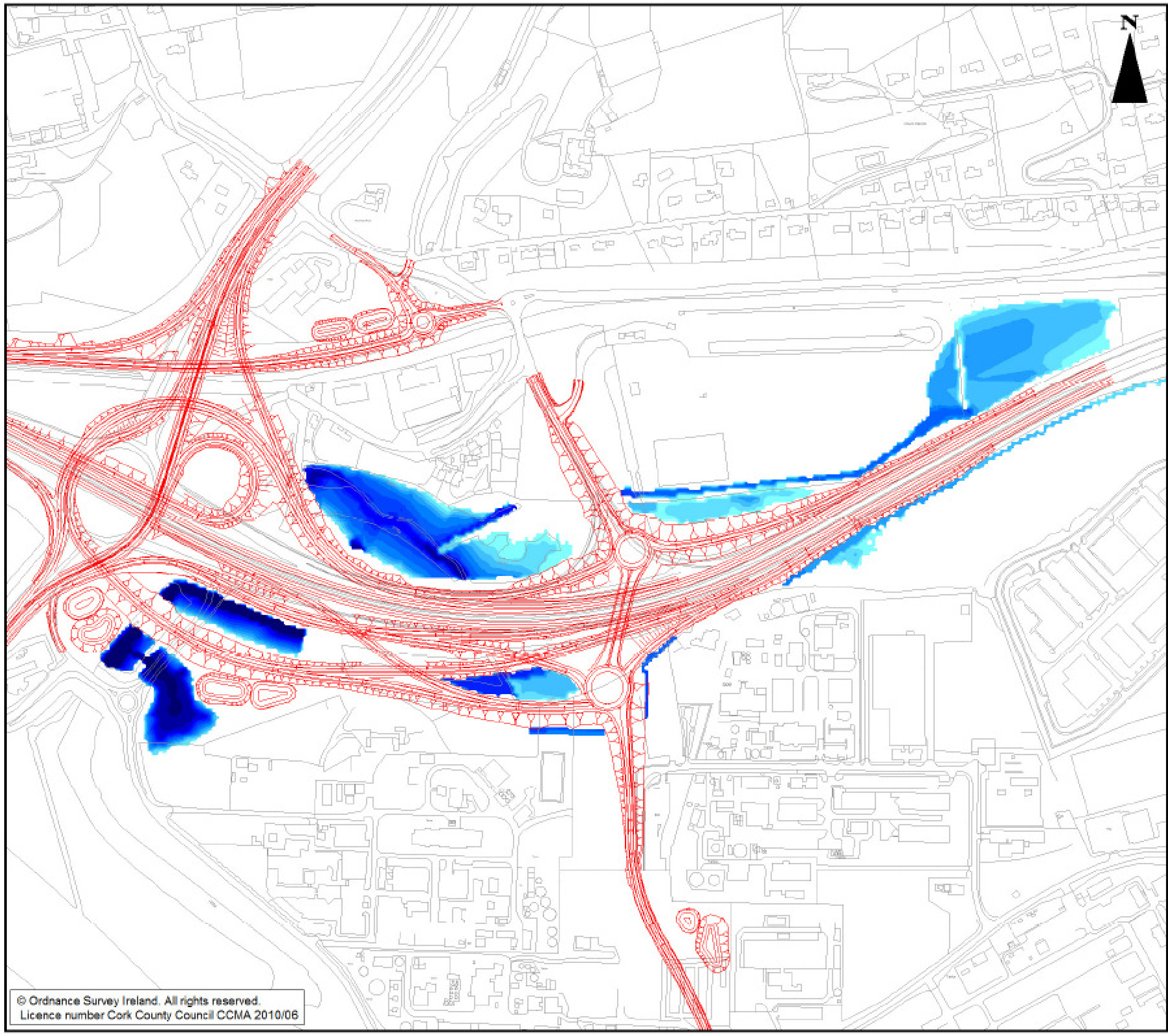

Scale: Not to Scale

Maximum Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- 1.25 - 1.50
- 1.50 - 1.75
- 1.75 - 2.00
- 2.00 - 2.25
- 2.25 - 2.50
- 2.50 - 2.75
- 2.75 - 3.00
- 3.00 <

Proposed Road Scheme

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Dunkettle Flood Risk Assessment

Spring Tide
Maximum Flood Depth
Proposed Road Scheme
Including Compensatory Intertidal Areas

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Appendix 7.1 Assessment of Impacts: Made Ground (Pre-Mitigation)

Receptor		Importance of Receptor	Phase	Potential Impact	Magnitude of Impact	Impact Assessment	Limitations / Remarks
Surface & Ground Waters	Shallow groundwater (within superficial deposits)	Very High	Construction	Degradation of water quality via ▪ Accidental spillages ▪ Creation of pathways during piling activities	Moderate Negligible Moderate	Profound / Significant Imperceptible	Location of proposed contractor chemical stores, refuelling areas etc. not determined at this stage. Piling methodology not determined at this stage.
	Shallow groundwater (within superficial deposits)	Very High	Operation	Degradation of water quality via ▪ Leaching of contaminants from re-used materials ▪ Leaching of contaminants from imported materials ▪ Leaching from concrete (including additives) from structures and piles ▪ Accidental spillages resulting from road/railway use	Negligible Negligible Negligible Moderate	Imperceptible Imperceptible Imperceptible Profound / Significant	Source and nature of materials to be re-used and/or imported to site not determined at this stage. Nature of concrete (and additives) not known at this stage.
	River Lee / Lough Mahon (including designated sites)	Very High	Construction	Degradation of water quality via ▪ Accidental spillages ▪ Dewatering discharges ▪ Sediment ingress ▪ Inappropriate materials management ▪ Ingress of contaminated shallow groundwater	Moderate Negligible Small adverse Small adverse Negligible	Profound / Significant Imperceptible Significant / moderate Significant / moderate Imperceptible	Location of proposed contractor chemical stores, refuelling areas etc. not determined at this stage Dewatering requirements not determined at this stage. Materials management locations, requirements not determined at this stage.
	River Lee / Lough Mahon (including designated sites)	Very High	Operation	Degradation of water quality via ▪ Lateral migration of contaminants along/within shallow water table ▪ Accidental spillages resulting from road/railway use	Negligible Moderate	Imperceptible Profound / Significant	Potential for contamination of shallow groundwater resulting from re-use / importation of materials not determined at this stage.
	Bedrock aquifer	Very High	Construction	Degradation of water quality via ▪ Vertical migration of contaminants from shallow groundwater ▪ Accidental spillages ▪ Creation of pathways during piling activities	Negligible Moderate Negligible	Imperceptible Profound / Significant Imperceptible	Source and nature of materials to be re-used and/or imported to site not determined at this stage. Nature of concrete (and additives) not known at this stage.
	Bedrock aquifer	Very High	Operation	Degradation of water quality via ▪ Vertical migration of contaminants from shallow groundwater	Negligible	Imperceptible	Potential for contamination of shallow groundwater resulting from re-use / importation of materials, and subsequent migration to deeper aquifer, not determined at this stage.
Human Health	Acute Risks to Construction Workers	High	Construction	Harm to human health via: ▪ Inhalation ▪ Ingestion ▪ Dermal contact ▪ Inhalation of vapours / ground gases	Small Adverse	Moderate / Slight	The completed risk assessments indicate no risk to human health. However, additional ground investigation should be undertaken to fully discount potential risks to the receptor.
	Acute Risks to Maintenance Workers	High	Operation	Harm to human health via: ▪ Inhalation ▪ Ingestion ▪ Dermal contact ▪ Inhalation of vapours / ground gases	Small Adverse	Moderate / Slight	The completed risk assessments indicate no risk to human health. However, additional ground investigation should be undertaken to fully discount potential risks to the receptor.
	Chronic Risks to Site Users / Maintenance Workers	High	Operation	Harm to human health via: ▪ Inhalation ▪ Ingestion ▪ Dermal contact ▪ Inhalation of vapours / ground gases	Negligible	Imperceptible	The completed risk assessments indicate no risk to human health. However, additional ground investigation should be undertaken to fully discount potential risks to the receptor.
Infrastructure	Concrete structures (inc. piles)	High	Operation	Degradation of concrete structures as a result of aggressive ground conditions	Small adverse	Moderate / Slight	
	Confined spaces	High	Operation	Accumulation of potentially explosive ground gases within confined spaces e.g. culverts	Moderate Adverse	Significant / Moderate	An assessment of the ground gas regime at the site has not been completed at this stage.

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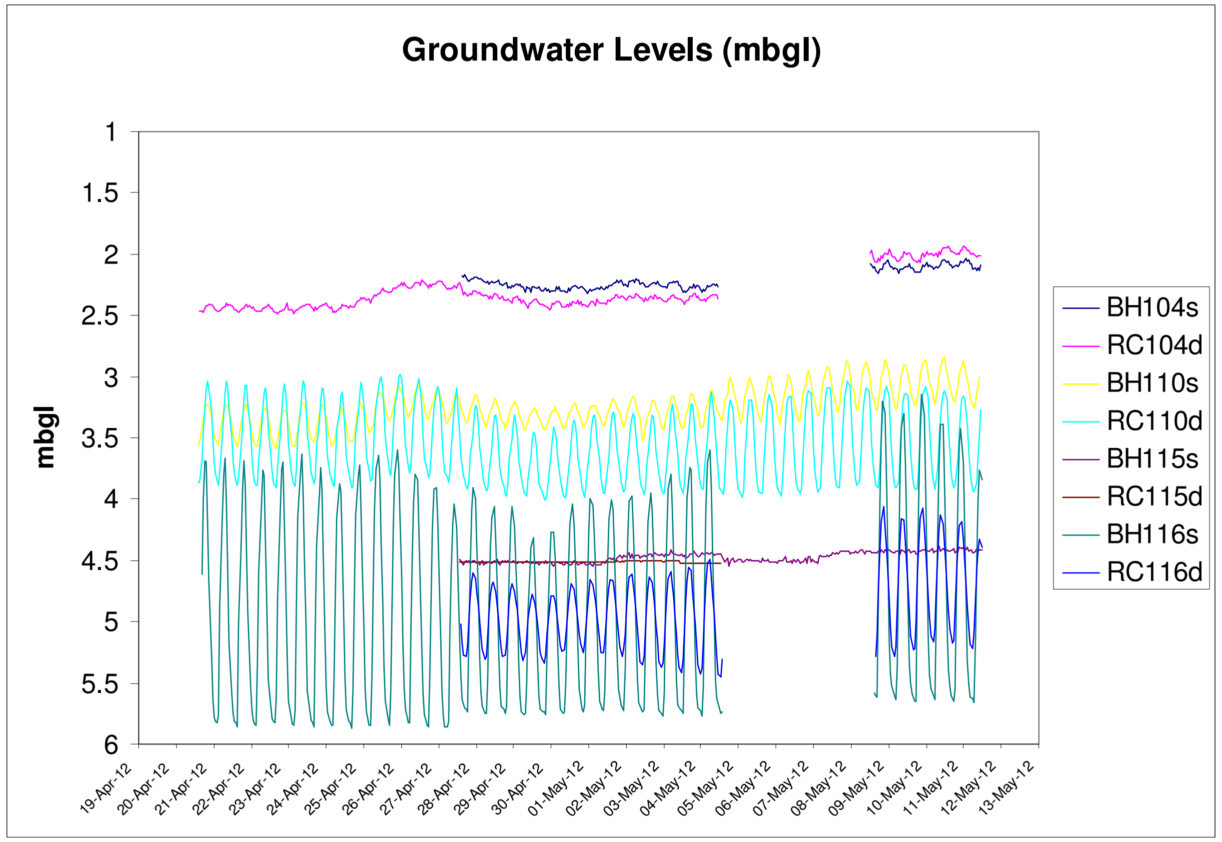
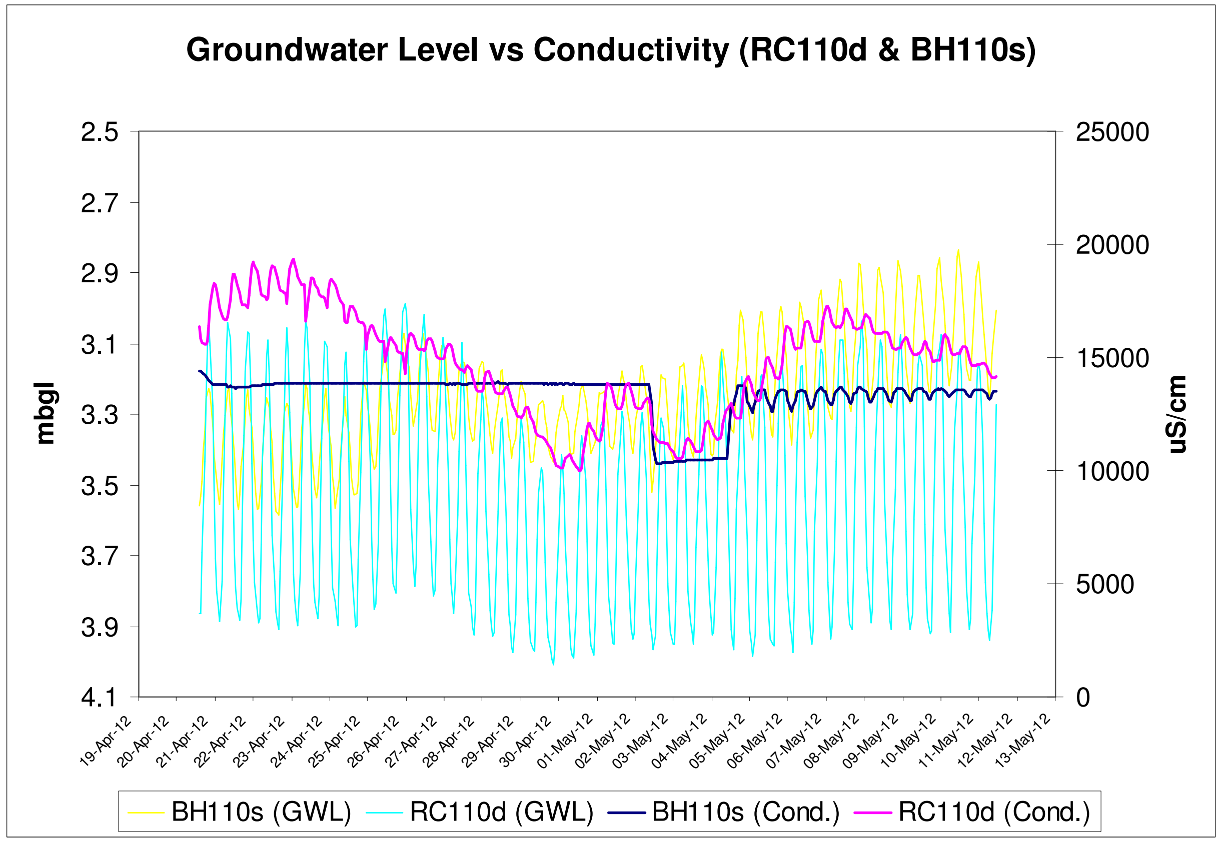
Appendix 7.2 Assessment of Residual Impacts and Mitigation Measures: Made Ground (Post-Mitigation)

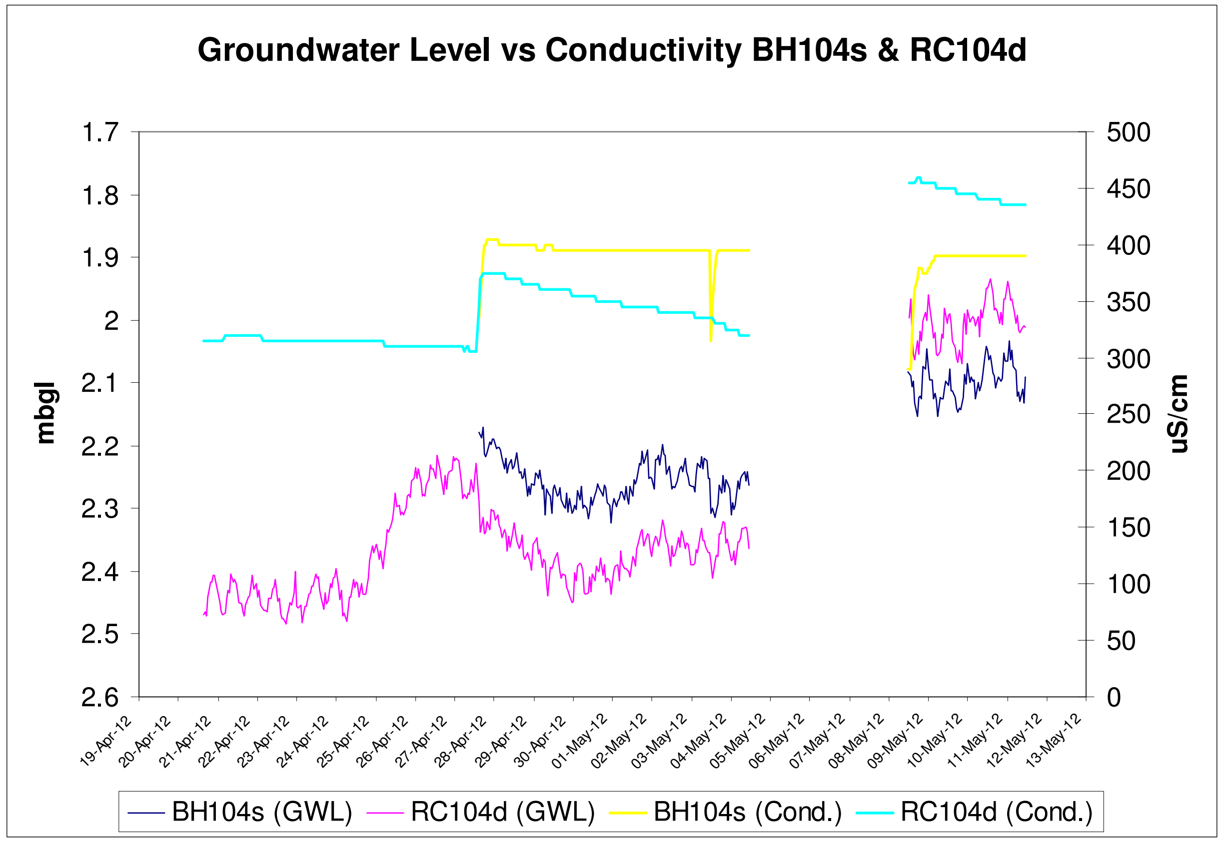
Receptor		Phase	Impact Assessment	Mitigation Measures	Residual Impact
	Shallow groundwater (within superficial deposits)	Construction	Profound / Significant Imperceptible	▪ Compliance with *CIRIA Control of Water Pollution from Construction Sites – A Guide to Good Practice;* ▪ A contaminant spill emergency plan will be put in place to contain, remove or remediate any catastrophic spill before it reaches any groundwater or surface water receptor. Emergency equipment/spill kits to facilitate the implementation of such plan will be made available in secured locations within the area (see section 7.3.5 (b) (i)); ▪ Piling will be completed in accordance with 7.3.5 (a) (i).	Imperceptible
	Shallow groundwater (within superficial deposits)	Operation	Imperceptible Imperceptible Imperceptible Profound / Significant	▪ Imported material used within the proposed development will not contain any contaminated material; ▪ The contractor will establish re-use acceptability criteria for site-won material to prevent contaminated material being reused.	Imperceptible
	River Lee / Lough Mahon (including designated sites)	Construction	Profound / Significant Imperceptible Significant / moderate Significant / moderate Imperceptible	▪ Compliance with *CIRIA Control of Water Pollution from Construction Sites – A Guide to Good Practice;* ▪ Fuel storage tanks will be bunded to a capacity at least 110% of the volume of the storage tank. Re-fuelling of plant will not occur within 50 m of any watercourse and only in bunded refuelling areas; ▪ Emergency procedures and spillage kits will be available and construction staff will be familiar with emergency procedures; ▪ Implementation of measures to minimise sediment release to surface waters; ▪ The contractor will undertake stockpiling of materials in compliance with the DEFRA (2009) Construction Code of Practice for the Sustainable Use of Soils on Construction Sites.	Imperceptible
	Bedrock aquifer	Construction	Imperceptible Profound / Significant Imperceptible	▪ Compliance with *CIRIA Control of Water Pollution from Construction Sites – A Guide to Good Practice;* ▪ The construction contractor will establish procedures in the event of previously unidentified contaminated materials being identified during earthworks or piling activities on-site, as per section 12.5.1 (f); ▪ Fuel storage tanks will be bunded to a capacity at least 110% of the volume of the storage tank. Re-fuelling of plant will not occur within 50 m of any watercourse and only in bunded refuelling areas; ▪ Emergency procedures and spillage kits will be available and construction staff will be familiar with emergency procedures; ▪ Piling will be completed in accordance with 7.3.5 (a) (i).	Imperceptible
	Bedrock aquifer	Operation	Imperceptible	▪ The contractor will establish re-use acceptability criteria for site-won material to prevent contaminated material being reused. ▪ Imported material used within the proposed development will not contain any contaminated material. ▪ Selection of structural materials to prevent long-term contaminant leaching to the environment.	Imperceptible
	Acute Risks to Construction Workers	Construction	Moderate / Slight	▪ Identification of, and implementation of, Personal Protective Equipment (PPE) and hygiene procedures to prevent potential dermal absorption, ingestion and / or inhalation of contaminants. Additional measures may be required dependent on the findings of additional or previously unidentified contamination encountered at construction stage; ▪ Water misting or sprays will be used if particularly dusty activities are necessary during dry or windy periods; ▪ Gas monitoring will be undertaken during construction works associated with any confined spaces (culverts, chambers, utilities etc).	Imperceptible
	Acute Risks to Maintenance Workers	Operation	Moderate / Slight	▪ Implementation of Personal Protective Equipment (PPE) and hygiene procedures; ▪ Dampening of earthworks during dry periods; ▪ Gas monitoring will be undertaken during construction works associated with any confined spaces (culverts, chambers, utilities etc).	Imperceptible

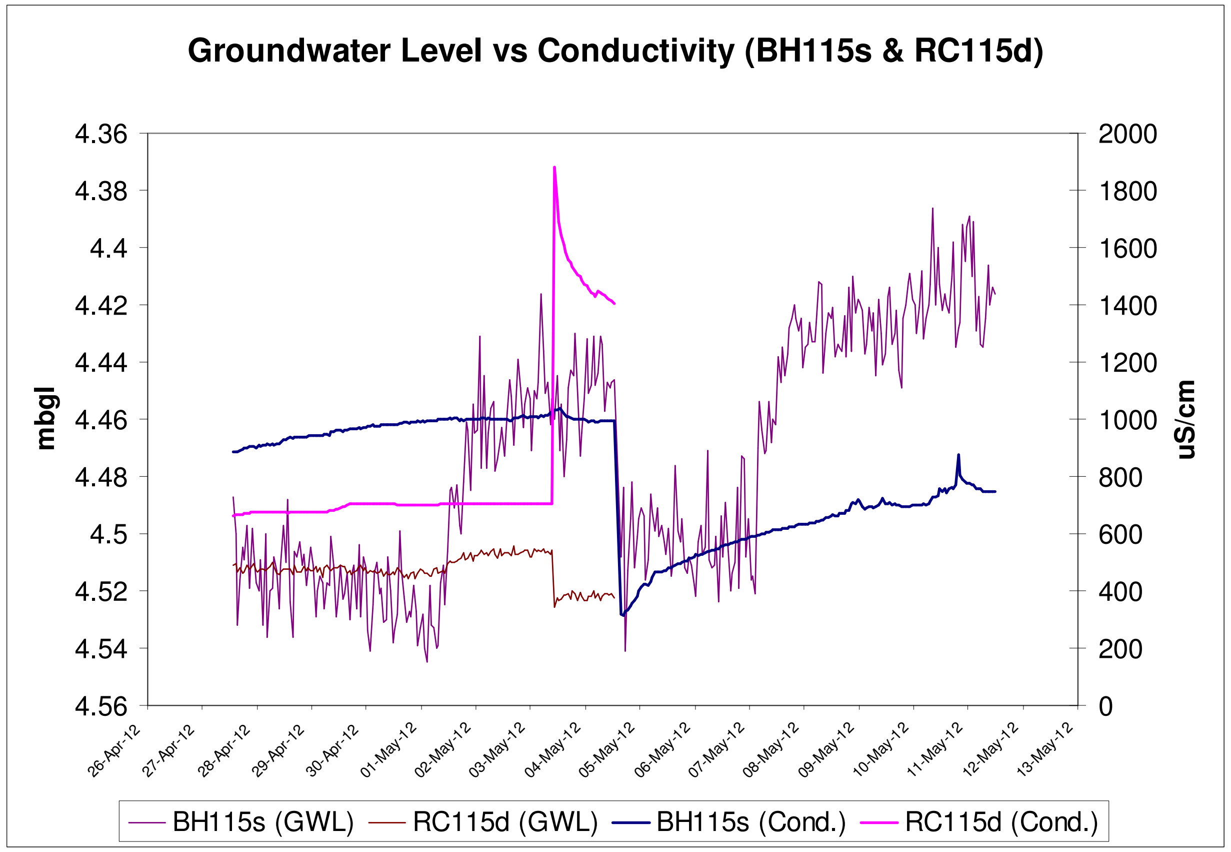
Receptor		Phase	Impact Assessment	Mitigation Measures	Residual Impact
	Chronic Risks to Site Users / Maintenance Workers	Operation	Imperceptible	▪ Identification of, and implementation of, Personal Protective Equipment (PPE) and hygiene procedures to prevent potential dermal absorption, ingestion and / or inhalation of contaminants.	Imperceptible
	Concrete structures (inc. piles)	Operation	Moderate / Slight	▪ Concrete materials resistant to corrosion in the identified ground conditions will be used.	Imperceptible

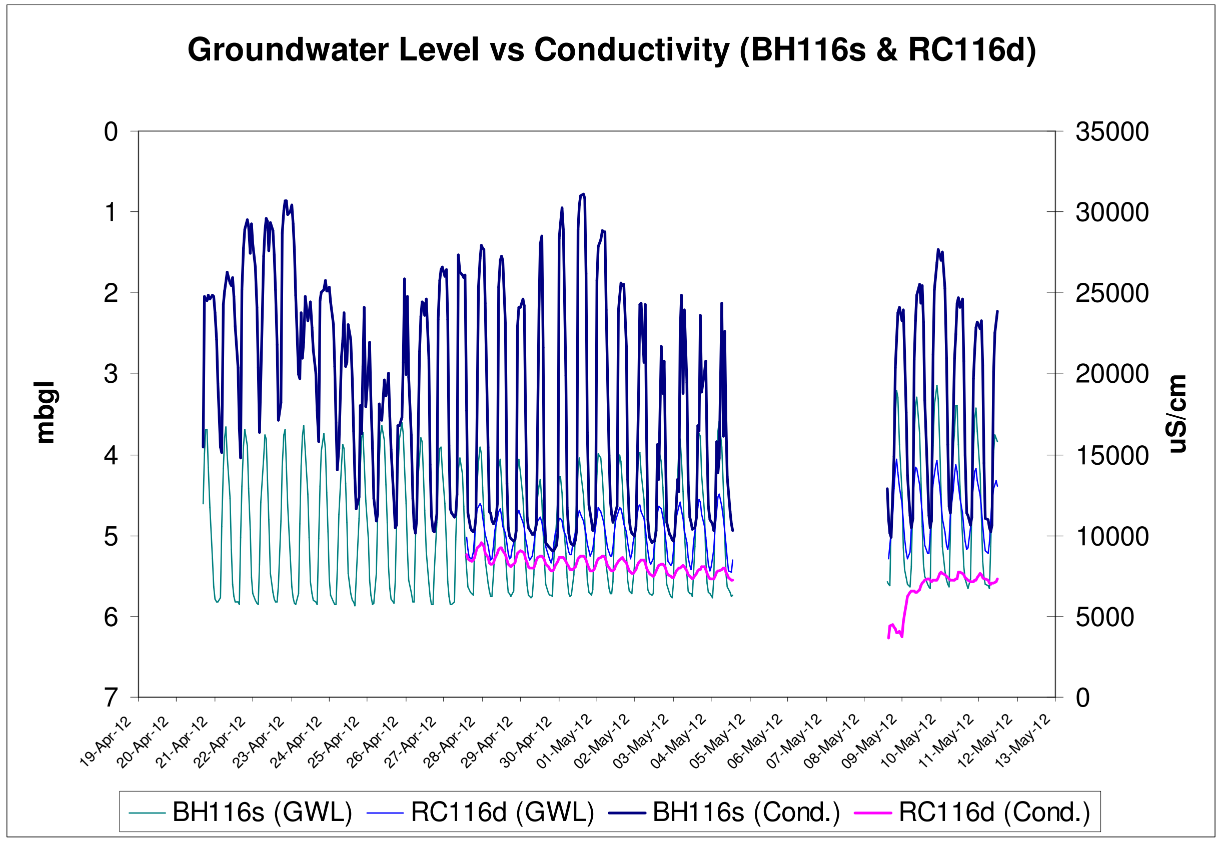
Appendix 7.3 Groundwater Levels and Conductivity











Groundwater Level vs Conductivity (BH116s & RC116d)
mbgl
uS/cm
0
1
2
3
4
5
6
7
35000
30000
25000
20000
15000
10000
5000
0
19-Apr-12
20-Apr-12
21-Apr-12
22-Apr-12
23-Apr-12
24-Apr-12
25-Apr-12
26-Apr-12
27-Apr-12
28-Apr-12
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11-May-12
12-May-12
13-May-12
BH116s (GWL)
RC116d (GWL)
BH116s (Cond.)
RC116d (Cond.)