DART+ South West

Flood Risk Assessment

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Tionscadal Éireann
Project Ireland
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NTA
Údarás Náisiúnta Iompair
National Transport Authority

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CIE

Iarnród Éireann
Irish Rail

Contents

Glossary of Technical Terms

Term	Meaning
Annual Exceedance Probability	The probability, typically expressed as a percentage, of a flood event of a given magnitude being equalled or exceeded in any given year. For example, a 1% AEP flood event has a 1%, or 1 in a 100, chance of occurring or being exceeded in any given year.
Flood Zone A	Where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding);
Flood Zone B	Where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding); and
Flood Zone C	Where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.
Environmental Impact Assessment	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the Environmental Impact Assessment Directive and Regulations, including the publication of an Environmental Impact Assessment Report.
Justification Test	An assessment of whether a development proposal within an area at risk of flooding meets specific criteria for proper planning and sustainable development and demonstrates that it will not be subject to unacceptable risk nor increase flood risk elsewhere. The justification test should be applied only where development is within flood risk areas that would be defined as inappropriate under the screening test of the sequential risk-based approach adopted by the DOEHLG (2009) Flood Risk Management Planning Guidelines. There are two types of Justification Tests, the Plan-making Justification Test Justification Test (used at plan preparing stage) and the Development Management Justification Test (used at the planning application stage).
Light Detection and Ranging (LiDAR)	Remote sensing technology that uses light in the form of a pulsed laser to measure distances to the Earth.
Mitigation measures	Measures envisaged to avoid, prevent or reduce any identified significant adverse effects on the environment (EU, 2017).
One Dimensional (1D) Model	In 1D models, flow is averaged over depth and across defined cross sections. Used for modelling surface water drainage networks, in bank flows, in channel hydraulic structures and narrow well-defined floodplains.
One Dimensional Model / Two-Dimensional (1D/2D) Model	The channel is modelled in 1D and linked to a 2D model of the floodplain so that they can exchange flow. Used where there is a need to understand both the channel and floodplain processes. Used where there is need to understand how the surface water drainage network interacts with overland flows.

Term	Meaning
Return Period	A term that is used to describe the probability of a flood event, expressed as the interval in the number of years that, on average over a long period of time, a certain magnitude of flood would be expected to occur. This term has been replaced by 'Annual Exceedance Probability, as Return Period can be misleading.
The Developer	Irish Rail
The Proposed Development	The DART+ South West Project will deliver an improved electrified network, with increased passenger capacity and enhanced train performance between Hazelhatch & Celbridge Station to Heuston Station (circa 16km) on the Cork Mainline, and to Glasnevin via Phoenix Park Tunnel Branch Line (circa 4km).
Two-Dimensional (2D) Model	In 2D models, flow is averaged over the flow depth and horizontally over a model grid cell or element. Used for modelling floodplain flows where the channel capacity and transition between in bank and out of bank flow is not important. Used for modelling overland flow where interaction with the surface water drainage network is not important. Used for coastal inundation modelling.
Vulnerable Development	Vulnerable development is classified as High, Less or Water Compatible for differing land uses and types of development. Classification of the vulnerability to flooding of different types of development is defined in Table 3.1 of The Planning System and Flood Risk Management – Guidelines for Planning Authorities" (DOEHLG, 2009). In board terms the three classes of vulnerability can be categorised as: • Highly vulnerable development - residential dwellings, healthcare facilities, emergency services buildings and essential transport or utility infrastructure; • Less vulnerable development – Buildings used for retail, leisure, warehousing, commercial, industrial and non-residential institutions; and • Water Compatible – Flood control infrastructure, maritime infrastructure, water-based recreation facilities and green open spaces. Reference should be made to Table 3.1 of DOEHLG (2009) for a complete definition of each class of vulnerability.

Acronyms and Abbreviations

AEP	Annual Exceedance Probability
AMAX	Annual Maximum
BFI	Baseflow Index
BGL	Below Ground Level
CFRAM	Catchment Flood Risk Assessment and Management
CIÉ	Córas Iompair Éireann
CWI	Catchment Wetness Index
DCC	Dublin City Council
DDF	Depth Duration Frequency
DTM	Digital Terrain Model
DTTA	Department of Transport, Tourism, and Sport
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EPA	Environmental Protection Agency
ERR	Exponential Recession Replacement
EU	European Union
FAS	Flood Alleviation Scheme
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
FRC	Flood Resilient City
FRM	Flood Risk Management
FRS	Flood Relief Scheme
FSE	Factorial Standard Error
FSR	Flood Studies Report
FSU	Flood Studies Update
GEV	Generalised Extreme Value
GSI	Geological Survey of Ireland
HA	Hydrometric Area
HEFS	High End Future Scenario
HEP	Hydrological Estimation Point
HWA	Hydrograph Width Analysis
ICM	Integrated Catchment Modelling
ICPSS	Irish Coastal Protection Strategy Study
ICWWS	Irish Coastal Wave and Water Level Modelling Study
IE	Iarnród Éireann
IH	Institute of Hydrology
IVB	??
IW	Irish Water
KCC	Kildare County Council
LAP	Local Area Plan

LCA	Landscape Character Area
LiDAR	Light Detection and Ranging
MCA	Multi Criteria Analysis
MRFS	Mid-Range Future Scenario
NIFTI	National Investment Framework for Transport in Ireland
NTCC	National Train Control Centre
OHLE	Overhead Line Equipment
OPW	Office of Public Works
OSI	Ordnance Survey Ireland
OSR	Option Selection Report
P & C	Points and Crossings
PCD	Physical Catchment Descriptor
POSR	Prelimary Option Selection Report
PFRA	Preliminary Flood Risk Assessment
PPT	Phoenix Park Tunnel
P&C	Points and Crossings
RO	Railway Order
ROI	Region of Influence
SAAR	Standard Average Annual Rainfall
SDCC	South Dublin County Council
SDZ	Strategic Development Zone
SFRA	Strategic Flood Risk Assessment
SPR	Standard Percentage Runoff
SuDS	Sustainable Urban Drainage Systems
SWMP	Stormwater (or surface water) Management Plan
TEN-T	Trans European Network
TER	Telecommunications Equipment Room
TP	Time to Peak
TTAJV	TYPSA, TUC RAIL and ATKINS Design Joint Venture
UAF	Urban Adjustment Factor
UK	United Kingdom
UPO	Unit-Peak-at-Origin
URBEXT	Urban Extent
WRAP	Winter Rain Acceptance Potential

Units

Unit	Description
km	Kilometres
km^2	Kilometres squared
m	Metres (length; 1,000 cm)
m/km	Metre per Kilometre
m^2	Square metres
m^3	Cubic metres
m^3/s	Cubic metres per second
mm	Millimetre
mOD	Metres Ordnance Datum
s	Seconds

1. Introduction & Background

Córas Iompair Éireann, hereafter referred to as CIÉ or the applicant, is applying to An Bord Pleanála ("the Board") for a Railway Order ("RO") for the DART+ South West Project under the Transport (Railway Infrastructure) Act 2001 (as amended and substituted) hereafter referred to as 'the 2001 Act".

Iarnród Éireann have appointed TTAJV (TYPSA, TUC RAIL and ATKINS Design Joint Venture) to prepare the Design for the proposed DART+ South West Project, referred as the "proposed Development" in this Report. TTAJV is preparing the Environmental Impact Assessment Report (EIAR) and Railway Order along with a Flood Risk Assessment (FRA) report. The European Union (Railway Orders) (Environmental Impact Assessment) (Amendment) Regulations 2021 (S.I. No. 743 of 2021) gives further effect to the transposition of the EIA Directive (EU Directive 2011/92/EU as amended by Directive 2014/52/EU) on the assessment of the effects of certain public private projects on the environment by amending the Transport (Railway Infrastructure) Act 2001 ('the 2001 Act').

A Flood Risk Assessment (FRA) of the proposed DART+ South West Project is required to inform the design and support the RO application and EIAR for the proposed Development.

1.1. Proposed Development

The DART+ South West Project, referred to hereafter as 'the proposed development' or 'the project', will deliver an electrified network, with increased passenger capacity and enhanced train service between Hazelhatch & Celbridge Station to Heuston Station (circa 16km) on the Cork Mainline, and Heuston Station to Glasnevin Junction via the Phoenix Park Tunnel (PPT) Branch Line (circa 4km).

The project will complete four tracking between Park West & Cherry Orchard Station and Heuston Station and will also re-signal and electrify the route. The project will also deliver track improvements along the PPT Branch Line. Upon completion of DART+ South West electrification, new electric DART trains will be used on this railway corridor.

Figure 1-1 provides a schematic layout of the proposed DART+ South West Project.

The proposed Project has been divided into four distinct geographic zones along the length of the corridor (Zones A to D) as outlined in EIAR (and consequently the FRA) and summarised below. The proposed Project is described from west to east along the railway corridor.

- Zone A – Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station;
- Zone B – Park West & Cherry Orchard Station to Heuston Station (incorporating Inchicore Works;
- Zone C – Heuston Yard & Station (incorporating New Heuston West Station); and
- Zone D – Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line).

Figure 1-2 illustrates the project zones.

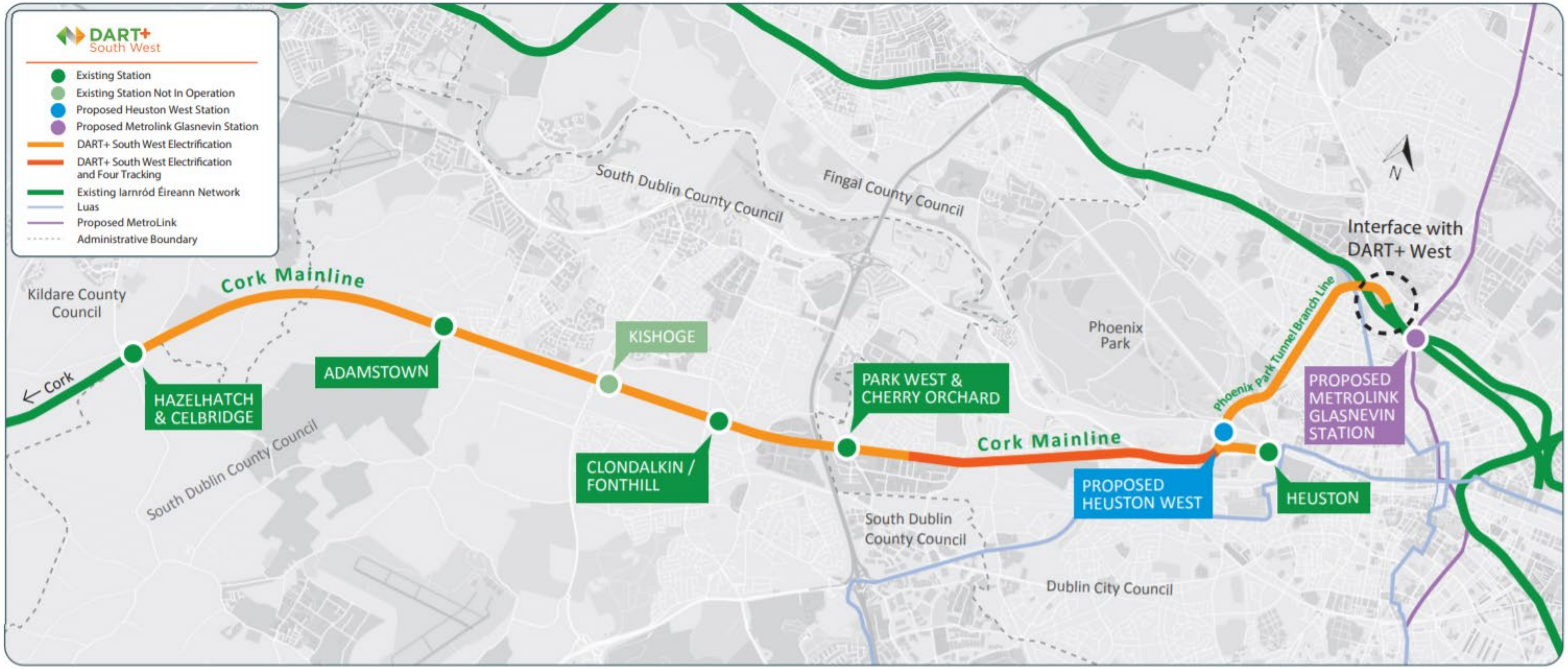

Figure 1-1 DART+ South West Route Map

Figure 1-2 DART+ South West Zones

1.2. Key Infrastructural Elements of DART+ South West

The electrification of the rail line will predominantly follow the existing railway corridor. The principal project components are as follows:

- Diversions for utilities located along the route as part of the enabling works for the project.
- Construction of overhead line equipment (OHLE) from Hazelhatch & Celbridge Station to Heuston Station and also from Heuston Station to Glasnevin Junction, via the Phoenix Park Tunnel Branch Line.
- Signalling upgrades and additional signalling infrastructure.
- Telecommunications infrastructure including buildings.
- Ancillary equipment cabins.
- Works to the Permanent Way (or track or railway corridor) including all ancillary installations such as rails, sleepers, ballast interfaces with existing utilities, boundary treatments, drainage works, vegetation management and other ancillary works.
- Construction of a new portal structure at the South Circular Road Junction.
- Works to Phoenix Park Tunnel including horizontal and vertical realignment to ensure that structural and passing clearances are achieved.
- Construction of six electrical substations at intervals along the rail line to provide power to the network.
- Undertaking improvements/reconstructions of bridges to achieve vertical and horizontal clearances.
- Retaining walls supporting widening of the rail corridor and replacement bridges.
- Overhead electrified line protection works at bridges including parapets.
- Construction and delivery of a new Heuston West Station
- Provision of construction compounds to support the construction works.

Interventions outside of CIÉ lands will be required at a number of locations for some of the scheme elements such as:

- Widening of the railway corridor for four-tracking from Park West & Cherry Orchard Station to Heuston Station;
- Bridge reconstruction and/or improvements;
- Construction of substations (to facilitate the provision of power to the line); and
- Use of land for temporary construction/storage compounds and all ancillary works required for the project.

The design is compatible with future stations at Kylemore and Cabra, although the construction of these stations is not part of the project.

1.3. Report Objectives

As part of this project, TTAJV has carried out a FRA of the proposed development. This FRA is required to address the flooding risk for the proposed Development as set out in the Government's 2009 Planning System and Flood Risk Management Regulations (hereafter referred to as the FRM Guidelines). The objective of this FRA is to:

- Review the available flood risk information to establish the root causes and mechanism of any flooding;
- Generate flood zone mapping for existing and proposed scenarios;
- To investigate residual flood risk to the site and surrounding area;
- To appraise any proposed flood mitigation works; and
- To inform a Railway Order application for the proposed Development.

1.4. Receptor Vulnerability

For the purpose of this assessment, the proposed Development is characterised into the following categories:

- All works associated with the railway line itself and regionally important transport infrastructure will be considered as Highly Vulnerable Developments. Any works associated with this development shall be located outside of Flood Zone B (0.1% Annual Exceedance Probability (AEP) flood event) or subject to a Justification Test;
- All works associated with local access roads will be considered Less Vulnerable Development. Any works associated with this development shall be located outside of Flood Zone A (1% AEP flood event) or subject to a Justification Test;
- All works associated with landscaping and drainage i.e., attenuation ponds, will be considered as Water Compatible Development. Any works associated with this development can be located within Flood Zone A (1% AEP flood event).

All works shall avoid any increase in flood risk elsewhere.

1.5. Report Structure

The FRA is structured as follows:

- Chapter 1 forms the Introduction and outlines the background information of the study area.
- Chapter 2 sets out the Flood Risk Assessment Methodology.
- Chapter 3 presents the findings of the FRA from Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station (Zone A).
- Chapter 4 presents the findings of the FRA from Park West & Cherry Orchard Station to Heuston Station (incorporating Inchicore Works) (Zone B).
- Chapter 5 presents the findings of the FRA Heuston Yard & Station (incorporating New Heuston West Station) (Zone C).

- Chapter 6 presents the findings of the FRA from Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line) (Zone D).
- Chapter 7 presents the Justification Tests for the proposed developments as required by the Government's FRM Regulations.
- Chapter 8 concludes the findings of FRA.

1.6. Disclaimer

This FRA has been prepared by using information, datasets and models provided by the Office of Public Works and Contains Office of Public Works information © Office of Public Works. The use of the data is subject the Terms and Conditions agreed with the Office of Public Works.

1.7. Existing Topography

The existing ground generally falls from west to east across the site. The ground levels decrease from approximately 67 at Hazelhatch to 9 mOD at the south bank of the River Liffey. The Ordnance Survey Ireland (OSI) contour map covering the study area is shown in Figure 1-3 with a representation of the nature of the slopes along the alignment of the Permanent Way in the study area.

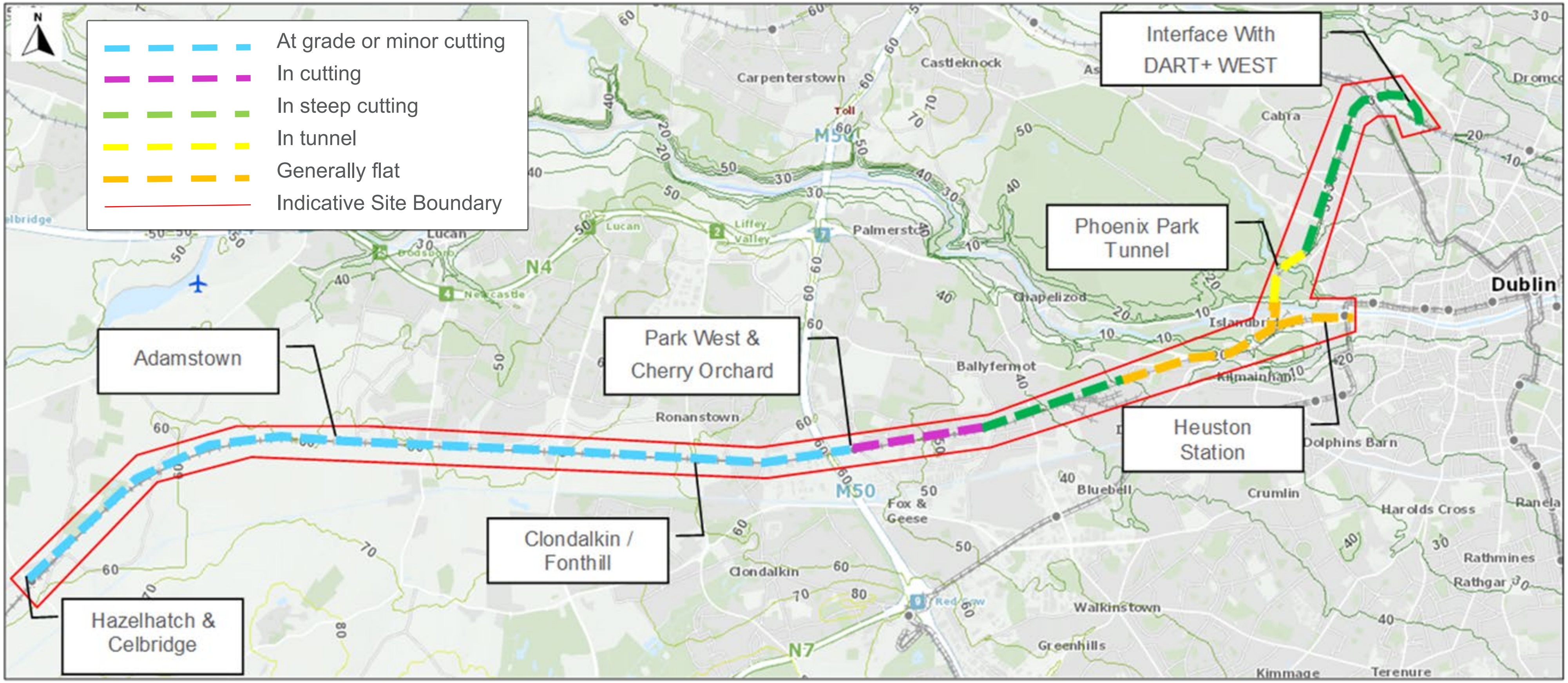

Figure 1-3 OSI Contour Map along the DART+ South West Route

1.8. Geographic Context and Adjacent Land Uses Overview

The DART+ South West Project passes through the administrative areas of three local authorities, notably Dublin City Council (DCC), South Dublin County Council (SDCC) and Kildare County Council (KCC). Hazelhatch, on the border between County Kildare and South Dublin marks the western extent of the DART+ South West Project. As the line approaches Dublin's city centre, it enters into the administrate area of DCC.

The receiving environment is a mix of urban, sub-urban and rural areas. The western extents of the project route corridor are located adjacent to rural agricultural land. The adjacent land becomes gradually more urban as the route travels east through the western suburbs of Dublin and into Dublin city centre. As such, the baseline environment consists of non-agricultural properties including residential, amenity, commercial, community and development lands. The line passes through the residential areas of Hazelhatch, Adamstown, Clondalkin, Park West, Ballyfermot, Inchicore, Kilmainham, Islandbridge, Cabra and Glasnevin and is in proximity to several industrial areas such as Clondalkin and Grangecastle.

Other uses include the local road network, railway traffic on the existing rail line, agricultural land uses and motorway associated traffic such as the M50 which intersects the study area at Park West.

1.9. Salient Hydrological Features

The proposed development site crosses over the Royal Canal, the River Liffey and its tributaries, namely from west to the east of the railway route:

- Hazelhatch Stream;
- Shinkeen Stream;
- Coneyburrow Stream;
- Lucan Stream;
- Griffeen River;
- Blackditch Stream; and
- River Camac, which is culverted beneath Heuston Station.

The Environmental Protection Agency (EPA) map shows the Creosote Stream crossing the Phoenix Park and discharging into the Liffey immediately after crossing Chapelizod Road. The Creosote Stream crosses under the abutments of Sarsfield Road Bridge (UBC4) and flows in a north-easterly direction and as such it is presented in Chapter 4 (Section 4.1 - the FRA for the section between Park West & Cherry Orchard Station and Inchicore). The most immediate hydrological features in the vicinity of the proposed development are presented in Figure 1-4.

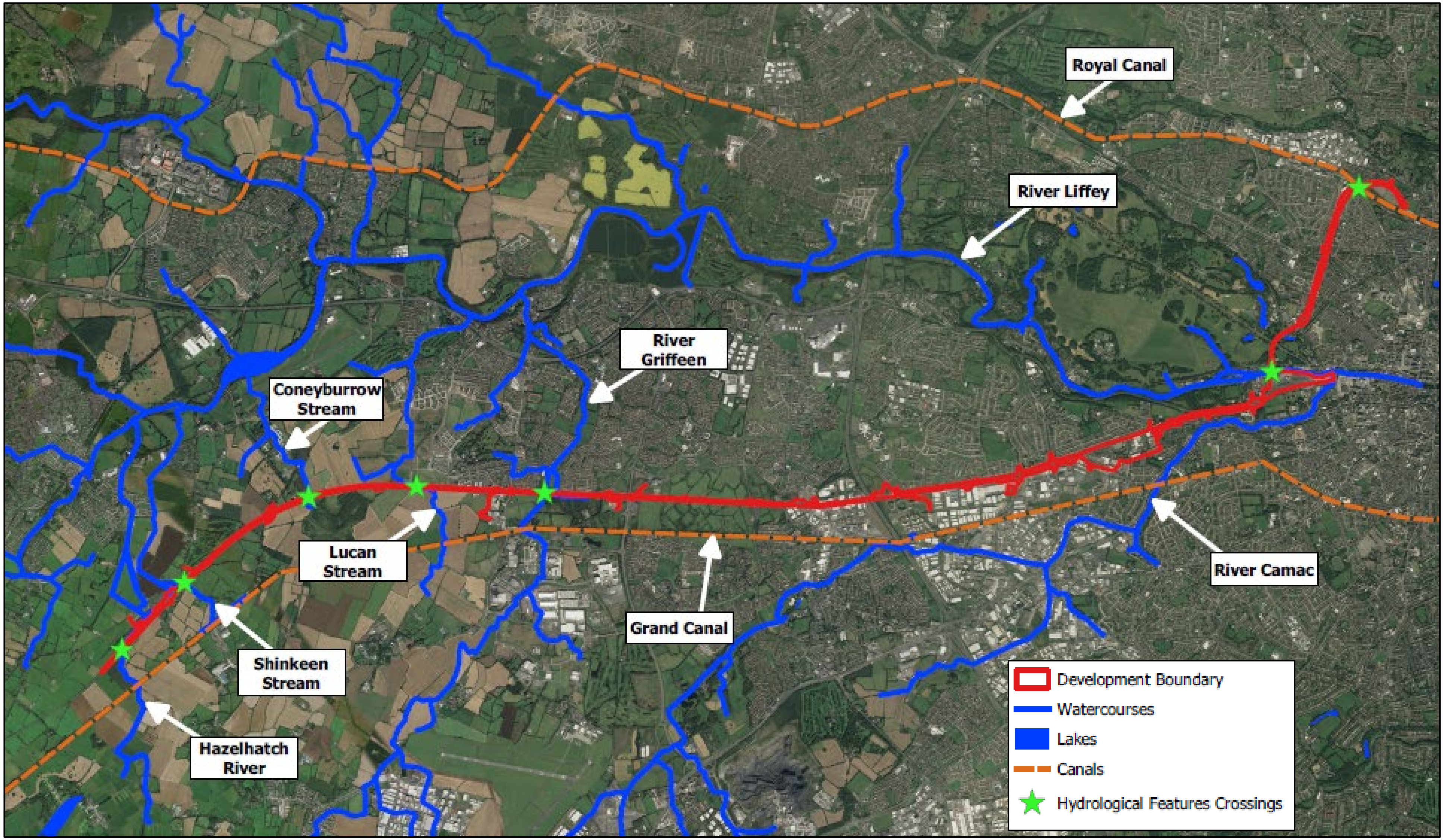

Figure 1-4 Salient Hydrological Features along the Study Area, EPA Rivers

2. Flood Risk Assessment Methodology

2.1. Overview

The FRM Guidelines outlines the key principles that should be considered when assessing flood risk to proposed sites. It recommends that the following staged approach should be adopted:

1. **Stage 1: Flood Risk Identification**

To identify whether there may be any flooding or surface water management issues relating to the proposed Project sites that warrant further investigation.

2. **Stage 2: Initial Flood Risk Assessment**

To confirm the sources of flooding that may affect the proposed Project sites, to appraise the adequacy of existing information and to determine what surveys and modelling approach is appropriate to match the spatial resolution required and complexity of the flood risk issues. This stage involves the review of existing studies, to assess flood risk and to assist with the development of FRM measures.

3. **Stage 3: Detailed Flood Risk Assessment**

To provide a quantitative appraisal of potential flood risk to a proposed or existing development, of its potential impacts on flood risk elsewhere and of the effectiveness of any proposed mitigation measures. This will typically involve use of an existing or construction of a hydraulic model across a wide enough area to appreciate the catchment wide impacts and hydrological process involved.

2.2. Methodology

The method followed to identify the risk of flooding to the development site is based on what is commonly known as the **Source-Pathway-Receptor** model (Figure 2-1) as outlined in the FRM Guidelines. The model identifies all sources of flooding, the pathway (rivers, drainage systems, and overland flow) and receptors (the proposed development and other areas directly connected to the development).

The model requires that for a flood risk to exist, there must be a pathway linking the source of flooding to the receptor. The main pathways within the study area are assessed based on the Office of Public Works (OPW) flood maps, Geological Survey of Ireland (GSI) maps and other historic information.

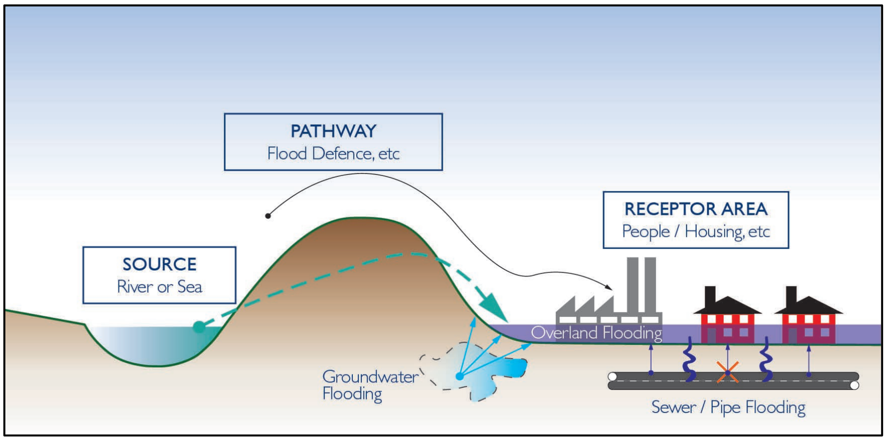

Figure 2-1 Source-Pathway-Receptor Model

2.3. Flood Zones

The FRM Guidelines recommend identifying flood zones which show the extent of flooding for a range of flood event probabilities. The FRM Guidelines identify three levels of flood zones:

- Flood Zone A – where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding),
- Flood Zone B – where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding), and
- Flood Zone C – where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.

The flood zones should be generated without the inclusion of climate change factors. The flood zones only account for inland and coastal flooding. They should not be used to suggest that any areas are free from flood risk as they do not account for potential flooding from pluvial and groundwater flooding. Similarly, flood defences should be ignored in determining flood zones as defended areas still carry a residual risk of flooding from overtopping, failure of the defences and deterioration due to lack of maintenance.

2.4. Sequential Approach, Justification Test and Flood Risk Vulnerability

The FRM Guidelines recommend using a sequential approach to reduce the flood risk to development. Development should be avoided in areas at risk of flooding, where this is not possible, a land use that is less vulnerable to flooding should be considered. Figure 2-2 shows the sequential approach. If the proposed land use cannot be avoided or substituted a Justification Test must be applied and appropriate sustainable flood risk management proposals should be incorporated into the development proposal. The Justification Test is used to assess the appropriateness of developments in flood risk areas. The test is comprised of two processes. The first is the Plan-making Justification Test and is used by Planning Authorities at the plan preparation stage where it is intended to zone or otherwise designate land which is at moderate or high risk of flooding. The second is the Development Management Justification Test and is used at the planning application stage where it is intended to develop land at moderate or high risk of flooding for uses or development vulnerable to flooding that would generally be inappropriate for that land.

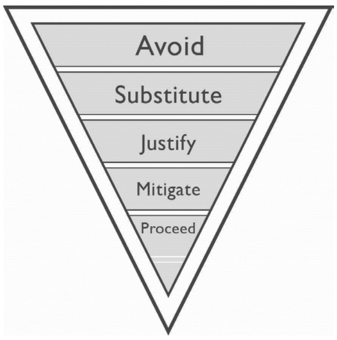

Figure 2-2 Sequential approach principles in Flood Risk Management

2.5. Development Flood Risk Vulnerability

Table 2.1 below illustrates those types of development that would be appropriate to each flood zone and those that would be required to meet the Justification Test. The FRM Guidelines also define classification of vulnerability for different types of development. Essential infrastructure such as transportation links can be classified as highly vulnerable depending on their strategic importance during flooding events.

Table 2.1: Matrix of Vulnerability versus Flood Zone to illustrate appropriate development and that required to meet the Justification Test (Source: FRM Guidelines)

	Flood Zone A	Flood Zone B	Flood Zone C
Highly vulnerable development	Justification Test	Justification Test	Appropriate
Less vulnerable development	Justification Test	Appropriate	Appropriate
Water compatible development	Appropriate	Appropriate	Appropriate

2.6. Hydrology

2.6.1. Catchment Review

Catchments have been reviewed and updated using the automated catchment delineation tools available in Arc Hydro and the best available Digital Terrain Models (DTM). Arc Hydro is a suite of GIS based tools that use raster processing algorithms to determine watershed and flow paths from rasterised digital terrain datasets. The updates were checked against aerial imagery and historical OSI mapping. The updated defined catchments are shown in their respective sections for each FRA zone.

2.6.2. Hydrological Methodology

2.6.2.1. Overview

The design flows estimation for all FRAs employed Flood Studies Update (FSU) and UK IH (Institute of Hydrology) techniques to predict flood discharges at various locations across the modelled extents. The FSU method for estimation of peak flows is an index-flood method, involving two stages. The index flood can be thought of as a typically-sized flood for a particular catchment, and in the FSU it is defined as the flood with a 50% probability of being exceeded in a particular year. This is equivalent to the median of the Annual Maximum (AMAX) flood series, denoted Qmed. The first stage of the method involves estimating Qmed, and in the second stage a flood growth curve is estimated. The growth curve is a dimensionless version of the flood frequency curve which defines how the flood magnitude grows as the probability reduces, i.e. for more extreme design floods. The design flood for a particular exceedance probability is then simply calculated as the product of Qmed and the value of the growth curve for that probability (known as the growth factor).

2.6.2.2. Peak Flows Estimation

2.6.2.2.1. Index Flood Estimation

The first step in determining design flows for the various Hydrological Estimation Points (HEPs) will be the estimation of the Index-flood (Qmed) at each HEP. The Index-flood is a crucial flood statistic as it can be robustly determined from suitable gauged locations with a significant record length (more than 14 years). For the ungauged river catchments, it is generally estimated using the catchment Physical Catchment Descriptor (PCD) based regression equation. Estimation of the index-flood for the ungauged catchments in their rural form, referred to henceforth as Qmed-rural will initially be based on the FSU methods for ungauged catchments, i.e. using regression equations derived from FSU Work Packages 2.3 and 4.2:

FSU 7-varibale: $Q_{med\ rural} = 1.237 * 10^{-5} * \ Area^{-0.937} * BFI_{soil}^{-0.922} * SAAR^{1.306} * FARL^{2.217} * DRAIND^{0.341} * S1085^{0.185} * (1 + ARTDRAIN2)^{0.408}$

FSU 5-varibale: $Q_{med\ rural} = 2.0951 * 10^{-5} * \ Area^{0.9245} * BFI_{soil}^{-0.903} * SAAR^{1.2695} * FARL^{2.3163} * S1085^{0.2513}$

FSU 3-varibale: $Q_{med\ rural} = 0.000302 * \ Area^{0.829} * BFI_{soil}^{-1.539} * SAAR^{0.898}$

The FSU 7-variable Qmed equation has been derived through regression analysis and has a Factorial Standard Error (FSE) of 1.37 and is recommended for use only for catchment areas larger than 25 km^2.

The FSU 5-variable and 3-variable Qmed equations are generally recommended for catchments less than 25 km^2 and have FSE values associated with these equations of 1.686 and 2.059 respectively.

Further to the above-mentioned FSU methods, a catchment characteristics-based method, the UK IH recommended 3-variables equation (IH124, 1994) for estimating the Flood Studies Report (FSR) index-flood (Qbar) for small ungauged catchments was also used.

IH124 3-varibale: $Q_{bar\ rural} = 0.00108 * \ Area^{0.829} * SOIL^{2.17} * SAAR^{1.17}$

This equation is recommended for catchments less than 25 km^2 and has an associated FSE value of 1.65.

The relevant PCDs are obtained from the FSU datasets but they have also been furthered updated and reviewed using the latest available information (Light Detection and Ranging (LiDAR), Topographical Surveys and EPA Corine dataset).

2.6.2.2.2. Pivotal Site Adjustment

FSU recommends that ungauged Qmed estimates are adjusted where there is appropriate observed data available and it is believed that the catchment descriptor equation over or under-estimates Qmed in the particular catchment. The gauged catchment from where this adjustment is derived is referred to as a ‘pivotal’ site and it may refer to a gauging station upstream or downstream or a gauging station from a different catchment which is hydrologically similar. Preference can be given to hydrologically similar gauges that are geographically close to the area of interest.

Analysis was undertaken to identify the adjustment factor for all watercourses. The FSU utilises the AREA, Baseflow Index (BFI)soil and Standard Annual Average Rainfall (SAAR) in an equation to calculate the hydrological similarity parameter (D_{ij}) between a subject site and candidate pivotal site(s) as given in the FSU WP 2.2 (Eq. 10.2). As a rule-of-thumb, a D_{ij} value less than 1.0 indicates "high" similarity while a value greater than 2.0 indicates "low" similarity. Adjustment factors for each river catchment were calculated for the most geographically gauging stations along with factors for each HEP in the FRAs using the mean value of adjustment factors of hydrological similar gauged catchments throughout Ireland. Comparisons were undertaken to assess which type of adjustment factor was most suitable for each individual FRA.

2.6.2.2.3. Urban Adjustment

The Qmed $_{rural}$ and Qbar $_{rural}$ values do not consider the effects of urbanisation. Qmed rural considers urbanisation separately through an Urban Adjustment Factor (UAF) calculated as follows:

$$UAF = (1 + URBEXT)^{1.482}$$

The final Qmed which considers the effect of urbanisation is then calculated:

$$Q_{med} = UAF * Q_{med\ rural}$$

Qbar $_{rural}$ considers urbanisation calculated as follows:

$$Q_{bar\ urabn} = Q_{bar\ rual} * (1 + URBAN)^{2NC} * (1 + URBAN * \left(\frac{21}{CIND}\right) - 0.31)$$

Where: NC is rainfall continentality factor

NC = 0.92 – 0.000024*SAAR for 500 ≤ SAAR ≤ 1100mm,

NC= 0.74 -0.000082*SAAR for 1100 ≤ SAAR ≤ 3000mm, and

CIND is catchment index defined as a function of SOIL and catchment wetness index (CWI)

CIND = 102.4*SOIL +0.28(CWI – 125)

The above adjustments for urbanisation have been applied to all catchments located within the study area. The URBEXT parameter has been updated using the latest available information from the updated EPA CORINE dataset.

2.6.2.3. Growth Factor/Curve Development

2.6.2.3.1. Growth Curve Estimation

A growth curve defines the relationship between the index-flood flow Qmed and the various event probability peak flows. A growth curve can be defined from AMAX data from a single site, such as for gauging stations and is defined by the at site flood frequency curve. However, this approach is not recommended for defining flood events with a return period more than twice the number of AMAX years available. In this case pooled analysis is undertaken based on the IH124 and FSU methodologies to determine growth factors for a range of design events.

The choice of final growth factors for design flow estimation considers the confidence in the ratings following rating reviews, the length of record, and the return period (T) under consideration amongst other things. Table 2.2 below, adapted from the UK Flood Estimation Handbook (FEH), Volume 3, Table 8-2 outlines the preferred decision framework in selecting the method.

Table 2.2: Selection of At-Site or Pooled Growth Factors / Curves

Record Length	At-Site Analysis	Pooled Analysis	Preferred Method
<T/2 or 14 years	No	Yes	Pooled
T/2 to T years	For confirmation	Yes	Pooled
T to 2T years	Yes	Yes	Joint
> 2T years	Yes	For confirmation	At-Site

The up to date AMAX Flows dataset for all stations (up to the hydrometric year 2019/2020) comprising the possible pooling groups for all HEPs have been obtained from OPW, EPA and Northern Ireland Rivers Authority and used in the pooling analysis.

2.6.2.3.2. Pooling Analysis

Pooling group was formed using the Region-of-Influence (ROI) approach as proposed by Burn (1990). The ROI approach selects stations, which are nearest to the subject site in catchment descriptor space, to form the pooling group for that subject site. In the FSU studies a distance measure in terms of three catchment descriptors of AREA, SAAR and BFI was used in forming a pooling group. The recommended distance measure in the FSU studies is:

$$d_{ij} = \sqrt{\left(\frac{lnArea_i - lnArea_j}{\sigma_{lnArea}}\right)^2 + \left(\frac{lnSAAR_i - lnSAAR_j}{\sigma_{lnSAAR}}\right)^2 + \left(\frac{lnBFI_i - lnBFI_j}{\sigma_{lnBFI}}\right)^2}$$

where i is the subject site and j=1, 2,….M are the donor sites.

The size of the pooling group was determined based on the FEH recommended 5T rules (i.e. the total number of station-years of data to be included when estimating the T-year flood should be at least 5T). The donor sites associated with the pooling group sizes were selected based on the lowest distance measures among the available gauging sites in the pooling region.

The following factors were considered to select an appropriate growth curve distribution:

- Suitability of a distribution in fitting the individual at-site records;
- No. of distribution parameters; and
- Shape of the pooled growth curve.

A number of flood-like distributions (EV1, Generalised Extreme Value (GEV), LN2 and GLO) as recommended in FSU were reviewed for use in deriving flood frequency growth curves for all HEPs.

2.6.2.3.3. AMAX Flow Data and Statistical Properties

The AMAX Flow records for 163 hydrometric gauging sites located across Republic of Ireland and Northern Ireland River catchments were collected to form a pooling region for growth curve analysis. Figure 2-3 illustrates the spatial distribution of these gauging sites.

2.6.2.4. Design Hydrographs

Once the design peak flow is estimated, the next step is to determine the hydrograph shape to ensure it is a true representation of the catchment in question under a flood flow. The method adopted for this study is the FSU approach as discussed in the Technical Research Report Volume III[1]. The method is similar in principle to the estimation of the index flood in that it uses catchment descriptors to arrive at an initial estimate of the hydrograph shape, defined in three parameters, and then uses a pivotal site to adjust the shape based on observed data.

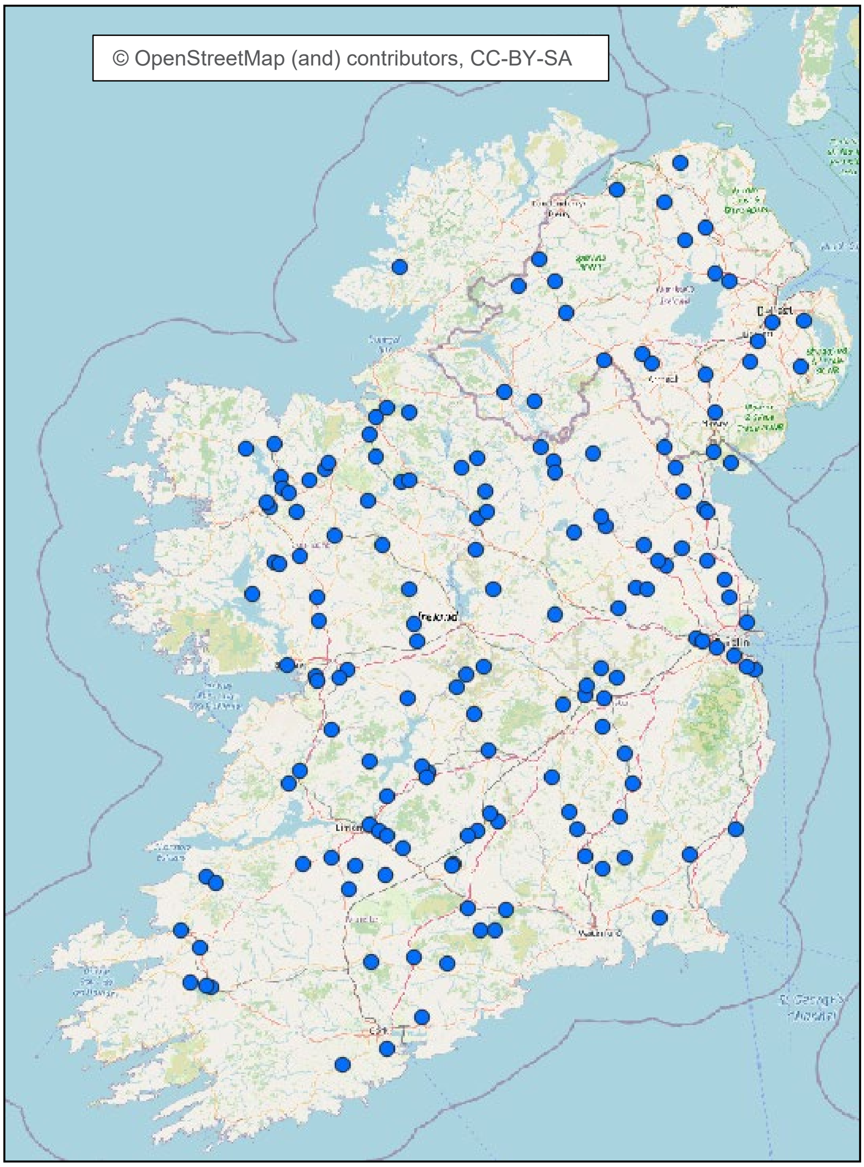

Figure 2-3 Locations of 163 Gauging Sites

[1] https://opw.hydronet.com/data/files/Technical%20Research%20Report%20-%20Volume%20III%20-%20Hydrograph%20Analysis(1).pdf

2.6.2.4.1. FSU Hydrograph Width Analysis

The approach considers all the observed hydrographs represented within the AMAX series for the particular gauged catchment. Firstly, hydrographs are analysed to isolate the individual event shape with data from before and after this point removed. Hydrograph width is then determined for each 10th percentile of the peak flow and median widths determined for each percentile. The median hydrograph thus formed is called the characteristic hydrograph, which is a semi-dimensionless flood hydrograph with unit peak and has time coordinates in hours. This approach is called a non-parametric method for deriving a characteristic hydrograph for gauged site using the observed flood hydrographs. This non-parametric characteristic hydrograph is then represented/smoothened using a parametric mathematical model. In FSU a parametric Unit-Peak-at-Origin (UPO)- Exponential Recession Replacement (ERR)-Gamma model was used to approximate this non-parametrically derived characteristic hydrograph, in which the hydrograph shape up to the inflection point was represented by a 2 -parameter Gamma curve, while the recession limb of the hydrograph was represented by a 1-parameter exponential recession curve (ERR model). The proposed parameters of this UPO-ERR-Gamma model are:

n – Shape parameter of Gamma distribution

T_r – Rise time (=translation parameter)

C - Recession parameter (hours)

The FSU WP 3.1 presents a set of regression equations for estimating the above-mentioned parameters of characteristic hydrograph from the following catchment descriptors:

BFISOIL – the baseflow index estimated from soil characteristics

FARL – a measure of flood attenuation due to reservoirs and lakes

ALLUV – the proportion of the catchment covered in alluvial soils

ARTDRAIN – the proportion of the catchment that benefits from arterial drainage schemes

S1085 – the slope of the main channel.

2.6.2.4.2. FSU Design Hydrograph Method (pivotal site adjustment)

At the ungauged HEPs hydrograph shape parameters were estimated based on PCDs and then adjusted based on an appropriate pivotal site. In all cases for each FRA the most appropriate pivotal site data would be from the most hydrologically similar gauging station.

2.6.2.4.3. Design Flood Hydrographs

The characteristic flood hydrograph, when scaled up by multiplying its ordinates by the magnitude of the 'design peak flow' of a given return period, becomes the final 'design flood hydrograph' for that return period for the catchment (or site) under consideration.

The Hydrograph Width Analysis (HWA) hydrographs when applied at each of the HEPs might not have accurately captured the baseflow characteristics for each catchment. This was estimated based on catchment descriptors from the Flood Studies Supplementary Report No. 16 and as restated in the FEH Volume 4, equation 2.19 and is as follows:

$$BF = (33(CWI - 125) + 3 * SAAR + 5.5) * 10^{-5} * Area$$

Where:

BF = Baseflow (m_3/s)

CWI = Catchment Wetness Index

SAAR = Standard Average Annual Rainfall (mm)

2.6.3. Physical Catchment Descriptors

PCDs associated with each of the HEPs have been extracted/estimated from the FSU PCD dataset. 'URBEXT' for each HEP catchment was updated in accordance with EPA Corine 2018 data. The 1975 FSR Winter Rain Acceptance Potential (WRAP) maps were reviewed to identify the SOIL parameter. The most update to SAAR was generated for each catchment using Met Éireann data.

2.6.4. Coastal Hydrology

The Eastern Catchment Flood Risk Assessment and Management (CFRAM) studies carried out a comprehensive analysis of costal hydrology and tidal levels for the River Liffey. They examined the OPW Irish Coastal Protection Strategy Study (ICPSS,OPW, 2012) and Irish Coastal Wave and Water Level Study (ICWWS, OPW, 2018). They also undertook joint probability analysis for fluvial and tidal combinations. The CFRAM analysis concluded by identifying tidal boundaries for range of probabilities at the downstream end of the River Liffey model. The levels are shown in Table 2.3.

Table 2.3: Tidal Boundary Levels

AEP	Water Level OD Malin
50%	2.73
20%	2.82
10%	2.89
5%	2.96
2%	3.04
1%	3.11
0.5%	3.18
0.1%	3.33

2.6.5. Future Conditions

There are a number of future potential changes which could potentially impact the effectiveness of any flood management measures proposed. It is prudent that the potential impacts are identified and quantified such that effective planning and design for adaptation can be accommodated. The adjustments to be applied to the design flow estimates are outlined in 'Climate Change Sectoral Adaptation Plan, Flood Risk Management' (OPW, Sept. 2019) and are reproduced in Table 2.4.

In the above-mentioned document, specific advice on the expected impacts of climate change and the allowances to be provided for future flood risk management in Ireland is given for two future scenarios: The Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS).

The MRFS is intended to represent a 'likely' future scenario, based on the wide range of predictions available and with the allowances for increased flow, sea level rise, etc. within the bounds of widely accepted projections.

The HEFS is intended to represent a more extreme potential future scenario, but one that is nonetheless not significantly outside the range of accepted predictions available, and with the allowances for increased flow, sea level rise, etc. at the upper bounds of widely accepted projections.

Table 2.4: Future Condition Adjustments

Scenario	MRFS	HEFS
Extreme Rainfall Depths	+20%	+30%
Flood Flows	+20%	+30%
Mean Sea Level Rise	+500mm	+1000mm
Urbanisation	Review case-by-case	Review case-by-case
Afforestation[2]	-1/6 Tp	-1/3 Tp +10% SPR[3]

The scenarios encompass changes in extreme rainfall depths, flood flows, sea level, land movement, urbanisation and forestry. The sections below set out how design flood parameters for the future scenarios have been defined.

2.6.5.1.1. Changes in Flows & Rainfall Depths

The guidance states that flood flows shall be increased by 20% and 30% respectively for the MRFS and HEFS. This change has been implemented by scaling up the flood hydrograph for each HEP and for each probability by the specified percentage. In the case of rainfall runoff modelling approach design rainfall depths would have been increased by 20% and 30% for the MRFS and HEFS for each probability, however no rainfall-runoff modelling has been undertaken for this study.

2.6.5.1.2. Impact of Urbanisation on Hydrology

The catchment areas in the Dublin region have seen considerable growth in population and urban area in the last decade. However, considering development in the future must reduce its runoff to greenfield runoff rates (following guidance set out by all Local Authorities) no increases in runoff due to urbanisation are predicted. To assess potential impacts due to the effects the urban extent (URBEXT), the extent has been increased by 25% for the MRFS and by 50% for the HEFS conditions. These conditions may be revised during the hydraulic modelling stage if it is deemed that they are overly conservative.

2.6.5.1.3. Changes in Forestation

Under the MRFS scenario, it is recommended in the guidelines that the impacts of afforestation are investigated through a decrease in time to peak of a sixth; this allows for potential accelerated runoff that may arise as a result of drainage of afforested land. This means the volume of water in the river is unchanged, but the rate at which it runs off the land into the watercourse is increased. The change in the time to peak can have a positive or negative impact on flood risk depending on how it relates to the timing of peak runoff from contributing watercourses further downstream in the catchment. Under the HEFS scenario, the time to peak parameter is to be reduced by one-third and the Standard Percentage

[2] Reduce the time to peak (Tp) by a sixth or third. This allows for potential accelerated runoff that may arise as a result of drainage of afforested land
[3] Add 10% to the Standard Percentage Runoff (SPR) rate: This allows for increased runoff rates that may arise following felling of forestry.

Runoff (SPR) parameter is to be increased by 10% over the existing condition. The SPR parameter affects the magnitude of the flows but does not have any effect on timings.

2.7. Modelling scenarios

The following scenarios are proposed for this study to ensure compliance with Government's FRM Guidelines (DOEHLG, 2009):

- Flood Zone Mapping for the 1%, 0.5% and 0.1% AEP events for fluvial and coastal flooding for the existing scenario at development site and in the surrounding area; and
- Flood Zone Mapping for the 0.1% AEP (inclusive of climate change) events for fluvial and coastal flooding for the proposed scenario at development site and in the surrounding area.

These various scenarios will be examined for the existing and proposed conditions to assess the residual impact of developing the site (inclusive of the flood mitigation measures) on the surrounding area. As detailed in Section 2.5, railway infrastructure is classified as highly vulnerable depending on its strategic importance during flooding events. Additionally, as railway infrastructure is long term infrastructure, the proposed scenario has been modelled for the climate change 0.1% AEP HEFS scenario. This is the worst case scenario to mitigate against and protect the railway.

2.8. Hydraulic Modelling

2.8.1. Overview

The primary objectives of the hydraulic modelling were:

- To build and calibrate a robust 1D/2D hydraulic model to study the hydraulic characteristics and out of bank flow paths of the watercourses; and.
- To use the hydraulic model to estimate water levels, out of bank flow paths and flood outlines for the modelling scenarios outlined in Section 2.7.

2.8.2. OPW Hydraulic Models

RPS were provided with the Eastern CFRAM Study hydraulic models for the various watercourses within the extents of the study area. The use of these models is subject to a data usage agreement as stated in Section 1.6.

2.8.3. FRA Hydraulic Models

2.8.3.1. Overview

The extent of the CFRAM models for each watercourse was reduced to focus on the site specific region around each FRA Zone. The FRA zones are identified below:

- Zone A - Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station;
- Zone B - Park West & Cherry Orchard Station to Heuston Station (incorporating Inchicore Works)
- Zone C - Heuston Yard and Station (incorporating New Heuston West Station);
- Zone D - Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line).

1D/2D hydraulic models were built for the following watercourses using the corresponding software packages:

- Zone A: Shinkeen and Hazelhatch Rivers – Infoworks ICM (1D/2D)
- Zone A: Lucan Stream and Griffeen River – HEC RAS (1D/2D)
- Zone C – Camac and Liffey Rivers – Infoworks ICM (1D/2D)

2.8.3.2. Topographical Surveys

The existing CFRAM topographical information was utilised within the models.

2.8.3.3. Model Surface

A DTM of each study area and surrounding land was used as the basis of the 2D model. The DTMs were obtained from the publicly accessible information at Open Topographic Data Viewer by GSI. The web viewer provides processed LiDAR data in raster format from various public sector bodies and the data is licensed for re-use under the Creative Commons Attribution 4.0 International license http://creativecommons.org/licenses/by/4.0/.

2.8.3.4. Roughness Coefficients

The Manning values 'n' is a measure of the roughness of the bed and side slopes of the watercourse. Varying values were identified to reflect the floodplain conditions (vegetation, urban extent, and grassland) and channel conditions. Table 2.5 summarises the value of Manning's 'n' used within the hydraulic modelling analysis.

Table 2.5: Manning's Roughness Values

Feature	Units	Min	Max
Riverbed	n	0.033	0.05
Culverts	n	0.013	0.017
Riverbank/Grass Areas	n	0.03	0.15
Floodplain	n	0.011	0.06

2.9. Iarnród Éireann Flood Risk Management Operational Procedures

Iarnród Éireann has operating procedures which assist in managing flood risk for rolling stock during inclement weather and flooding events, these include:

- CCE-TMS-311 - Irish Rail Weather Management Procedures (2017)
- CCE-TEB-2014-05 - Guidance On Alerts And Service Restrictions During Adverse Weather Events; and
- CME-TMS-001-008 - Operation Of IE RU Rolling Stock On Flooded Track (2016)

These procedures specify how Iarnród Éireann:

- Monitors and disseminates applicable weather warnings from Met Éireann;
- Prepares and implements local weather management plans for predicted adverse weather events;

- Set out recommended flood level limits for their rolling stock passing over flooded tracks; and
- Set out actions to be undertaken by duty managers, drivers, signallers etc when high water alerts are issued.

Operational limits have been specified for the different rolling stock (i.e. types of trains) within their fleet (see Figure 2-4). The limits have been set in order to avoid damage to critical onboard equipment and to mitigate against the risk of a train becoming disabled in a flooded area. The limits are also such to change depending on the track and weather conditions. It is important to note that no trains may operate over flooded track until permitted to do so by Iarnród Éireann Infrastructure Department. The EMU is the type of rolling stock of primary concern for this study. The maximum limit identified within the procedure for the EMU is the top of the railway track. A typical railway track is approximately 170mm deep from ground level. Therefore flood levels along the railway for all FRA Zones will be assessed against this limit in order to identify if flood mitigation measures are required to protect the track.

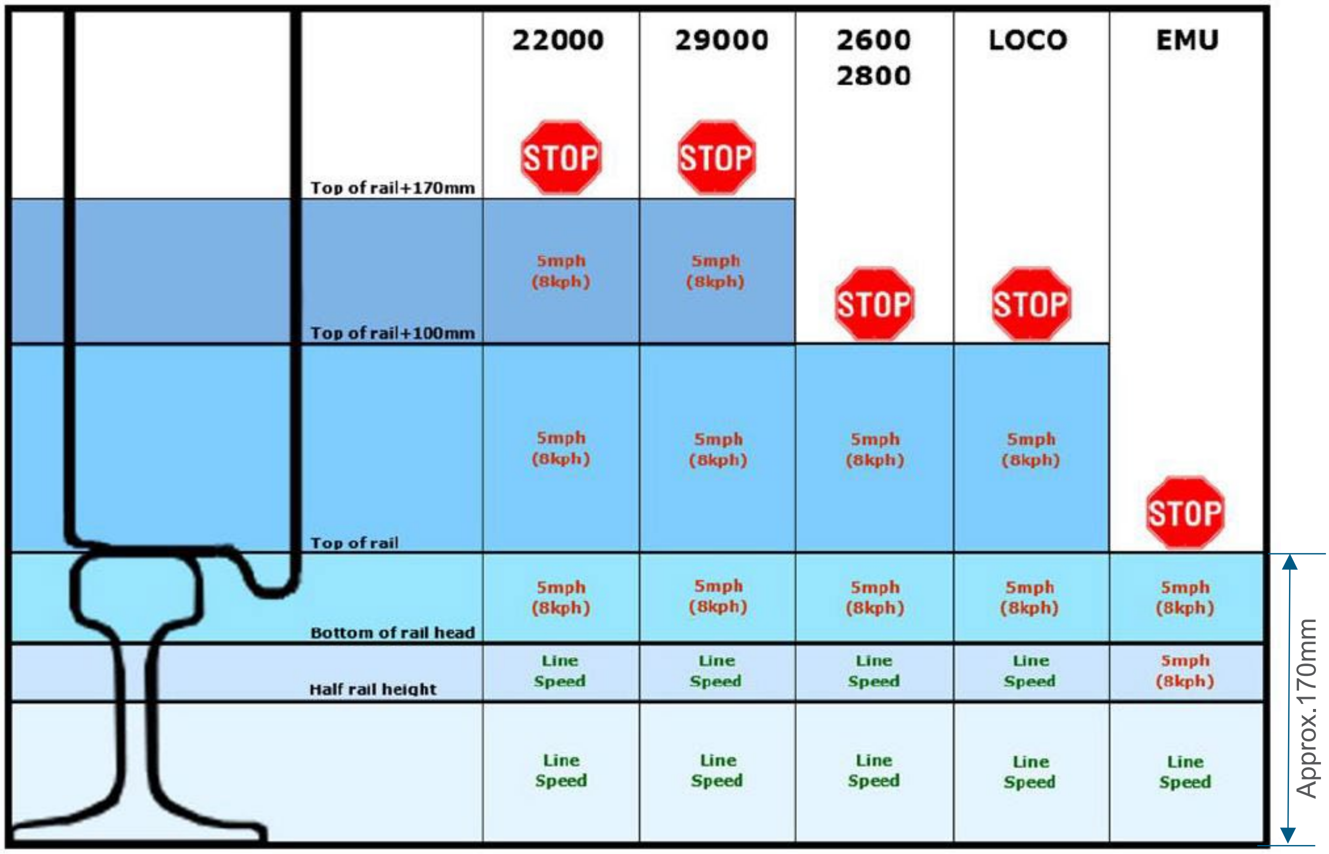

Figure 2-4 IE RU Rolling Stock Operating Procedure on Flooded Track Condition

3. Zone A - Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station FRA

3.1. Hazelhatch FRA: Stage 1 – Flood Risk Identification

3.1.1. Overview

The subject area focuses on the area of Hazelhatch & Celbridge Station. Currently, the four-track section on the Cork Mainline commences approximately 750m to the west of Hazelhatch & Celbridge Station and extends eastwards under a series of existing road bridges, foot bridges and station structures to Park West & Cherry Orchard Station. It is approximately 10km in length. The proposed development in this area involves the reconfiguration of the existing four running lines to convert them to Up Slow, Down Slow, Up Fast, Down Fast with provision for the electrification of the two tracks on the north side (Slow tracks) for the DART services. All of these works will fit within the existing boundary. New Points and Crossings (P&C) will be required in order to achieve the operational requirements.

3.1.2. Existing Structures and Facilities

Various structures are present along this section of the route, presented in sequence commencing in Hazelhatch and moving in an easterly direction towards Park West. This area was upgraded as part of the original Kildare Route Project and already accommodates four-tracks; therefore, the structures are not expected to significantly constrain reconfiguration of the horizontal track alignment.

- Hazelhatch R405 Road Bridge (OBC25)
- New Hazelhatch Footbridge (OBC24A)
- Hazelhatch Footbridge (OBC24)
- Straleek Footbridge (OBC23B)

3.1.3. Site Topography

The track gradient at Hazelhatch is nominally flat before rising at the mid-point between Hazelhatch & Celbridge Station. Site topography shown in Figure 3-1.

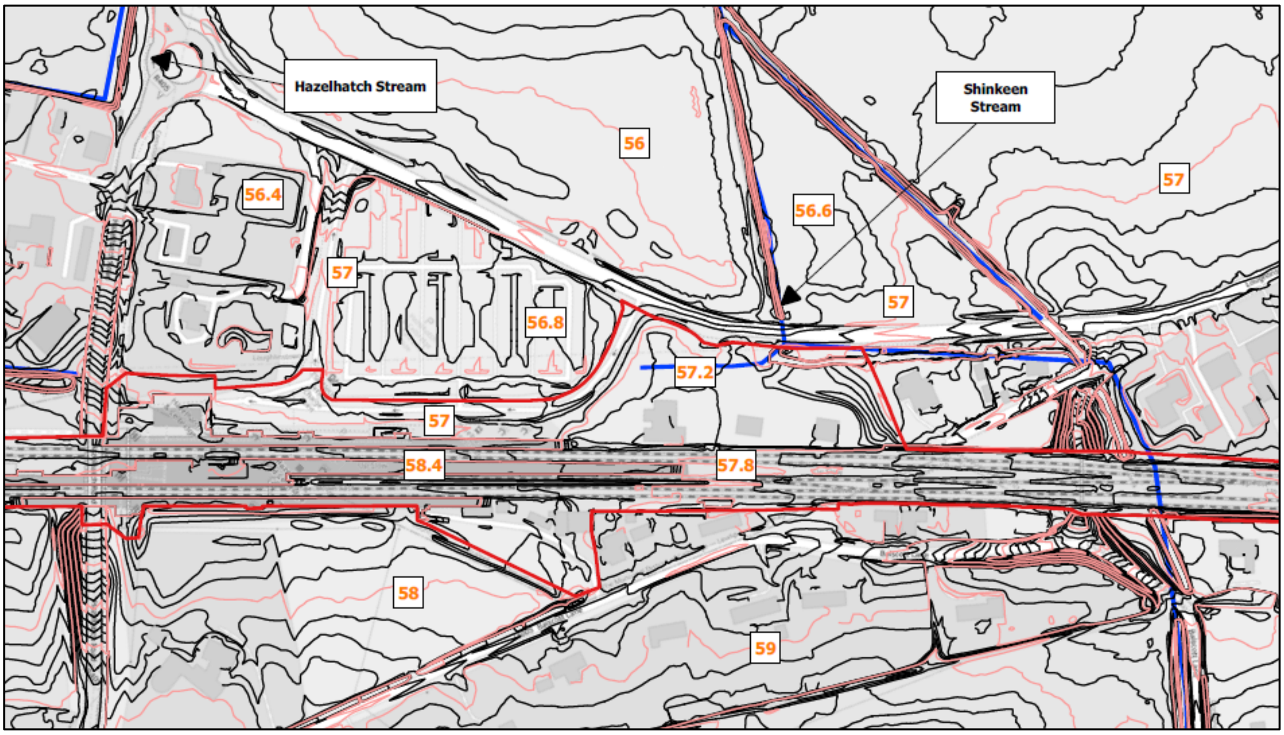

Figure 3-1 Site Topography in the vicinity of the Shinkeen Stream

3.1.4. Existing Site Drainage

The study area consists of drainage features such as localised embankments and small drainage channels in addition to the culverted sections of the streams crossing the railway. The existing drainage network in this zone will be adjusted to the new requirements of the Railway track levels, in order to ensure that the current performance of the existing drainage system is kept and does not interfere with the proposed electrification of the track. The arrangement of outfalls at the railway station and the cross linkage between the Shinkeen and Hazelhatch streams at this location was investigated as part of the Hazelhatch Further Study, 2020[4], but no linkage was apparent. Therefore, it is important to remark that the performance of the existing drainage is not fully known.

3.1.5. The Proposed Development

To facilitate the proposed increase in train frequency it is proposed as part of the DART+ South West Project to modify the trackwork with additional crossovers and adjustments to track alignment.

At Hazelhatch & Celbridge Station there will be significant modifications to the track layout commencing approximately 750m to the west of the station, the works include - new Points and Crossings (P&C), track realignment, provision of a new siding to the north to facilitate the DART services on the electrified Slow lines to the north side of the corridor.

The station layout consists of one central and two side platform areas with a turnback provided at the eastern end of the station, i.e. 5 platform faces in total, refer to Figure 3-2. The platforms are provided in an offset arrangement, with the central and southern platforms extending west below Hazelhatch R405 Road Bridge (OBC25). The station will operate as terminus station for proposed DART trains.

[4] Kildare County Council appointed RPS, to undertake the Strategic Flood Risk Assessment for the Hazelhatch area (Hazelhatch Further Study) with technical support provided by the OPW.

Hence, the turnback service will be enhanced for Heuston and Connolly services. The main station access building is at platform level, to the north of the track area. A pedestrian footbridge provides access via stairs and lifts to the platforms.

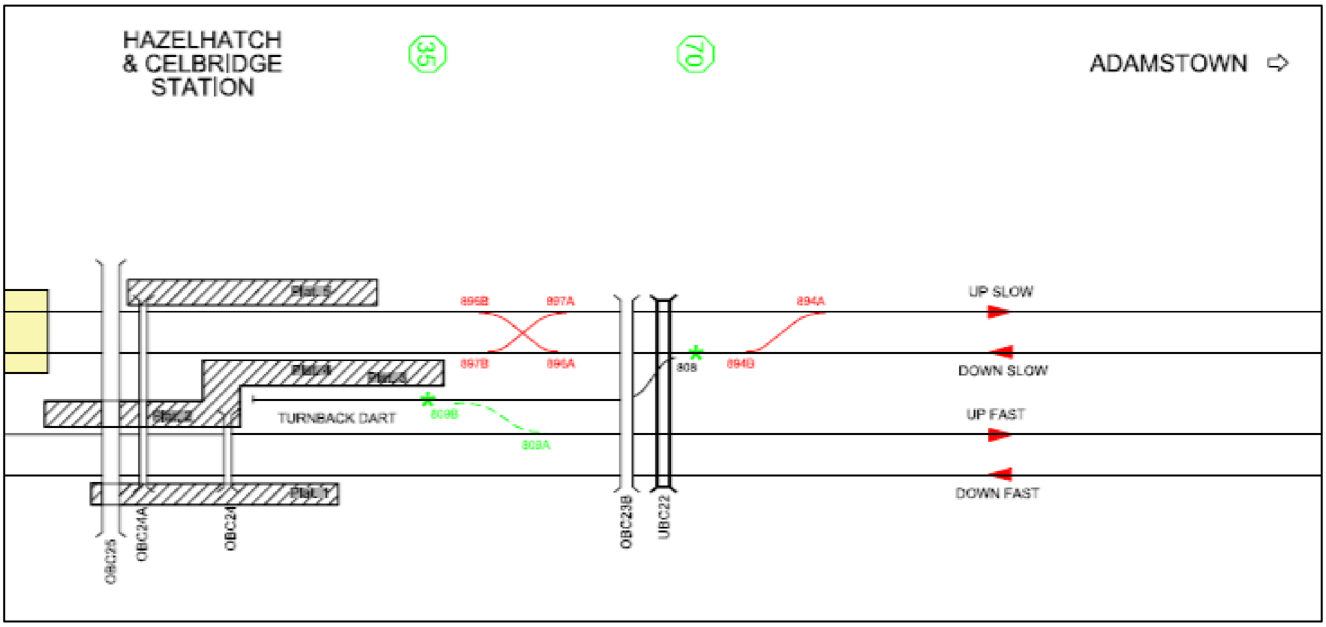

Figure 3-2 Hazelhatch & Celbridge Station – Schematic Track Plan (in red trackwork within this project)

Figure 3-3 shows the additional crossovers between Fast and Slow lines that fulfil the operational requirements (train movements) at this new Hazelhatch Junction. The alignment in the vertical plane essentially matches the existing track throughout this area with the implementation of necessary minor modifications to ensure that crossovers are situated on a level plane to ensure their correct operation.

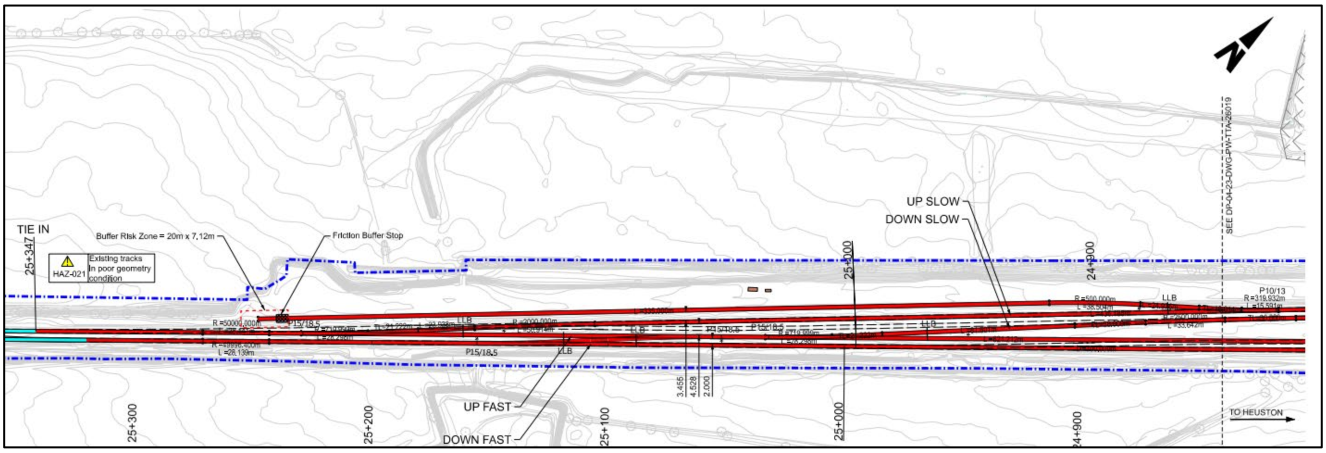

Figure 3-3 Hazelhatch & Celbridge Station – Track Plan Layout (1 of 3)

To the west of the station, the modifications include the installation of a new Turnback Siding (Approximately 356m in length) located on the north side of the rail corridor. A new crossover on the Slow lines will provide access into the siding from both Up and Down directions, see Figure 3-4.

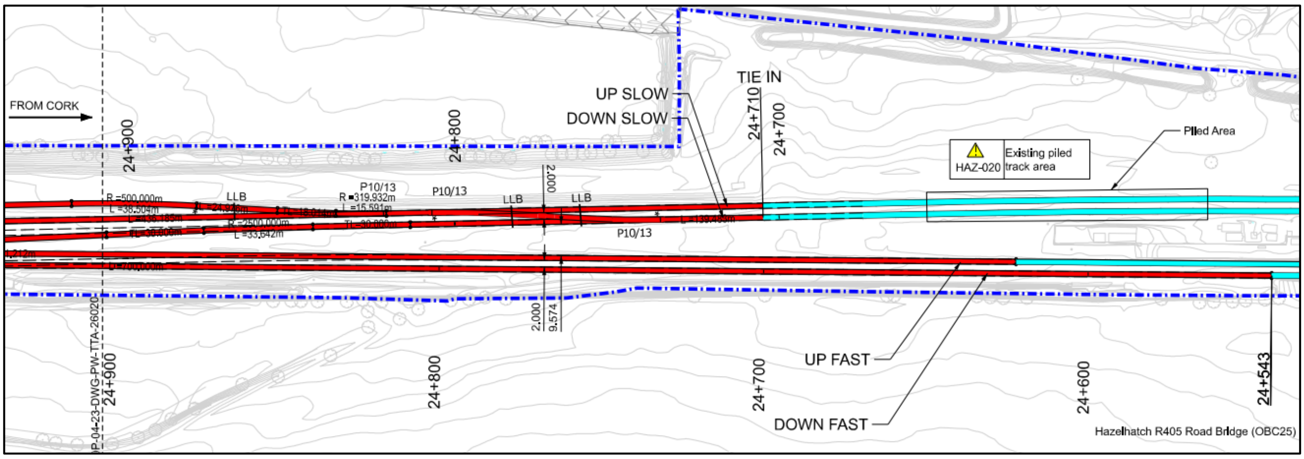

Figure 3-4 Hazelhatch & Celbridge Station – Track Plan Layout (2 of 3)

On the approach to the station, a new crossover will be installed between the Slow lines to provide access to the existing turnback. A new scissors crossover to the immediate east of the platforms provides required functionality.

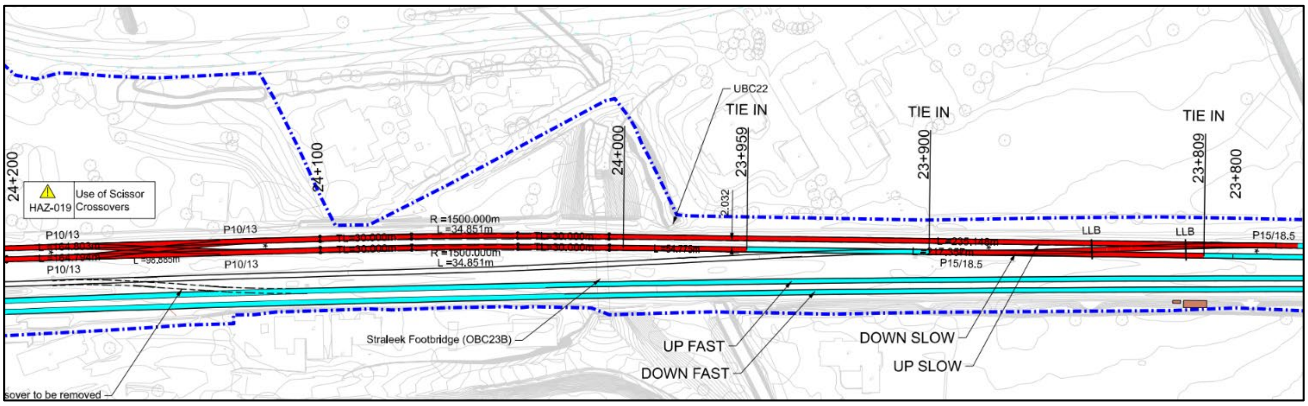

Figure 3-5 Hazelhatch & Celbridge Station – Track Plan Layout (3 of 3)

The proposed location of the substation at Hazelhatch is within a brown field site located to the north of the railway. The site is located adjacent to the Hazelhatch & Celbridge Station carpark. The site is predominantly surrounded by agricultural land with the exception of Hazelhatch and Celbridge train station and a number of adjacent private dwellings located on Loughlinstown Road and Railway Cottages to the southeast of the station on the opposite side of the railway. The site is in the ownership of CIÉ and there are currently three derelict residential dwellings on the site, all three of these buildings will need to be demolished to facilitate the construction of the new substation. To facilitate vehicle access to the substation site, the existing vehicle access track shall be utilised. The existing track enters Irish Rail boundary from Loughlinstown Road.

A construction compound will be established at Hazelhatch for undertaking electrification works along the corridor, in addition to localised works including the installation of new trackwork to facilitate the turnback of trains at the station. The proposed location for the site is on the north side of the corridor. It is proposed to locate the compound on the CIÉ property to the east of the main station car park, there are currently three vacant residential dwellings on the site.

The proposed Development for this section of the line is presented in Figure 3-6.

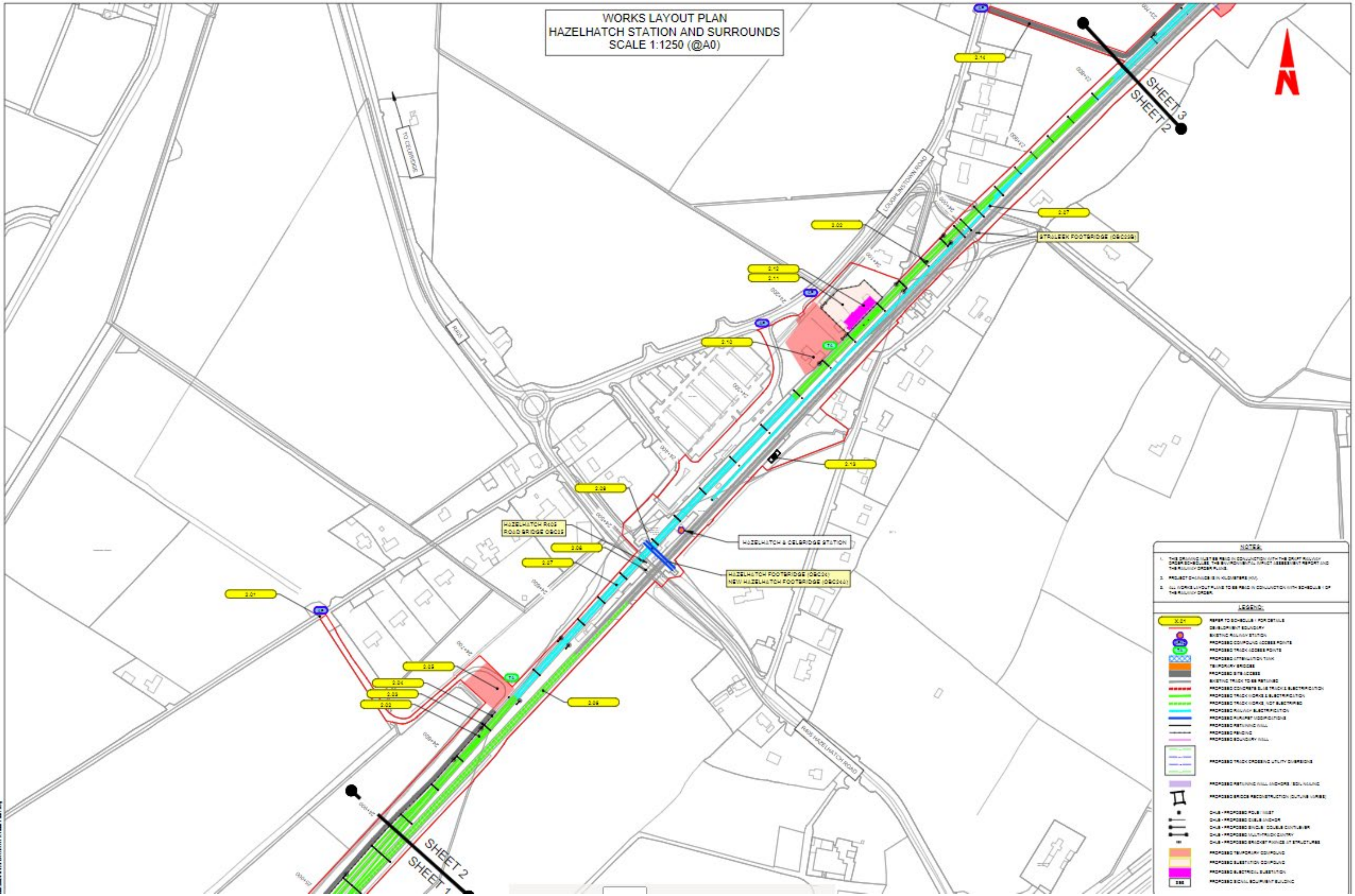

Figure 3-6 Schematic Layout of the proposed development in the environs of Hazelhatch Station

3.1.6. Land Use

The area west of Hazelhatch & Celbridge Station is broadly rural in nature with large open field areas, however there are also small clusters of residential development (Figure 3-7), notably houses along Lord's Road to the northwest of the station. These houses are within the 200-300m buffer area of the rail centreline at this location. The settlement of Celbridge town is located approximately 2km to the north.

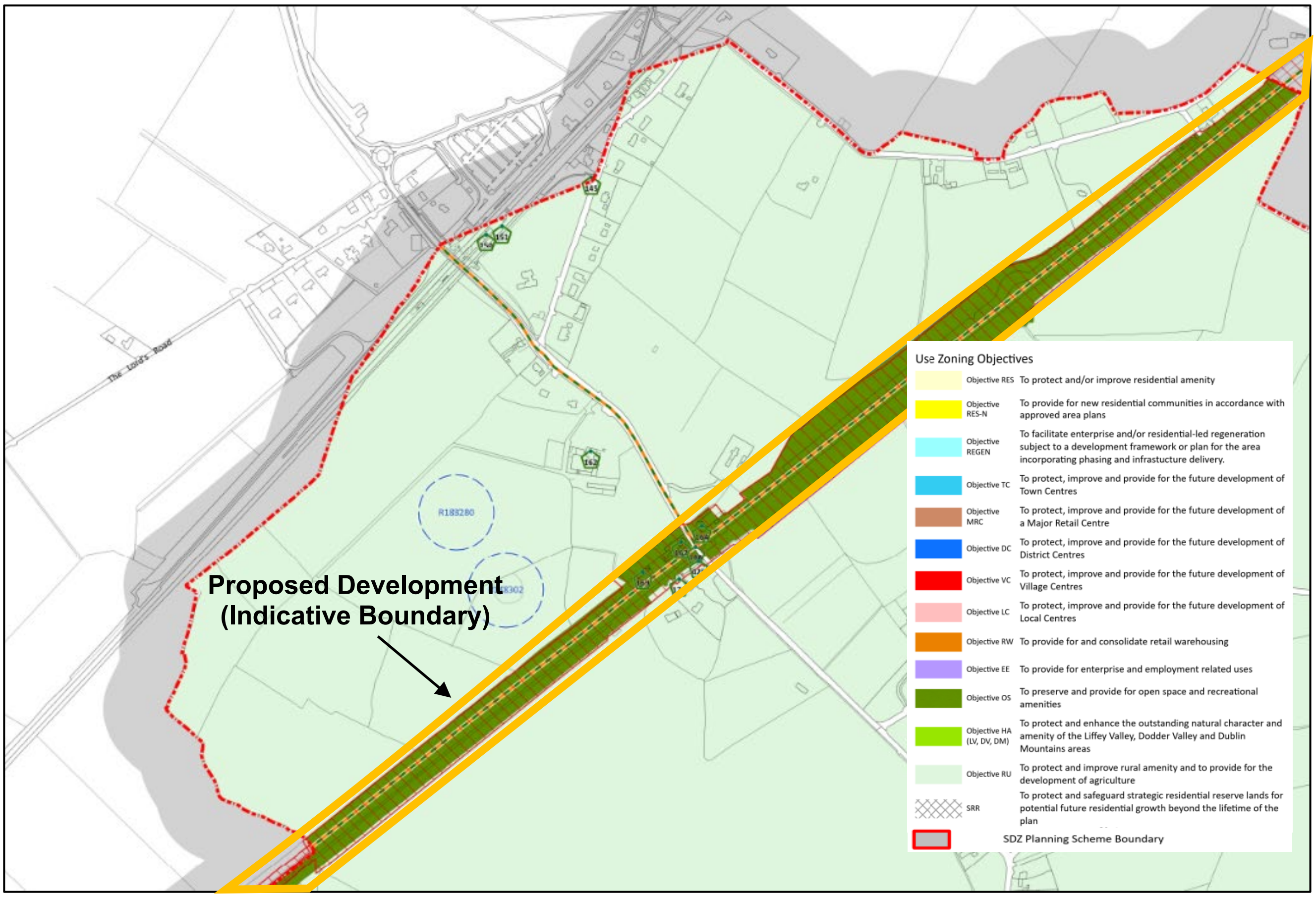

Figure 3-7 Land use map in the vicinity of Hazelhatch (South Dublin County Development Plan 2022-2028)

3.1.7. Existing Geology and Hydrogeology of the Area

The study catchments extend to the downstream extents of the Hazelhatch and Shinkeen watercourses where they discharge to the River Liffey. The catchments are mostly gently sloping and low-lying, with the exception of the upper extents of the catchments. The bedrock is predominantly dark grey to black limestone and shale, and mostly overlain by till derived from limestones. The upper catchment is mainly calcareous greywacke siltstone and shale with some dark muddy limestone. Figure 3-8 below is an overview of the underlying bedrock of the Hazelhatch and Shinkeen catchments.

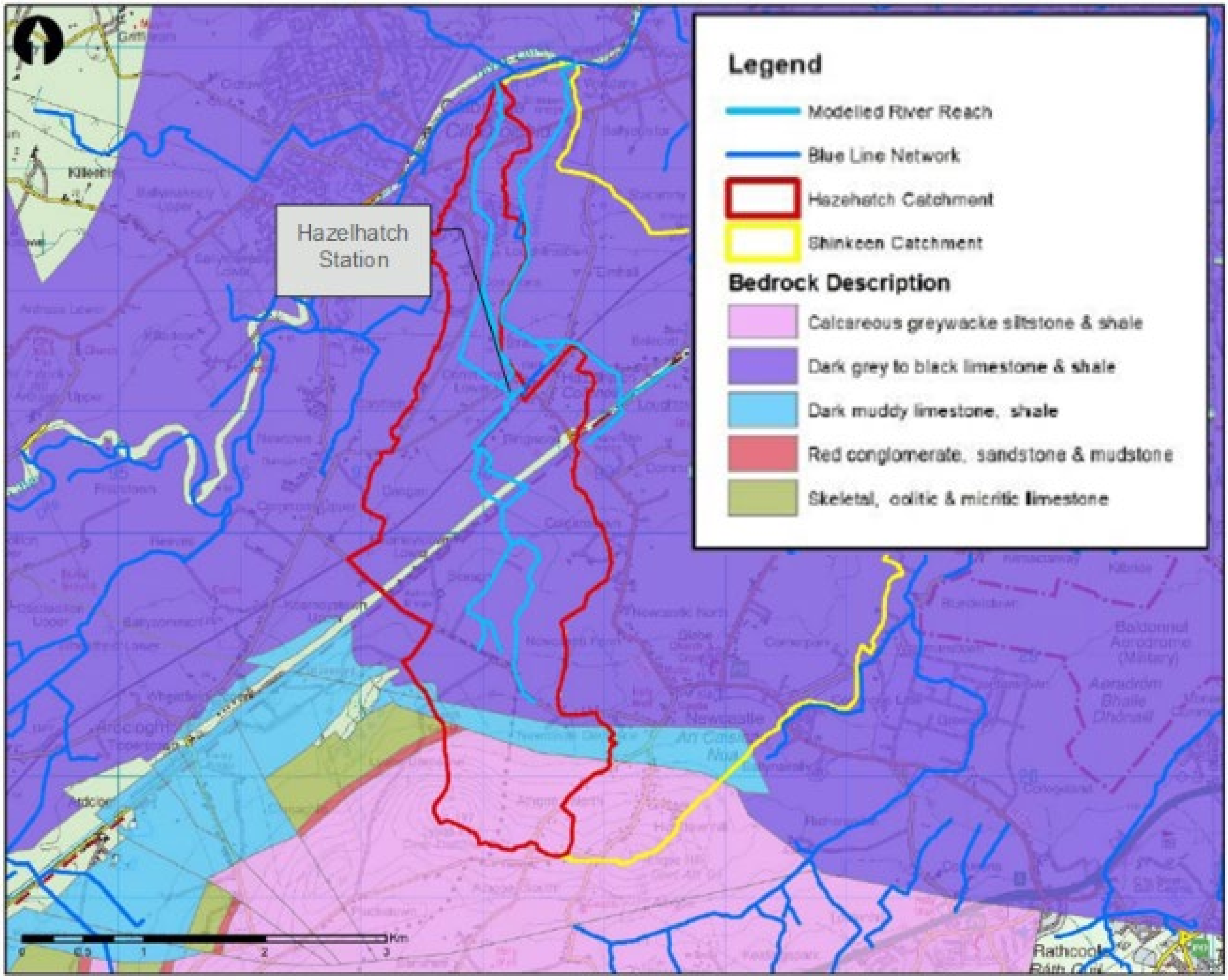

Figure 3-8 Bedrock Overview of the Hazelhatch Catchment

3.1.8. Salient Hydrological Features and Existing Flood Regime of the Area

The salient hydrological features, the impacts of which were assessed for flood risk, are the Hazelhatch and the Shinkeen Stream (Figure 3-10).

TTA reviewed historic flood records related to flooding within the study area. Sources of information on events included internet searches, consideration of the hydrometric data, a review of the Floodinfo.ie Hydrological Events, community magazines and newspapers and photographs. KCC were able to provide TTA with anecdotal evidence on flooding and photographs, along with further information and photos received via email from various members of the public who were impacted by the flooding. For some flooding events, limited data was available.

Fluvial flooding from the Hazelhatch watercourse presents the greatest risk of flooding in this area. There are multiple tributaries feeding into the Hazelhatch watercourse upstream of the main flood prone areas. The Shinkeen watercourse is situated to the East, partly fed by the canal, with little flood risk emanating from this watercourse. Following consultation with KCC and the OPW, it is considered that whilst pluvial flooding may contribute to flooding in the area, particularly around the GAA grounds, it has a minimal impact and consequently is not assessed within this study. Previous flood events have predominantly impacted the GAA grounds, the primary school, the tennis club and Primrose Gate. Flood extents were greater in these areas and along the Shinkeen watercourse prior to the Shinkeen flood works in 2001. However, significant flood risk from the Hazelhatch watercourse remains for these specified sites. Table 3.1 below summarises flood events in the Hazelhatch area.

Table 3.1: Records of Historical Flooding

Event Date	Description	Source
10th June 1993	Flooding reported to have impinged on the Railway Line and Hazelhatch Road. This was an extreme event which caused extensive flooding throughout the County, including Celbridge. Rainfall records identified during this rainfall event has a return period of approximately 1 in 200 year.	Floodinfo.ie
August 1996	Flooding to Hazelhatch Road.	Floodinfo.ie
9th April 1998	Flooding to homes on the Hazelhatch Road, Celbridge, tennis courts and Celbridge GAA club.	Floodinfo.ie
September 1999	Parts of Hazelhatch flooded to depths of more than 500mm and was impassable for some time. Hazelhatch Road flooded to depths varying from 100mm to 300mm. This cause traffic disruption. It was recorded that five or six houses on the Hazelhatch Road were surrounded with water. No internal damage was recorded, but water levels were to the top of the doorstep on some properties. Celbridge tennis courts were inundated with silt deposits causing damage. Celbridge GAA clubhouse carpark and football pitch was inundated. Some flooding of the clubhouse basement was experienced.	Floodinfo.ie
5th November 2000	Flooding to Hazelhatch railway lines caused closure of the southern train services. The Celbridge GAA club suffered damage.	KCC / Met Office
14th November 2014	Celbridge GAA club pitches, the primary school and courts 1 and 2 of the tennis club were flooded.	GAA & Tennis Clubs, Primary School
22nd/23rd November 2017	Celbridge GAA club pitches and courts 1, 2 and of the tennis club were flooded.	GAA & Tennis Clubs
8th November 2019	Celbridge GAA club pitches and tennis club were flooded.	GAA & Tennis Clubs

3.1.9. 5th November 2000

Heavy rain fell on 5th November 2000, with 56mm measured at Celbridge, a further 19.1mm recorded on the 6th of November, totalling 75.1mm over the 2 days. This data was gathered at the Met Office gauges at Celbridge. This event was preceded by almost 3 weeks of rain which had already saturated land and reduced its capacity to hold water. The Civil Defence took action by distributing sandbags in Hazelhatch, with some minor roads impacted by flooding in the area. The flooding of the rail line at Hazelhatch Train Station caused the cancellation of rail services between Cork and Dublin. The floods impacted the train station, GAA club, tennis club and much of the surrounding farmland. There are no further details on the return period or peak flows available for this event. Figure 3-9 shows flooding in the area.

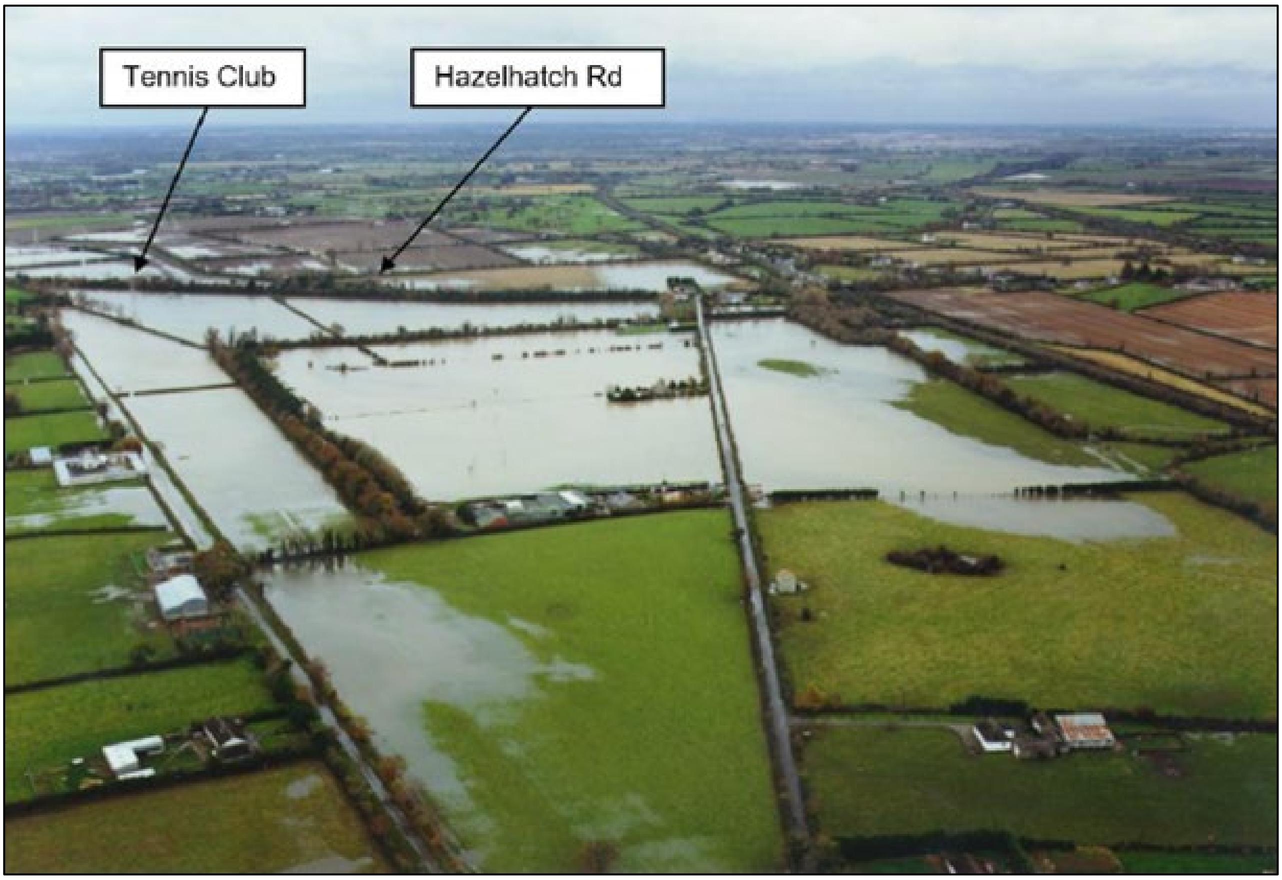

Figure 3-9 Aerial Photography of the 05/11/00 Flood Event

3.1.10. 14th November 2014

The Shinkeen watercourse had been identified as the major source of flooding at the tennis club in the early 2000s. Flood relief works were carried out on the Shinkeen by the OPW (in 2001) and although flood risk has greatly reduced, some still remains from the Hazelhatch watercourse. The tennis club owners have noted that the surrounding streams and drains are overgrown and often impacted by blockage, severely restricting flow.

3.1.11. 22nd/23rd November 2017

The GAA pitch and pitch in front of primary school were submerged following this event with the flooding occurring from the Hazelhatch watercourse. The GAA club noted that the stream had silted up over the years and the new housing estate downstream at Primrose Gate included new culverts which exacerbated the flooding problem. KCC maintain the culverts in the area and with the occurrence of flooding, on various occasions the GAA club have also cleaned the safety/trash grills in front of the culverts to try and alleviate blockages. The tennis courts were also flooded during this event. It was noted by locals that flooding took several days to subside.

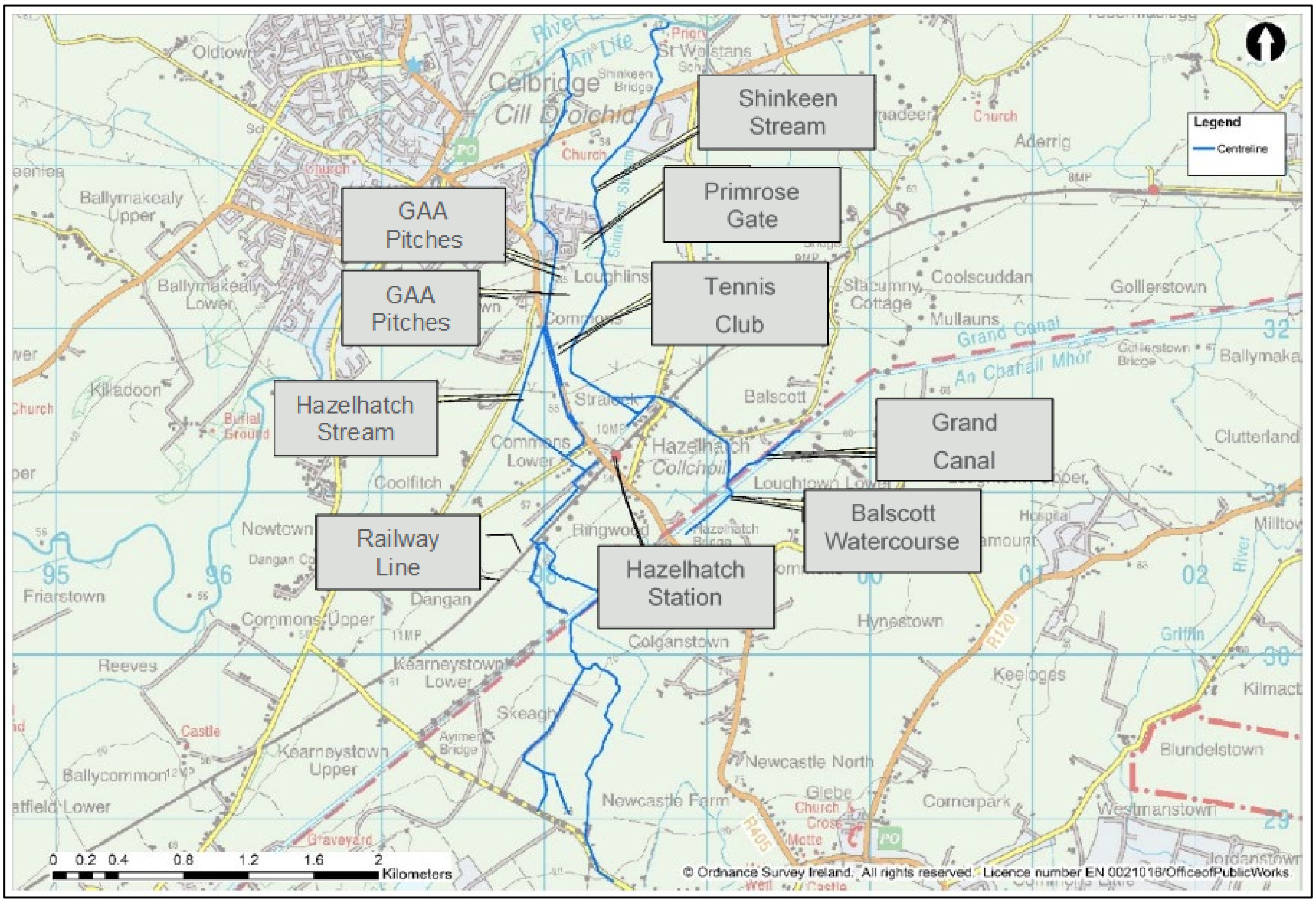

Figure 3-10 Hazelhatch and Key Locations

3.1.12. Existing Flood Studies

3.1.12.1. Eastern CFRAM Study – HA09 2016, 2017

The Eastern CFRAM Study Hydrology Report for Hydrometric Area 09 (HA09) details the available data, hydrological methods used in the study. The Eastern CFRAM Study Hydraulics Report (HA09) details all key hydraulic information on the input data, model build and model outcome.

3.1.12.2. FloodInfo.ie: Flooding in County Kildare 5-7 November 2000, Kildare County Council, 2000

This report notes the rainfall at selected gauges in the North-East Kildare/South-West Dublin area during this period of heavy rainfall, along with notes on the impacts of the flood event. The report noted that the flooding which took place was extraordinary and was due to prolonged heavy rain falling on already saturated ground, from weeks of rainfall beforehand. It was further noted that the response capability was affected by the swollen condition of the rivers and streams.

3.1.12.3. River Liffey Flood of November 2000, ESB International, 2001

The November 2000 floods are detailed within this report through the assessment of the Liffey catchment, split into lower, middle and upper regions. It assessed the extent and severity of rainfall, compared rainfall that occurred with design rainstorms and examined the flow and flood levels. It concluded that the November 2000 flood had a return period in excess of 60 years in the upper catchment and in excess of 20 years in the middle catchment.

3.1.12.4. Ardclough Flood Alleviation Scheme, Kildare County Council, 2002

Within this report, steps are outlined of the process of a flood alleviation scheme (FAS) for Ardclough. The main steps briefly summarised were a review of maps/catchments, public consultations, surveys, landowner negotiations, flooding history data collection, article review of historic flooding and liaisons with stakeholders.

3.1.12.5. Localised Flooding at Hazelhatch Road, Celbridge, Co. Kildare, OPW, 1999

This report provides some information on the flood relief works of the Shinkeen River at the time and provides information on flooding having occurred form this river, including letters from members of the public/stakeholders regarding some of the flooding.

3.1.12.6. South Dublin County Report on Flooding 5th & 6th November 2000, South Dublin County Council, 2000

This report provides information on the flooding in South Dublin on the 5th and 6th November 2000. Included is rainfall data, information on the geography of South Dublin, details of the flood and impacts and chronology of the response in relation to the flooding.

3.1.12.7. Landowner Reports

A landowner in the Hazelhatch area provided a report with a series of iterations, giving insight into local knowledge of the flooding in Hazelhatch from the Shinkeen and the impact of the canal overflow. The reports were reviewed to consider all points made. The key issue raised by the local landowner was the incorrect representation of the canal overflow within the CFRAMs hydraulic model. Within the CFRAMs model it was applied to the Balscott watercourse upstream of the canal, with the reports stating that the overflow is on the downstream side of the canal.

3.1.13. Results of the previous flood studies

3.1.13.1. Hazelhatch Further Study Fluvial Flood Risk, 2020

This study aims to identify viable structural and non-structural options and measures for the effective and sustainable management of flood risk within Hazelhatch. The model has been constructed using InfoWorks ICM software, incorporating some previously surveyed data from the CFRAM Study, and more recent data recorded in early 2020. The 14th of November 2014 and 22nd/23rd November 2017 flood events had sufficient data to use for model calibration. Blockage scenarios were simulated to replicate the observed flood events of those used for calibration. The design events remain as the scenarios for mapping, as with the CFRAM study. Modelled output comparisons of both extents and flows, along with the model performance assessed provided good confidence in the robustness of the model. Present day flood extent mapping and MRFS flood extent mapping are shown in Figure 3-12 to Figure 3-15.

Table 3.2: Node details – Hazelhatch Stream

Node Point	Flood Levels – Current Scenario			Flood Levels - MRF Scenario		
	10%AEP	1%AEP	0.1%AEP	10%AEP	1%AEP	0.1%AEP
09HAZE00365I	57.86	58.06	58.16	57.94	58.10	58.18
09SHIA00001	55.66	55.85	56.05	55.69	55.92	56.10

The most relevant nodes to the site are highlighted in grey in Table 3.2 above, shown on Figure 3-12 to Figure 3-15. It can be seen that the predicted water levels for the 1 in 10 year, 1 in 100 year, and 1 in 1,000 year fluvial events vary from 55.66mOD to 58.18mOD compared to the 57.50 mOD of the railway.

Table 3.3: Node details - Shinkeen Stream

Node Point	Flood Levels – Current Scenario			Flood Levels - MRF Scenario		
	10%AEP	1%AEP	0.1%AEP	10%AEP	1%AEP	0.1%AEP
09BALS00062	59.85	60.12	60.40	59.96	60.24	61.56
09STRA00014D	56.32	56.35	56.49	56.33	56.37	56.64

The most relevant node to the site is highlighted in grey in Table 3.3 above, shown on Figure 3-12 to Figure 3-15. The estimated flood extents for the 1 in 10 year, 1 in 100 year, and 1 in 1,000-year fluvial events vary from 56.32mOD to 61.56mOD compared to the 58.75mOD of the railway.

3.1.13.2. Pluvial Flood Risk - Preliminary Flood Risk Assessment Flood Maps

The main sources of flooding in the county are fluvial and pluvial. Hazelhatch was identified in the SDCC's Strategic Flood Risk Assessment (SFRA), using the OPW's Preliminary Flood Risk Assessment (PFRA) Flood Maps, as an area prone to pluvial flooding and that may require a pluvial flooding assessment to be carried out for planning applications. The study area of the railway is located in the vicinity of 1% and 0.1% AEP events, as shown in Figure 3-11. As such, the risk from extreme rainfall events is considered moderate.

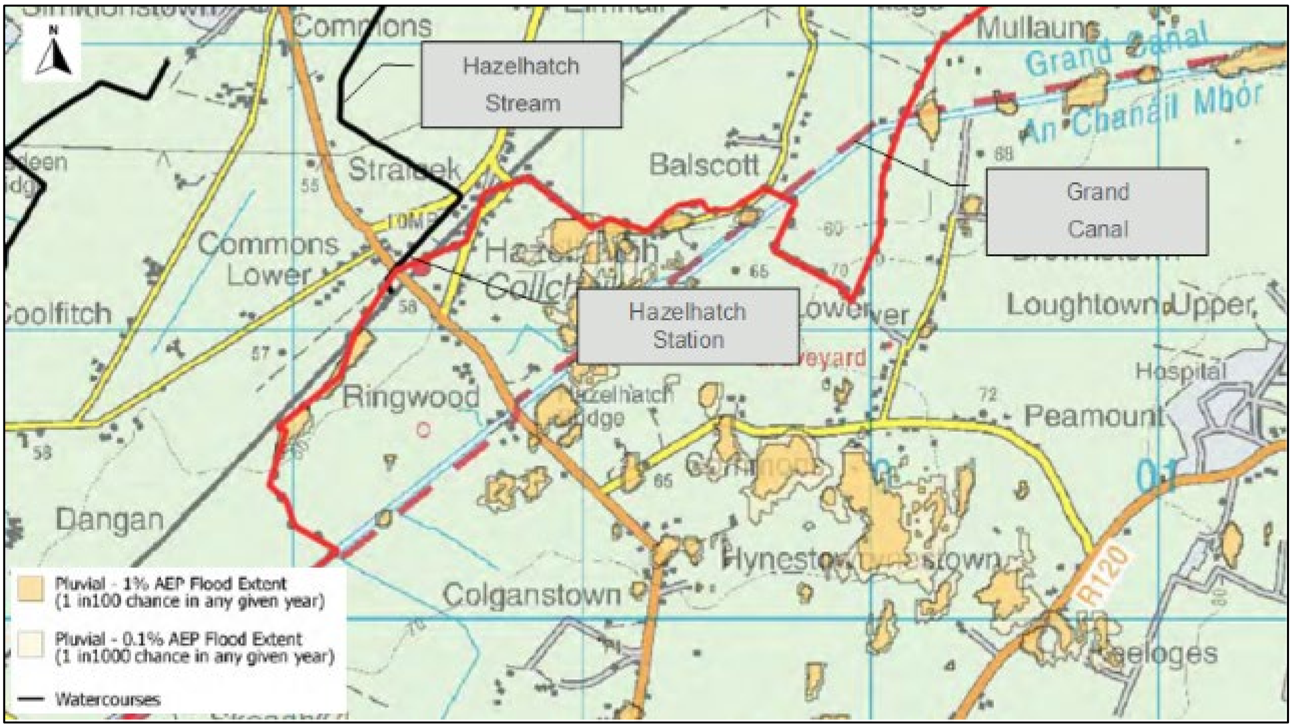

Figure 3-11 PFRA Indicative Pluvial Zone Mapping in Hazelhatch

3.1.14. Conclusion of Stage 1 – Flood Risk Identification

Records of historical flooding, the flood extent mapping generated for the study area, and other records outlined in the preceding sections indicated that the proposed Development is potentially at risk from fluvial and pluvial flooding and to a lesser extent from groundwater flooding. Therefore, the FRA was progressed to STAGE 2 – INITIAL FLOOD RISK ASSESSMENT.

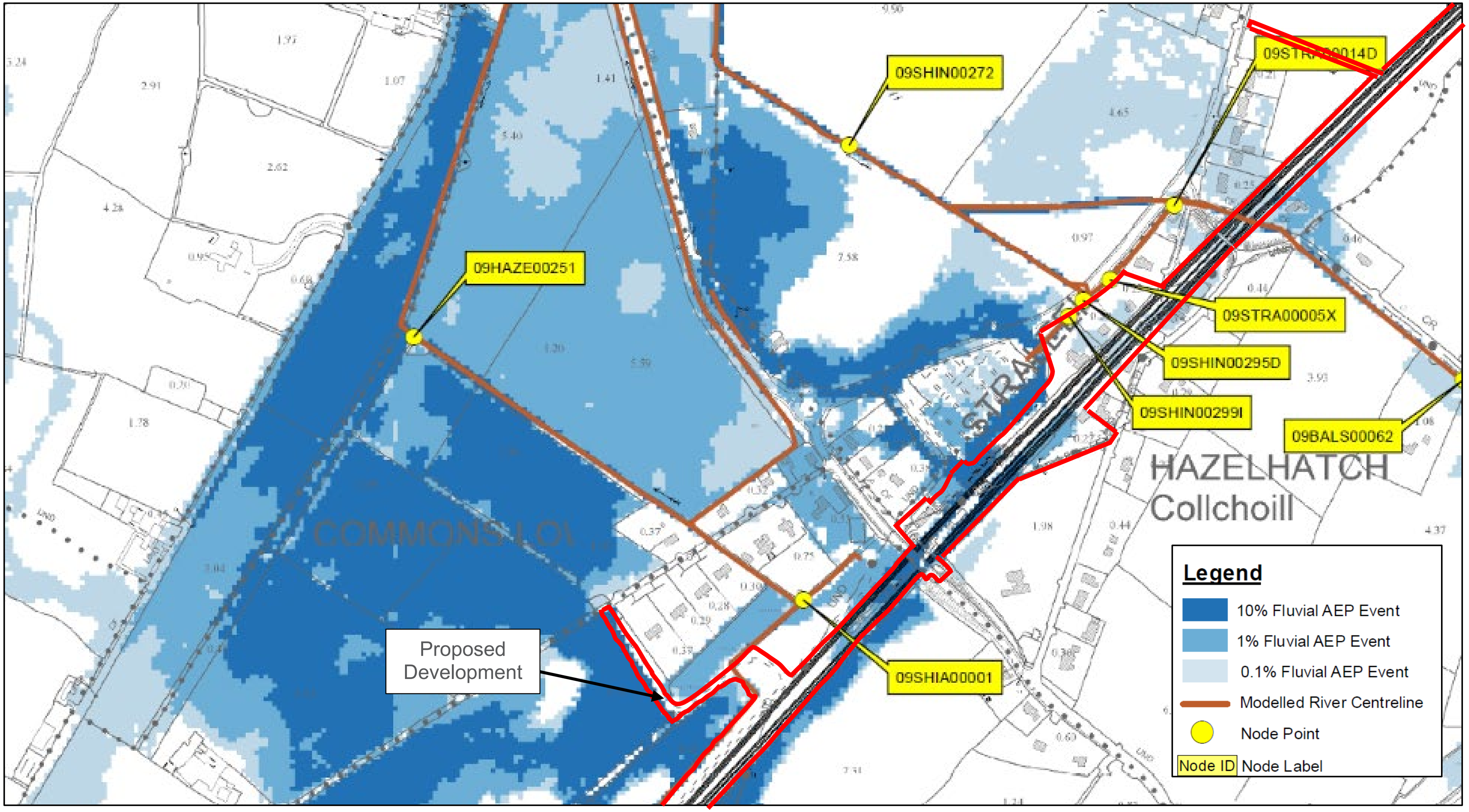

Figure 3-12 Hazelhatch Further Study (1) –Current Fluvial Flood Extent[5]

[5] Continues to Figure 3-13 to the west

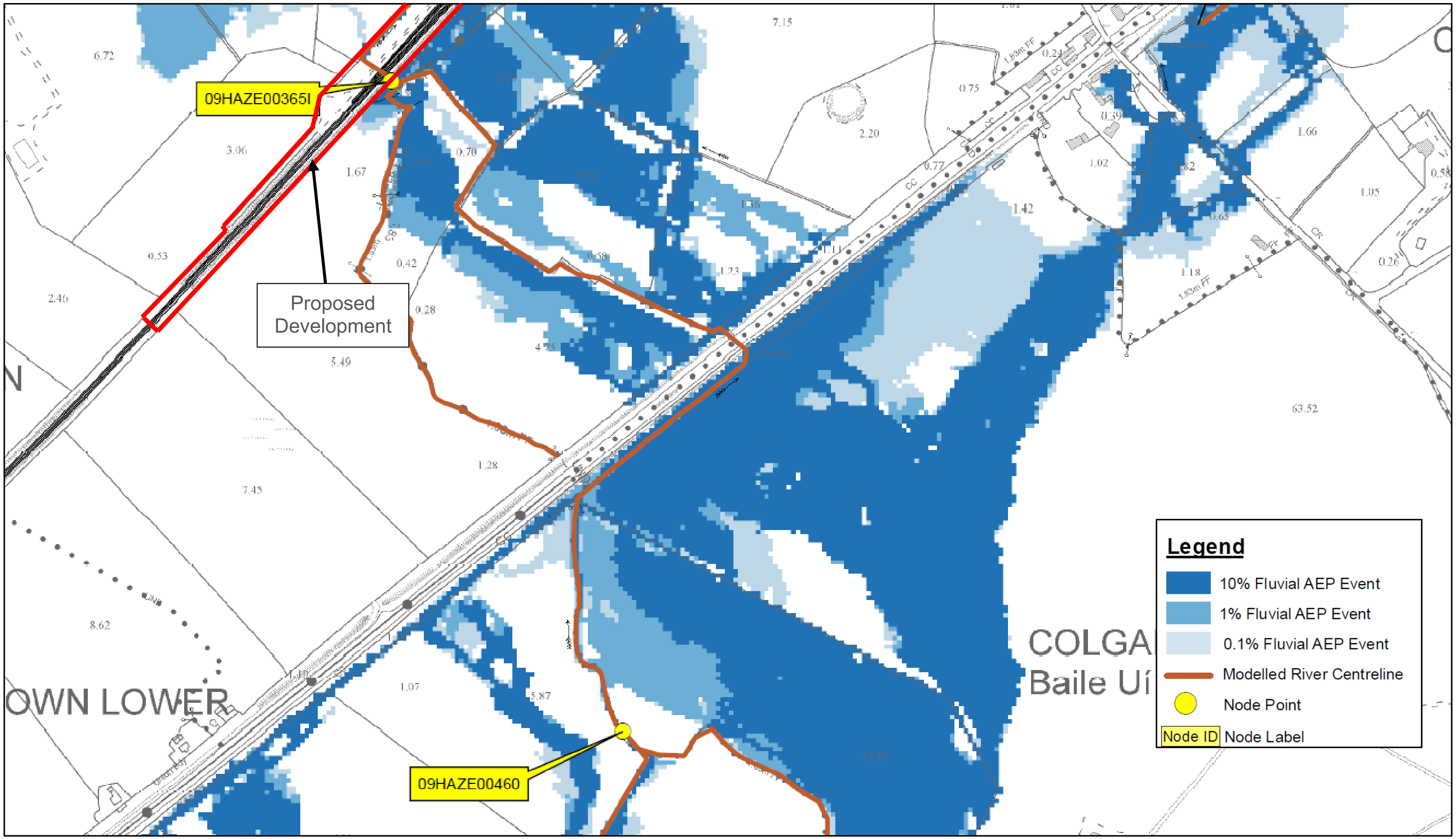

Figure 3-13 Hazelhatch Further Study (2) –Current Fluvial Flood Extent

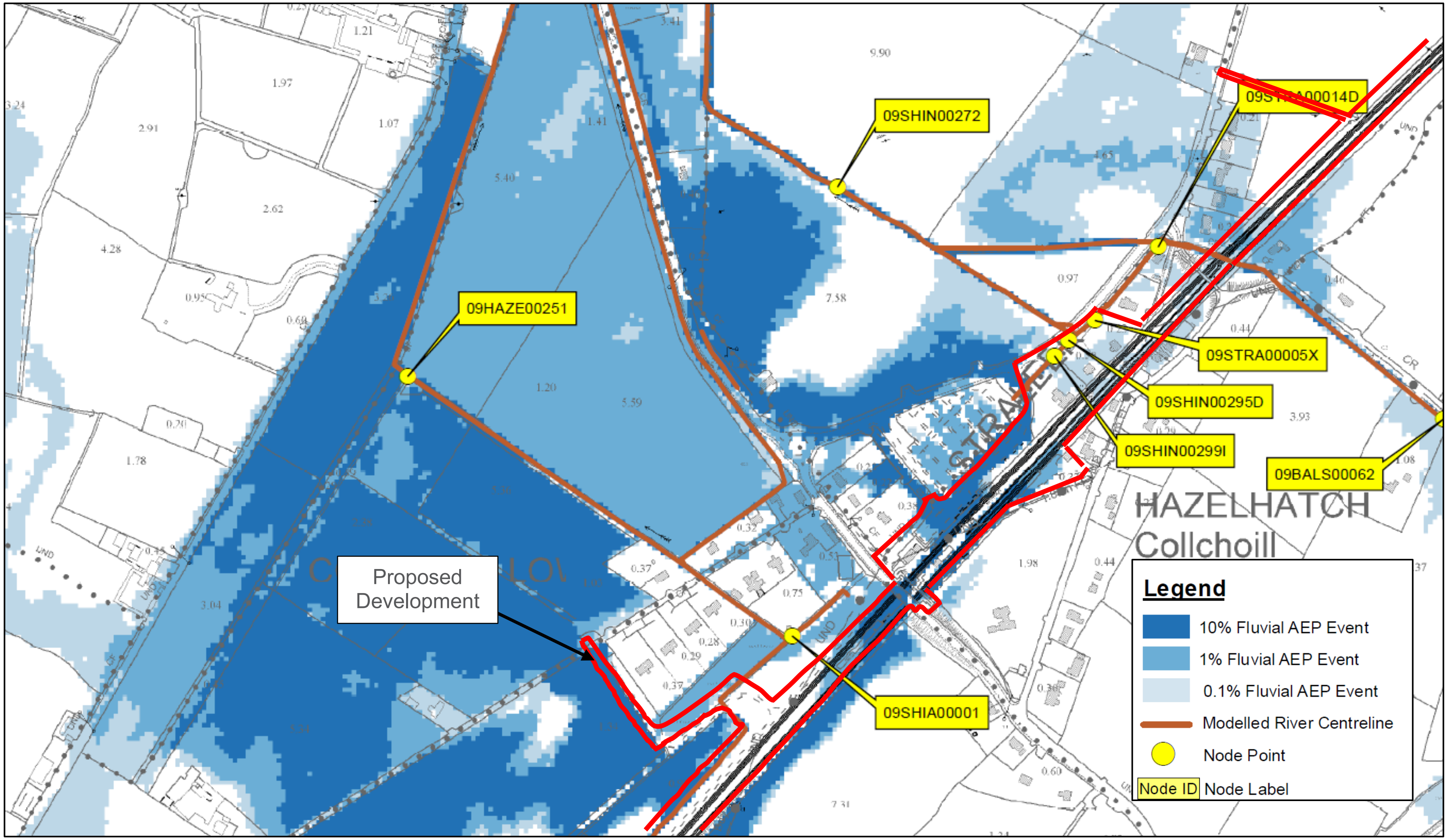

Figure 3-14 Hazelhatch Further Study (1) –MRFS Fluvial Flood Extent[6]

[6] Continues to Figure 3-15 to the west

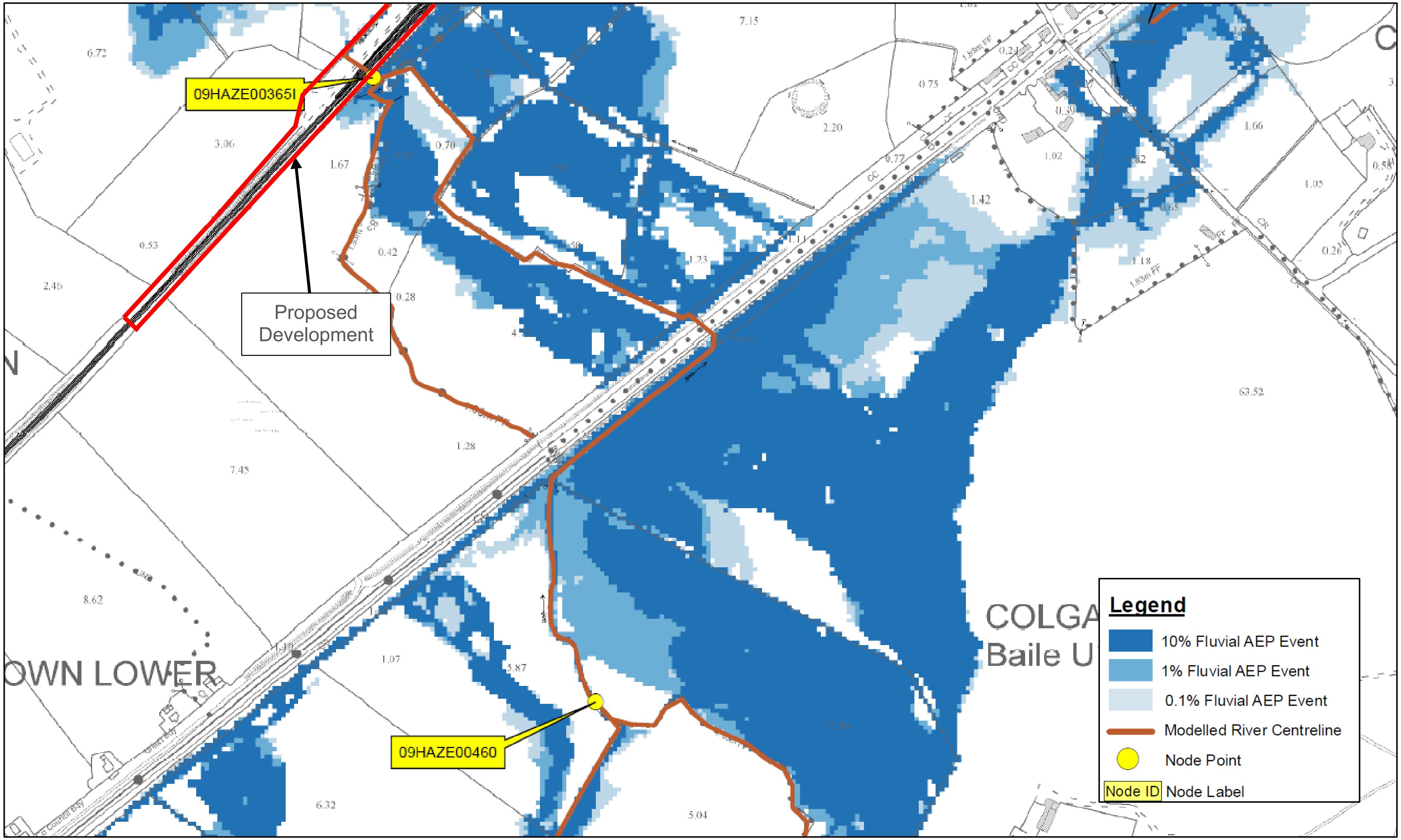

Figure 3-15 Hazelhatch Further Study (2) –MRFS Fluvial Flood Extent

3.2. Hazelhatch FRA: Stage 2 – Initial Flood Risk Assessment

3.2.1. Sources of Flood Risk

The purpose of the Stage 2 - Initial FRA was to appraise the availability and adequacy of the identified flood risk information, to qualitatively appraise the flood risk posed to the site and potential impacts on flood risk elsewhere and recommend possible mitigation measures to reduce the risk to acceptable level. In consideration of the above assessment, the primary flood risk to the Proposed Development was attributed to:

- Fluvial – High Risk; and
- Pluvial– Medium Risk.

3.2.2. Flood Risks and Flood Zone Mapping Summary

As discussed in Section 3.1.13, the most significant source of flooding based on the Hazelhatch Further Study Report, is fluvial, from Streams Hazelhatch and Shinkeen in the vicinity of Hazelhatch & Celbridge Station, which locates the site in **Flood Zone A and Flood Zone B,** given that the site boundaries are within the 1 in 100 and 1,000-year flood event extent.

A review of the predicted flood levels for the 1 in 10 year, 1 in 100 year, and 1 in 1,000 year shows fluvial events vary from 55.66mOD to 58.18mOD compared to the 57.50 mOD of the railway for the Hazelhatch Stream. Similarly, the Shinkeen Stream has predicted flood levels for the 1 in 10 year, 1 in 100 year, and 1 in 1,000 year fluvial events which vary from 56.32mOD to 61.56mOD compared to the 58.75mOD of the railway.

The study area is also susceptible to pluvial flooding based on the PFRA indicative pluvial mapping. It can be seen that the proposed site will potentially lie within **Flood Zone A and Flood Zone B.**

3.2.3. Conclusion of Stage 2 – Initial Flood Risk Assessment

The proposed Development was identified to have a fluvial and pluvial flood risk and hence a further assessment of the implications to the proposed site and surrounding areas is necessary. A review of the available flood extent mapping and reports indicates that the location of the proposed Development is at risk from fluvial flooding for the 1% and 0.1% AEP events, with and without any allowance for climate change.

The proposed Development shall be protected for the design event of 0.1% AEP inclusive of climate change in addition to a freeboard of 300mm.

Therefore, a 1D/2D hydraulic model has been prepared to assist the quantitative assessment of the flood levels and the impact of any mitigation measures (if required) along the railway line in the study area.

The protection levels proposed have not been investigated using hydraulic modelling therefore the FRA was progressed to STAGE 3 – DETAILED FLOOD RISK ASSESSMENT to improve the accuracy of these levels and to assess the residual impact of the proposed mitigation measures on the predicted 0.1% AEP event flood extents in the surrounding area.

3.3. Hazelhatch FRA: Stage 3 – Detailed Flood Risk Assessment

3.3.1. Overview

The objective of the detailed assessment is to identify locally predicted flood levels for the proposed development and also to assess the potential impact of the proposed mitigation measures. The proposed measures may displace flood waters and adversely impact the site itself or the surrounding area.

3.3.2. Hydrology

3.3.2.1. Existing Study

As discussed in Section 3.1.13.1, an updated study was undertaken for the Hazelhatch and Shinkeen Streams. The study was a recommendation from the Eastern CFRAM Study due to their being high uncertainty and low confidence in the outputs of the original Eastern CFRAM study. A comprehensive review of the hydrological regime of the area was undertaken to improve the peak flow estimates. Potential sources of uncertainty identified included:

- the effect of the Grand Canal, which traverses both catchments, on run-off and flood flows;
- to a lesser extent the effect of the Cork Mainline which traverses both catchments as well as the Hazelhatch & Celbridge Station located centrally within the study area;
- poor definition of the catchments within FSU, particularly the Hazelhatch catchment which is not defined and;
- other potential sources of flood water contributions namely pluvial and groundwater.

3.3.2.2. Catchment Review

The catchments for both streams were reviewed and updated using more recent LiDAR, OSI historical mapping and comprehensive walkover ground truthing surveys. Figure 3-16 and Figure 3-17 show the updated catchments and HEPs.

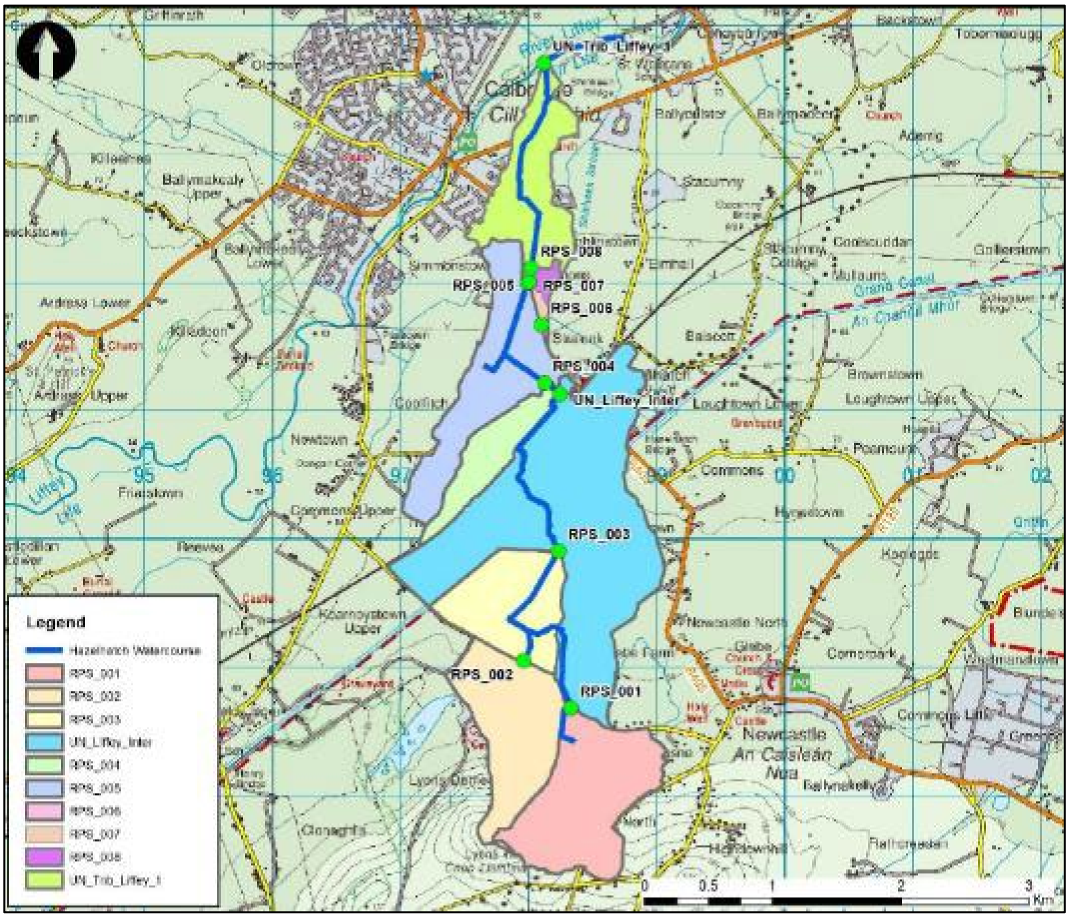

Figure 3-16 Hazelhatch Stream Catchments

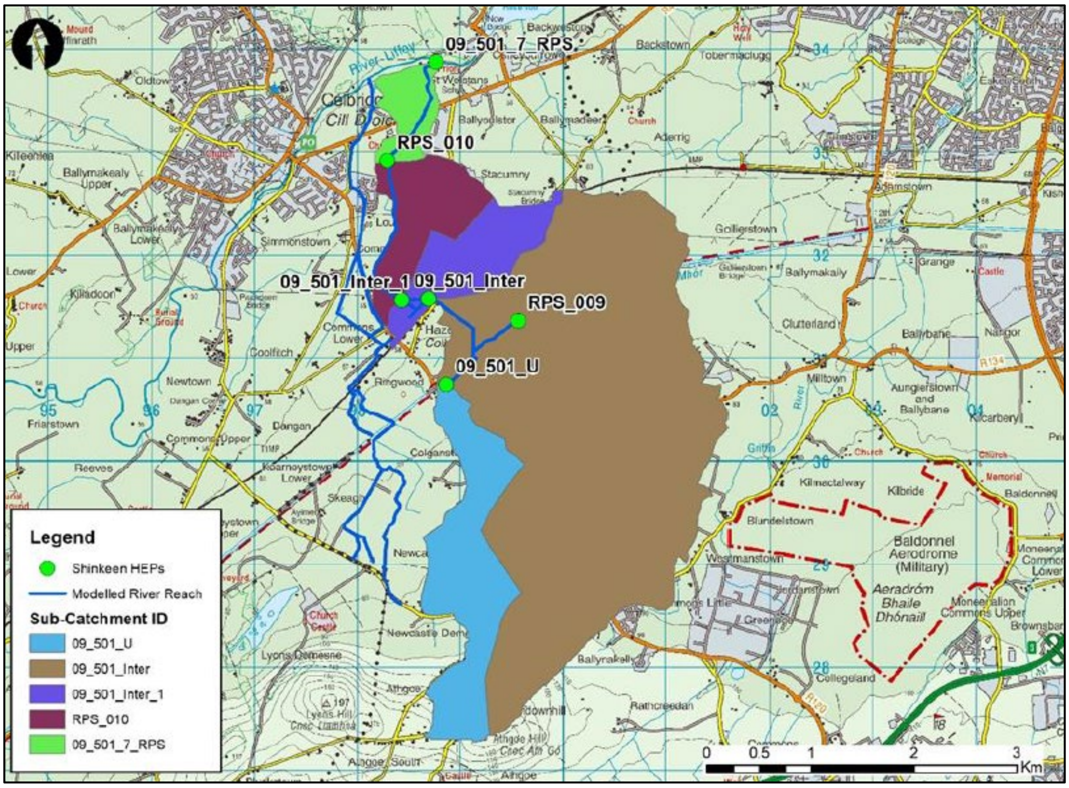

Figure 3-17 Shinkeen Stream Catchments

3.3.2.3. Peak Flows Estimation

As stated in Section 3.3.2.1 the design flows calculated as part of the updated Hazelhatch Study were completed following a comprehensive hydrological review of the study area catchments. They were also calibrated against recent flooding events and thus for this FRA those design flows have been incorporated into the hydraulic model for this FRA. The updated study used the same design flow, adjustment factor, growth factors and hydrograph generation methodologies are previously detailed in Section 2.6.

3.3.2.4. Physical Catchment Descriptors

Table 3.4: shows the PCD values associated with all HEPs identified in the study area.

Table 3.4: PCD values for HEPs

Watercourse	HEP	AREA (km^2)	SAAR (mm)	BFISOIL	DRAIND (km/km^2)	S1085 (m/km)	ARTDRAIN2
Hazelhatch	RPS_001	0.97	772.58	0.62	0.37	20.29	0
Hazelhatch	RPS_002	0.79	772.58	0.62	0.23	2.89	0
Hazelhatch	RPS_003	1.44	772.58	0.62	2.15	7.13	0
Hazelhatch	UN_Liffey_Inter	4.8	731.16	0.59	0.97	8.45	0.0089
Hazelhatch	RPS_004	5.15	731.16	0.59	0.91	8.14	0.0089
Hazelhatch	RPS_005	6.02	731.16	0.59	1	5.82	0.0089
Hazelhatch	RPS_006	0.01	731.17	0.59	0.95	53.33	0.5463
Hazelhatch	RPS_007	0.03	731.17	0.59	12.45	1.57	0.5463
Hazelhatch	RPS_008	6.1	731.17	0.59	1.15	5.42	0.5463
Hazelhatch	Un_Trib_Liffey_1	6.77	731.17	0.59	1.33	4.55	0.5463
Shinkeen	09_501_U	1.74	731.16	0.59	0.972	0.64	0.8715
Shinkeen	09_501_Inter	10.385	731.16	0.59	0.972	4.25	0.8715
Shinkeen	09_501_Inter_1	11.308	731.16	0.59	0.972	6.1	0.8715
Shinkeen	RPS_010	12.234	731.16	0.68	0.972	8.65	0.8715
Shinkeen	09_501_7_RPS	12.661	728.1	0.69	0.972	9.67	0.8715

3.3.2.5. Design Peak Flows

3.3.2.5.1. Index Flood Flows

Qmed Estimates

Table 3.5below presents the estimated Qmed values which have been estimated in accordance with the index-flood estimation methods discussed in Section 2.6.2.2.1.

Table 3.5: HEPs – PCD based Qmed & Qbar estimates

HEP	FSU PCD Qmed-rural (m^3/s)	
	7-Var	5-var
RPS_001	0.14	0.31
RPS_002	0.07	0.16
RPS_003	0.28	0.35
UN_Liffey_Inter	0.71	1.07

HEP	FSU PCD Qmed-rural (m^3/s)	
	7-Var	5-var
RPS_004	0.76	1.13
RPS_005	0.83	1.2
RPS_006	0.001	0.003
RPS_007	0.01	0.01
RPS_008	0.87	1.19
Un_Trib_Liffey_1	0.97	1.26
09_501_U	0.17	0.34
09_501_Inter	1.04	1.8
09_501_Inter_1	1.21	2.16
RPS_010	1.65	2.24
09_501_7_RPS	1.78	2.32

The updated Hazelhatch study used an average adjustment factor of 1.53 for the Lucan (9002) and Camac (0935) gauging stations. These are the two geographically closet suitable stations for using as pivotal sites.

3.3.2.5.2. Growth Factors / Curves Estimation

The growth factors from the Eastern CFRAM Study were retained for the updated study as they were considered sufficiently robust and accurate to be used. The growth factors for the Hazelhatch and Shinkeen Streams are shown inTable 3.6.

Table 3.6: Design Growth Factors

HEP	Growth Factors	
	1% AEP	0.10%AEP
Hazelhatch	3.323	5.925
Shinkeen	2..952	4.89

3.3.2.6. Additional Inflows

The updated study carried out an assessment of additional inflows from other sources and identified:

- An overflow from the Grand Canal; and
- Flow transfer from the nearby Baldonnel catchment during flooding events.

The peak estimate is shown in Table 3.7 for these additional inflows at HEP RPS_009.

3.3.2.7. Estimated Peak Flows

Table 3.7 presents the estimated design peak flows for all HEPs selected on the proposed model watercourse for a 1% and 0.1% AEPs.

3.3.2.8. Future Conditions

Future Condition peak flows were defined taking into consideration all parameters discussed in Section 2.6.5.

Table 3.7: Estimated Design Peak Flows

HEP	Peak Flows (m^3/s)	
	1% AEP	0.10%AEP
RPS_001	1.039	1.852
RPS_002	0.526	0.938
RPS_003	1.424	2.538
UN_Liffey_Inter	3.610	6.436
RPS_004	3.864	6.89
RPS_005	4.22	7.524
RPS_006	0.01	0.018
RPS_007	0.02	0.035
RPS_008	4.423	7.887
Un_Trib_Liffey_1	5.33	9.503
09_501_U	2.853	3.745
09_501_Inter	2.11	3.495
RPS_009	9.328	14.472
09_501_Inter_1	10.17	15.866
RPS_010	12.396	19.554
09_501_7_RPS	13.117	20.748

3.3.3. Hydraulic Modelling

3.3.3.1. Existing Scenario

3.3.3.1.1. Flood Zone Mapping

Figure 3-18 shows that the proposed Development site is impacted by the 1% and 0.1% AEP fluvial flood events and lies within Flood Zones A and B. The flood zone map is also shown in Appendix A. Table 3.8 shows the flood levels across the model extents. The location of flood levels checking points are illustrated in Figure 3-18 and it shows flooding on the track at Mon 01 and adjacent to Mon03a and 3b along the Shinkeen Stream.

Table 3.9 shows the flood depths across the track at Monitoring Point 01, and it can be seen that the depths are far in excess of the operational flood depth limits listed in Section 2.9. There is also flooding on the track for 0.1% AEP event from the Shinkeen stream at Mon 03a / 3b.

Table 3.10 shows predicted flood depths and durations of flooding at the railway track for the existing scenario at Mon 01. It can be seen from this table that during a 2% AEP flood event railway track will remain flooded for a period of 60 hours.

Table 3.8: Previous Study and FRA flood level comparisons

River	Monitoring Points	Previous Study Existing 1% AEP (m)	FRA Existing 1% AEP (m)	Difference (m)	Previous Study Existing 0.1% AEP (m)	FRA Existing 0.1% AEP (m)	Difference (m)
Railway Track	Mon 01	-	57.576	-	-	57.615	-
Hazelhatch	09HAZE00365I	58.06	58.062	0	58.16	58.157	0

River	Monitoring Points	Previous Study Existing 1% AEP (m)	FRA Existing 1% AEP (m)	Difference (m)	Previous Study Existing 0.1% AEP (m)	FRA Existing 0.1% AEP (m)	Difference (m)
Hazelhatch	Mon 02	-	57.047	-	-	57.107	-
Hazelhatch	09SHIA00001	55.85	55.852	-	56.05	56.047	-
Shinkeen	09BALS00062	60.12	60.124	0	60.4	60.399	0
Shinkeen	Mon 03a	-	58.035	-	-	58.616	-
Shinkeen	Mon 03b	-	57.592	-	-	57.92	-
Shinkeen	09STRA00014D	56.35	56.353	0	56.49	56.492	0

Table 3.9: Predicted Flood Depths

Existing FRA Scenario Flood **Depth (m)** above the **Railway Track**		
Monitoring Point	**1% AEP**	**0.1%AEP**
Mon 01	0.425	0.463
Mon 03/03b	0.000	0.551

Table 3.10 Predicted flood depths and durations of flooding for existing scenario

Flood depth at Mon 01 (Hazelhatch station) above the existing track - Present Day				
AEP	10% AEP (1 in 10 year)	2% AEP (1 in 50 year)	1% AEP (1 in 100 year)	0.1% AEP (1 in 1000 year)
Max Flood Depth above ground (m)	0.231	0.401	0.425	0.463
Duration for flood depth above the rail top (i.e. >0.17m above ground)	27 hrs	60 hrs	>67 hrs	>74 hrs

3.3.3.1.2. Updated Hazelhatch Study Comparison

Comparing Figure 3-12 and Figure 3-13 with Figure 3-18 it can be seen that overall there is good correlation between the flood extents. The flood levels shown in Table 3.8 indicate that the flood levels are the same indicating no errors in differences between the model runs for this FRA and the previous study.

3.3.3.2. Climate Change Sensitivity

Climate change HEFS flooding extents for the existing site are shown in Figure 3-19. It can be seen that there is an increase in Flood Zones A and B along the track but in particular adjacent to the Shinkeen stream near monitoring points Mon 03a and 03b. There is also predicted flooding for the 0.1% AEP HEFS event at the locations of the proposed substation (57.559 mOD) and compound (57.000 mOD) locations. The finished floor level, or any essential machinery must be situated above these flood levels, plus an additional freeboard. Table 3.11 shows predicted flood depths and durations of flooding for the future climate change scenarios at Mon 01. It can be seen from this table that during a 10% AEP flood event railway track will remain flooded for a period of 36 hours. The HEFS flood extent map is shown in Appendix A.

Table 3.11: Predicted flood depths and durations of flooding for climate change scenarios

Flood depth at Mon 01 (Hazelhatch station) above the existing track - MRFS/HEFS				
AEP	10% AEP + 30% (1 in 10 year)	2% AEP + 20% (1 in 50 year)	1% AEP + 30% (1 in 100 year)	0.1% AEP + 30% (1 in 1000 year)
Max flood depth above ground (m)	0.341	0.425	0.448	0.475
Duration for flood depth above the rail top (i.e. >0.17m above ground)	36 hrs	>67 hrs	>72 hrs	>79 hrs

3.3.3.3. Proposed Scenario

Predicted Impacts:

Flood impacts as a result of the proposed upgrading works to the existing railway track at the Hzaelhatch Station have been assessed by running a hydraulic model simulation with incorporating the proposed changes in the model geometry.

Noise barriers are proposed at a number of locations within Zone A to mitigate operational noise impact (Refer to Chapter 14 Noise & Vibration of Volume 2, EIAR for further details). The flood impacts due to installation of the proposed noise barriers along the railway track in the vicinity of the residential/urban development areas have also been examined. These barriers could cause obstruction to flood water flow paths, which consequently could cause an increase in flood levels in the upstream vicinity. It was identified that these proposed noise barriers in the Hazelhatch area are located within the 1% AEP and 0.1% AEP flood extents. Any likely impacts on the existing flooding due to the noise barriers have also been examined using the above-mentioned hydraulic modelling technique.

The hydraulic modelling results showed that proposed modifications to the existing railway tracks at the Hazelhatch station and upgrading of infrastructure at Hazelhatch to facilitate the electrification will not increase flood risk to the surrounding area as the proposed ground levels will be maintained at the current levels to ensure that displacement of floodwaters does not occur and cause a residual risk. However, the proposed noise barriers would cause some increases in flood levels (136mm to 379mm), particularly in the upstream vicinity of the proposed noise barriers, with a maximum increase of 379mm in the north-eastern vicinity of the railway culvert crossing on the Shinkeen River.

Figure 3-19a and Figure 3-19b illustrate the comparisons of the 0.1% AEP HEFS flood extents and depth changes respectively, between the existing and proposed development conditions. Table 3.12 presents a comparison of the flood levels between the existing and proposed development conditions at a number of monitoring points on the railway track and Hazelhatch & Shinkeen river channels. The causes of this flood level rise can mainly be attributed to the obstruction to flood water flow paths caused by the proposed noise barriers.

Proposed Flood Alleviation Measures:

Potential mitigation measures to alleviate the existing flooding risk along the railway track along with mitigating the above-mentioned predicted flood impacts as a result of installation of proposed noise barriers were investigated.

Hydraulic modelling of possible hard mitigation measures included at Hazelhatch would increase flood risk to the surrounding area and would not reduce flooding below the Iarnród Éireann flood depth operational limits. Therefore, it was recommended that no hard mitigation measures are implemented for this planning application and that Iarnród Éireann engage with the OPW which is currently progressing a Flood Relief Scheme for the wider Hazelhatch area. This scheme could reduce flooding to the railway station and its infrastructure. Hard mitigation measures developed solely for the railway station would increase flood risk to the surrounding area.

The following potential measures were considered, instead of any hard defences, to alleviate flooding in the Hazelhatch area:

- 2.0 x 1.5m additional culvert at the Mon 03a/3b (Shinkeen River).
- 1.0 x 1.0m additional culvert at the Mon 02 (Hazelhatch River).
- 2no. 3.0 x 1.5m proposed culverts adjacent to Mon 01 (Hazelhatch River).
- Construction of a 83m long and 2m wide conveyance channel along the railway track along the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. This channel will help in conveying the increased flood volume from the adjacent flooded land areas into the Shinkeen river and maintain the status quo flooding regime.

Table 3.12 shows that while flooding has been reduced in some residential areas and in the train station carpark, there is still flooding along the railway track. Table 3.12 shows that the flood level has been reduced at Monitoring Point Mon 01 and at points upstream of the railway however flood levels have been increased downstream of the station in the watercourses. Also flood depths have increased in private agricultural land as show in Table 3.12, the depth of flood water has increased by up to 30mm over a large surface area. The proposed mitigation measures while reducing the flood risk to the station and the track, do not reduce the flood level at Mon 01 to a flood depth below the operation limits discussed in Section 2.9.

Table 3.12: Comparison of 0.1% AEP HEFS Flood Levels

River	Monitoring Points	Flood Levels 0.1% AEP HEFS (mOD) (Existing condition)	Flood Levels 0.1% AEP HEFS (m) (Proposed conditions – including noise barriers)	Water Level Difference (m) (Impacts)	Flood Levels 0.1% AEP HEFS (mOD) (with mitigation measures)	Water Level Difference (m) (with mitigation measures)
Hazelhatch	09HAZE00365I	58.190	58.185	-0.005	58.007	-0.183 (decrease)
Hazelhatch	09SHIA00001	56.114	56.08	-0.034	56.113	-0.001 (decrease)

River	Monitoring Points	Flood Levels 0.1% AEP HEFS (mOD) (Existing condition)	Flood Levels 0.1% AEP HEFS (m) (Proposed conditions – including noise barriers)	Water Level Difference (m) (Impacts)	Flood Levels 0.1% AEP HEFS (mOD) (with mitigation measures)	Water Level Difference (m) (with mitigation measures)
Hazelhatch	Mon 02	57.124	57.125	0.001	57.245	0.121 (increase)
Hazelhatch	Mon 01	57.627	57.763	0.136 (increase)	57.489	-0.138 (decrease)
Shinkeen	09BALS00062	60.574	60.569	-0.005	60.569	-0.005 (decrease)
Shinkeen	09STRA00014D	56.691	56.625	-0.066	56.774	0.083 (increase)
Shinkeen	Mon 03a	58.736	59.115	0.379 (increase)	58.664	-0.072 (decrease)
Shinkeen	Mon 03b	57.987	58.125	0.138 (increase)	58.223	0.236 (increase)

The above-mentioned analysis showed that any localised flood protection measures at the railway track would pose increased flooding risks to the lands & properties located immediate upstream & downstream of the railway track. Given the complex nature of flood mechanisms and presence of flatter low-lying flood prone areas in the vicinity of the proposed development, a catchment wide flood mitigation option/approach should be adopted in coordination with the relevant local authority and OPW. This should be implemented under a separate flood relief scheme (FRS).

3.3.3.4. Conclusion Stage 3 Hazelhatch FRA: Stage

The conclusion and analysis of the Stage 3 Hazelhatch FRA: Stage is discussed in Section 3.7 to address all of Zone A in its entirety.

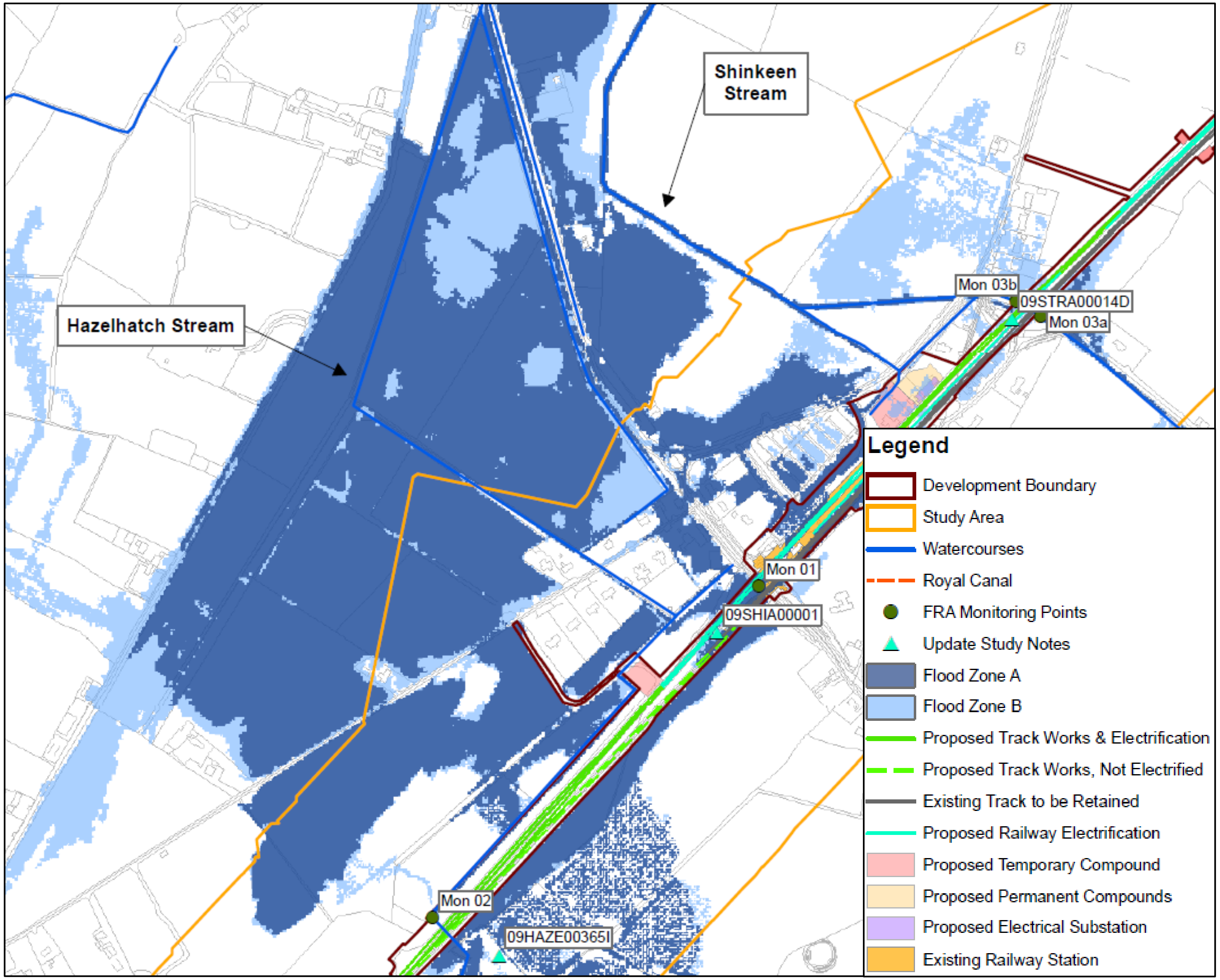

Figure 3-18 Hazelhatch FRA Flood Zones

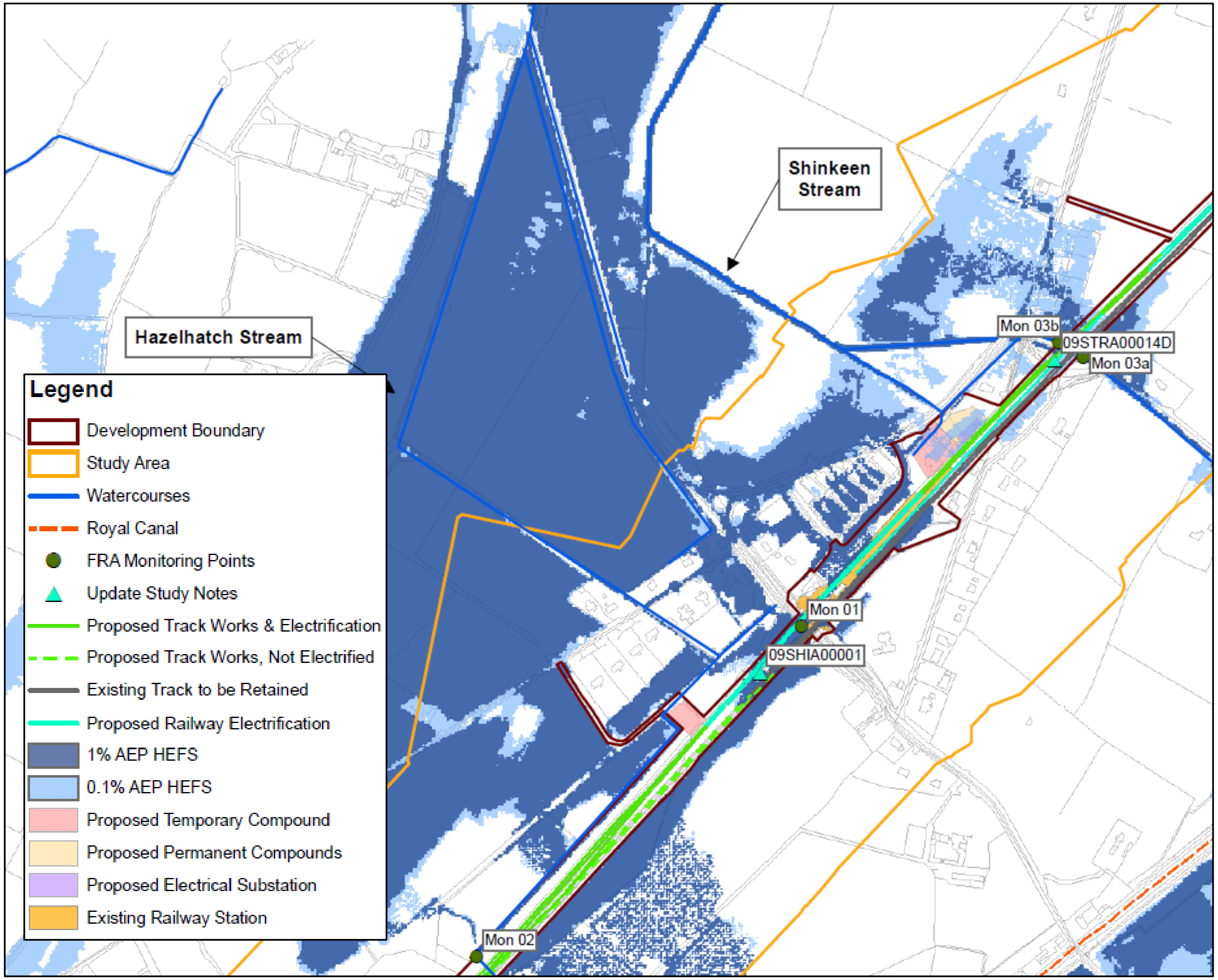

Figure 3-19 Hazelhatch FRA HEFS Flood Extents

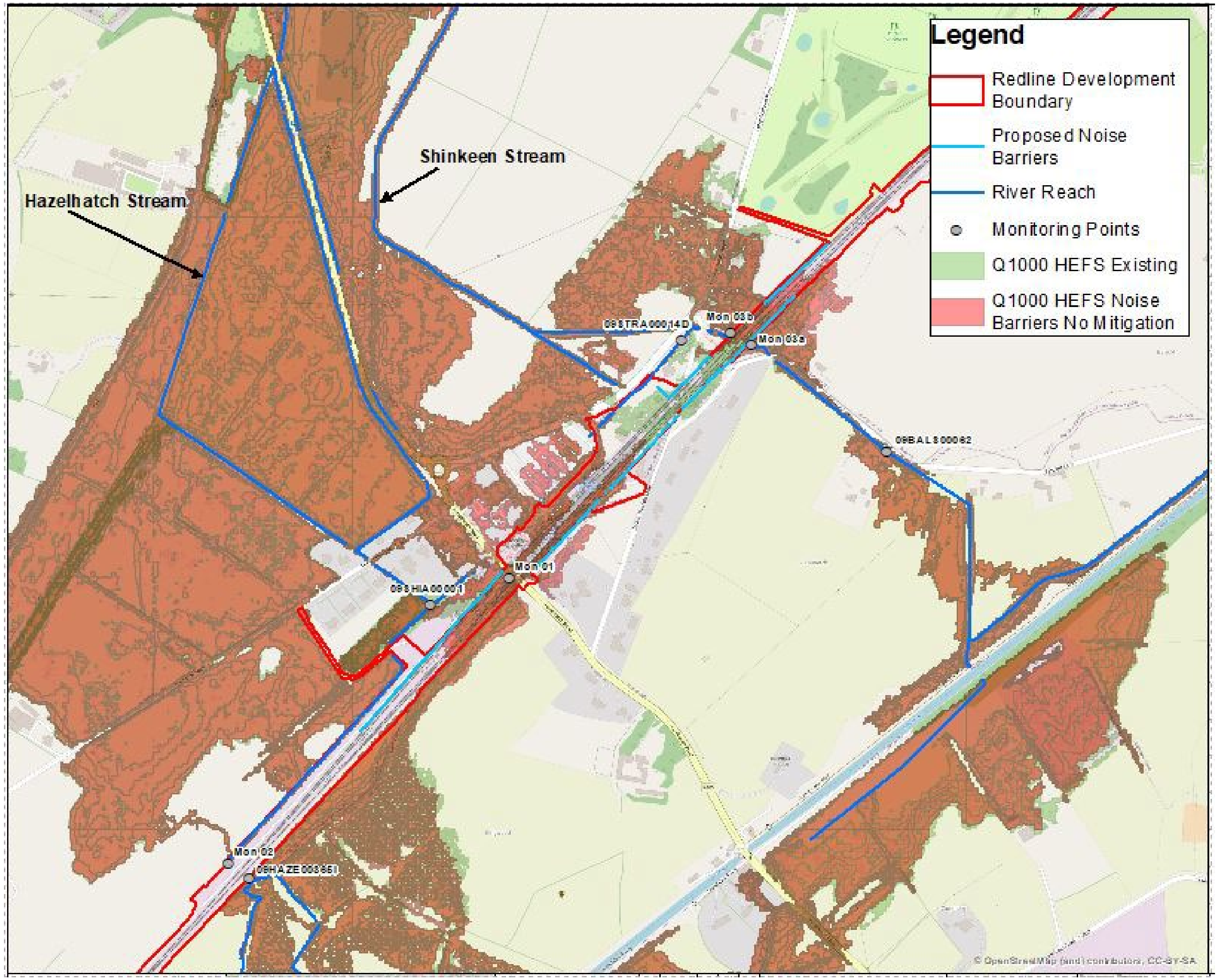

Figure 3-19a Comparison of 0.1% AEP HEFS flooding extents for existing and proposed scenarios (with noise barriers)

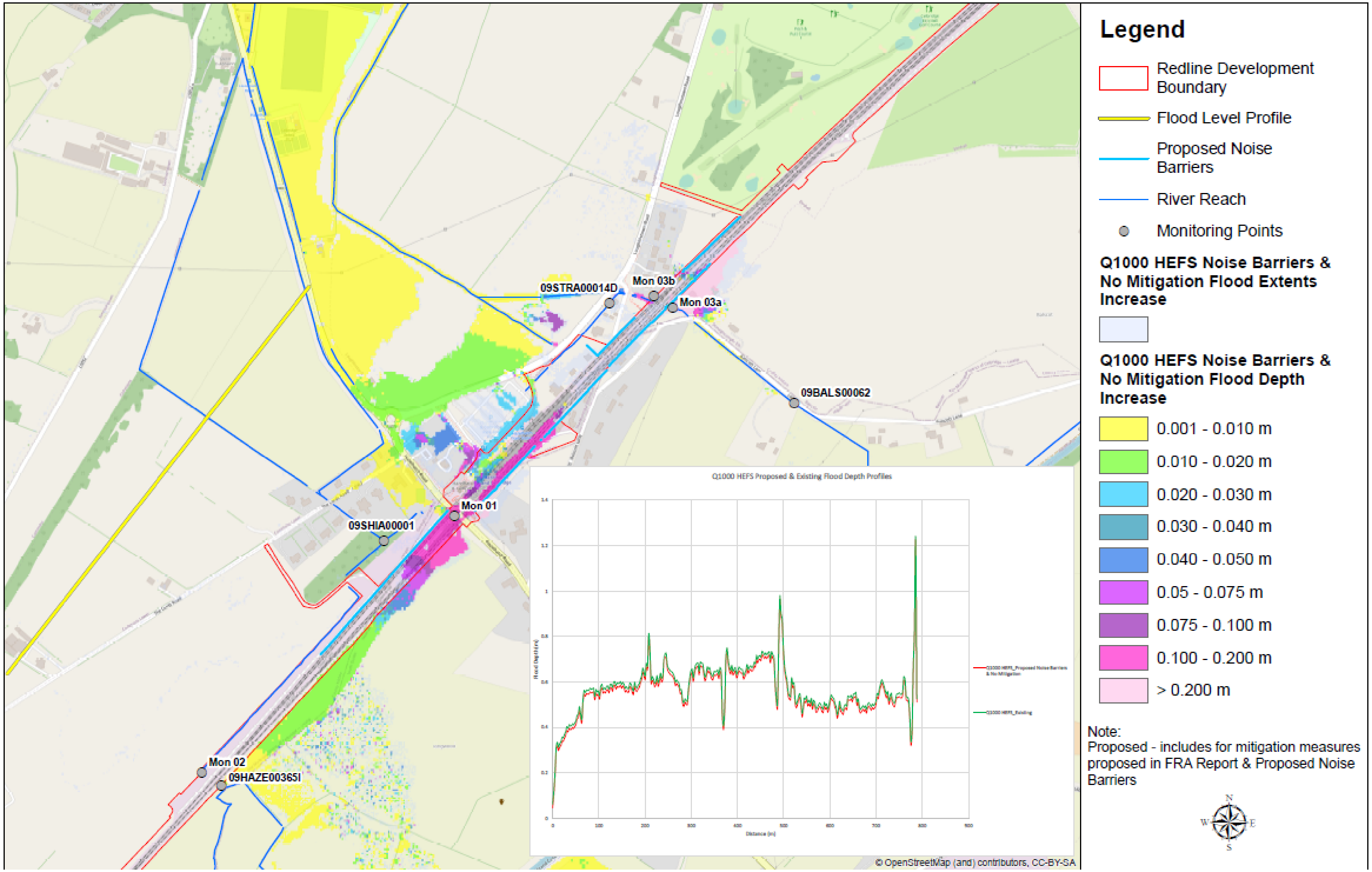

Figure 3-19b 0.1% AEP HEFS Flood profile through agricultural land downstream of the station showing increased flooding depth for the proposed scenario (with noise barriers)

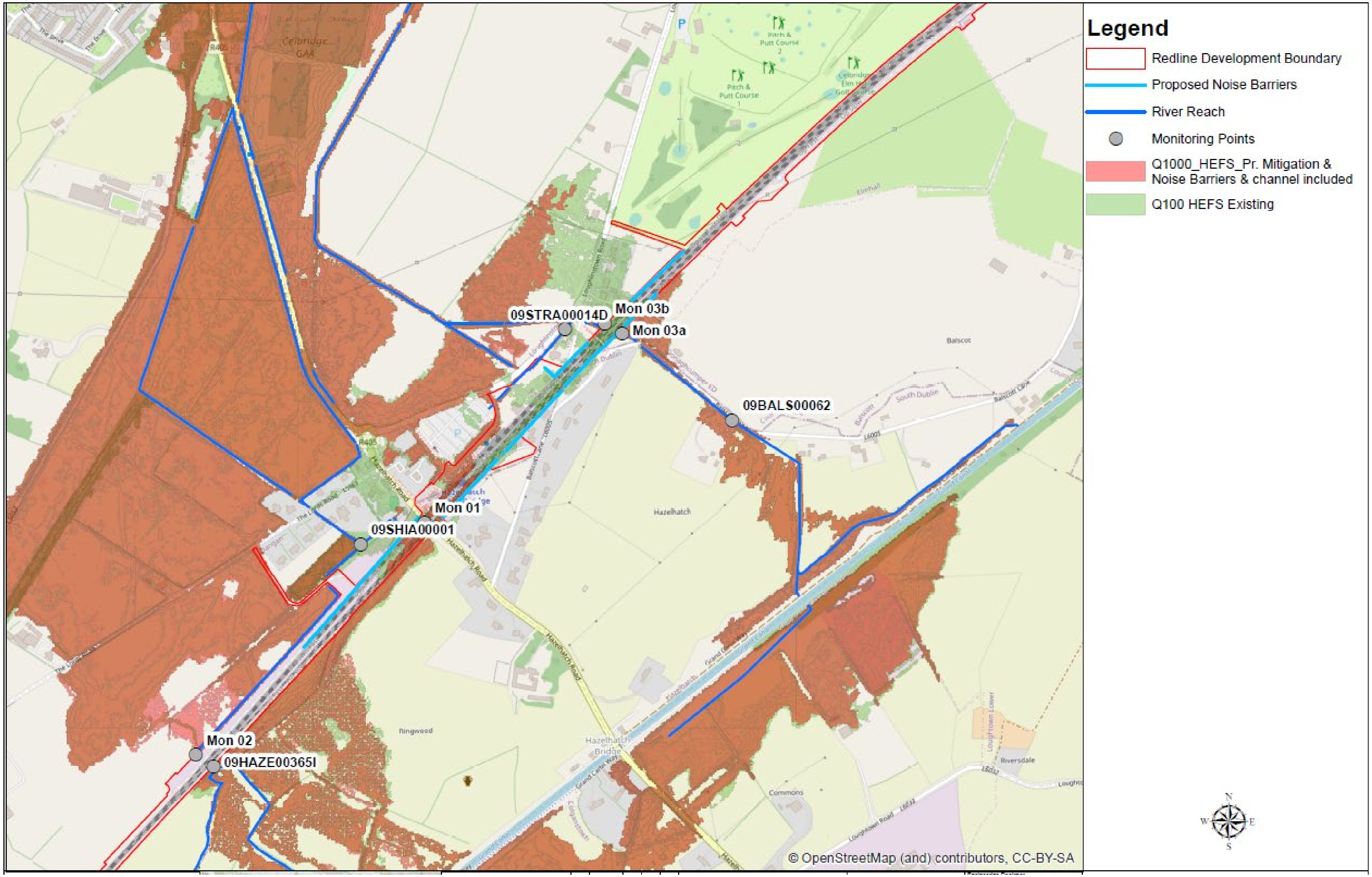

Figure 3 20 Comparison of 0.1% AEP HEFS flooding extents for existing and proposed scenarios (with mitigation measures)

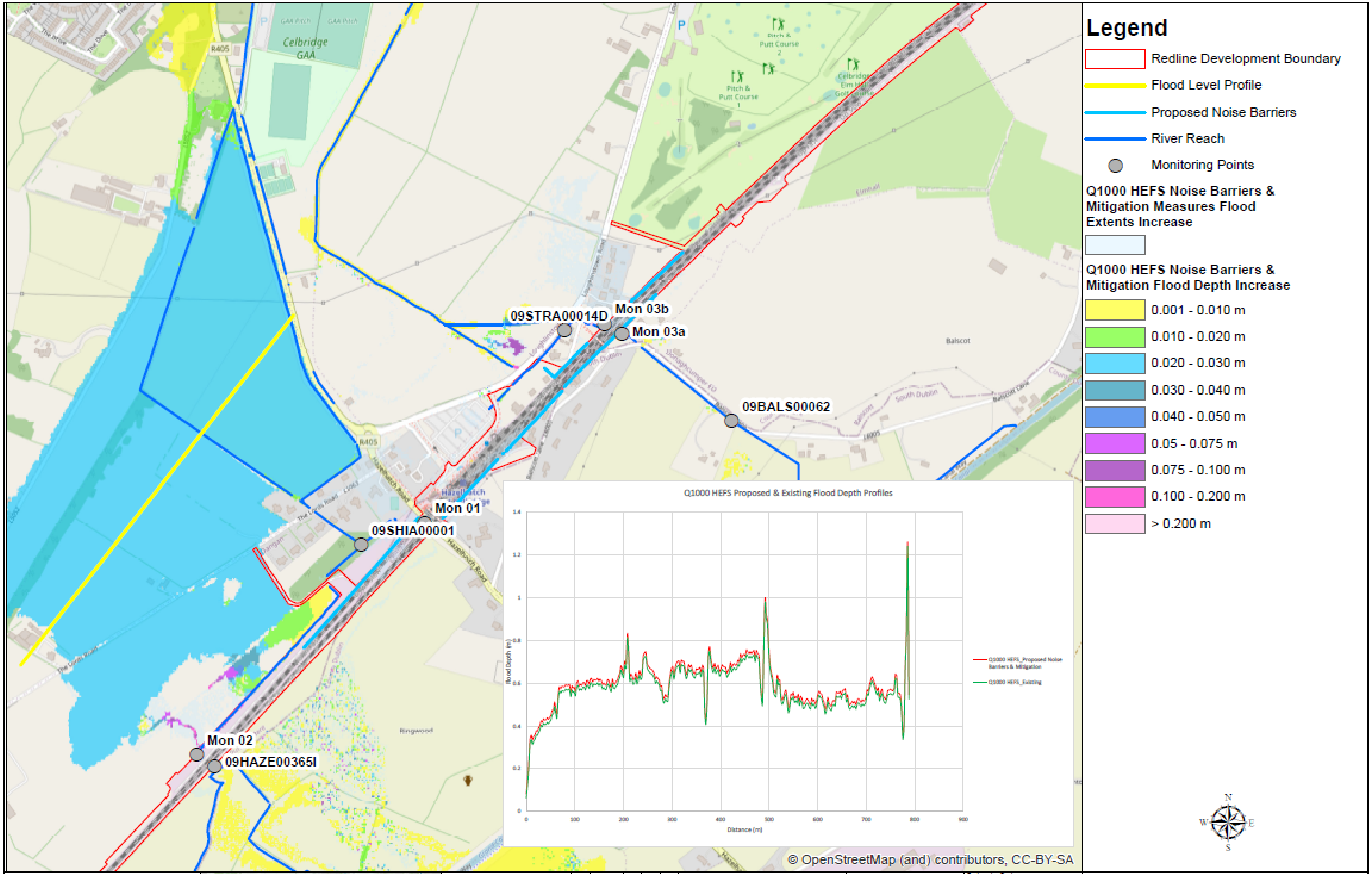

Figure 3 21 0.1% AEP HEFS Flood profile through agricultural land downstream of the station showing increased flooding depth for the proposed scenario (with mitigation measures)

3.4. Adamstown FRA: Stage 1 – Flood Risk Identification

3.4.1. Overview

The section encompasses the area between Hazelhatch and Adamstown

3.4.2. Existing Structures and Facilities

This section of the railway consists of four railway tracks and station platforms. In addition to the railway the existing infrastructure are listed below from west to east:

- Stacumny Road Bridge (OBC21);
- Crowley's Road Bridge (OBC20E) is a four span bridge that carries a third-party road over four railway tracks and Adamstown Avenue;
- Adamstown Station Building (OBC20D) is a two-span bridge that supports the Adamstown Station building over four railway tracks and the station platforms;
- Finnstown R120 Road Bridge (OBC19) is a two-span bridge that carries the R120 road over four railway tracks and Adamstown Avenue;
- Adamstown Footbridge (OBC16A) is a two-span footbridge that carries Haydens Lane over four railway tracks and Adamstown Avenue;

3.4.3. Site Topography

The general topography of the subject area is flat and sloping gently towards the south. The railway is generally at grade or minor cutting throughout the study area. Figure 3-20 and Figure 3-21 show the topography of the site.

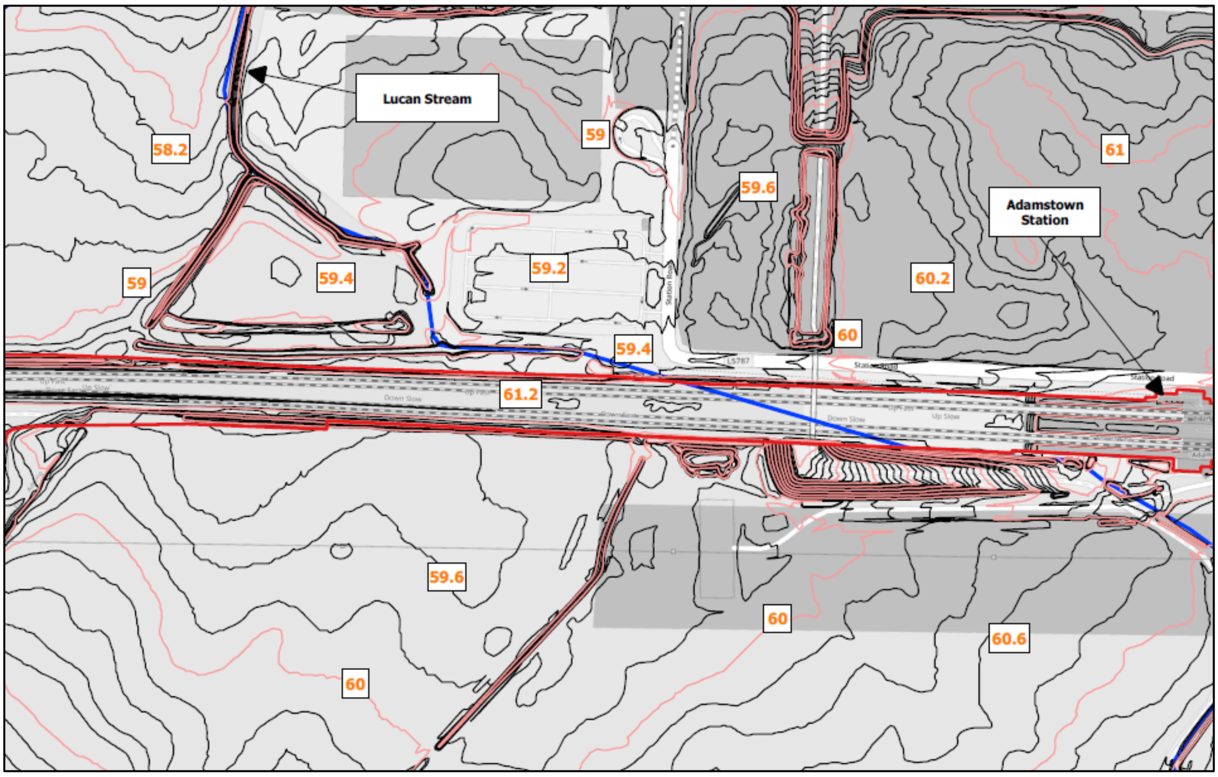

Figure 3-20 Site Topography in the vicinity of Lucan Stream

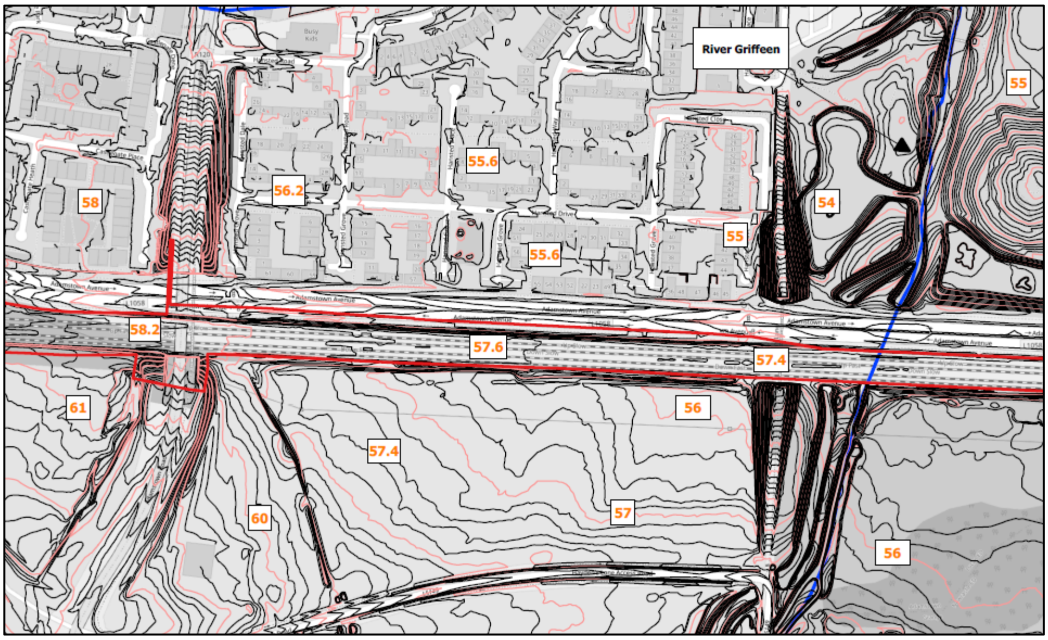

Figure 3-21 Site Topography in the vicinity of River Griffeen

3.4.4. Existing Site Drainage

The railway line traverses the site in an east-west direction and forms a natural constraint to any proposed drainage linking development both north and south of the line. The study area around Adamstown is currently drained by a series of open drains which ultimately discharge to the River Griffeen and the Grand Canal overflow / Camac River. Current outfalls from the site discharge into several primary surface water networks adjacent to the site (Figure 3-22 and Figure 3-23). No records from the Conneyburrow Stream were available from the IW GIS Database at the time of the assessment.

No track drainage structures are proposed for this area. The drainage catchments of the railway track remain as existing, and therefore, no additional drainage system is required for this section.

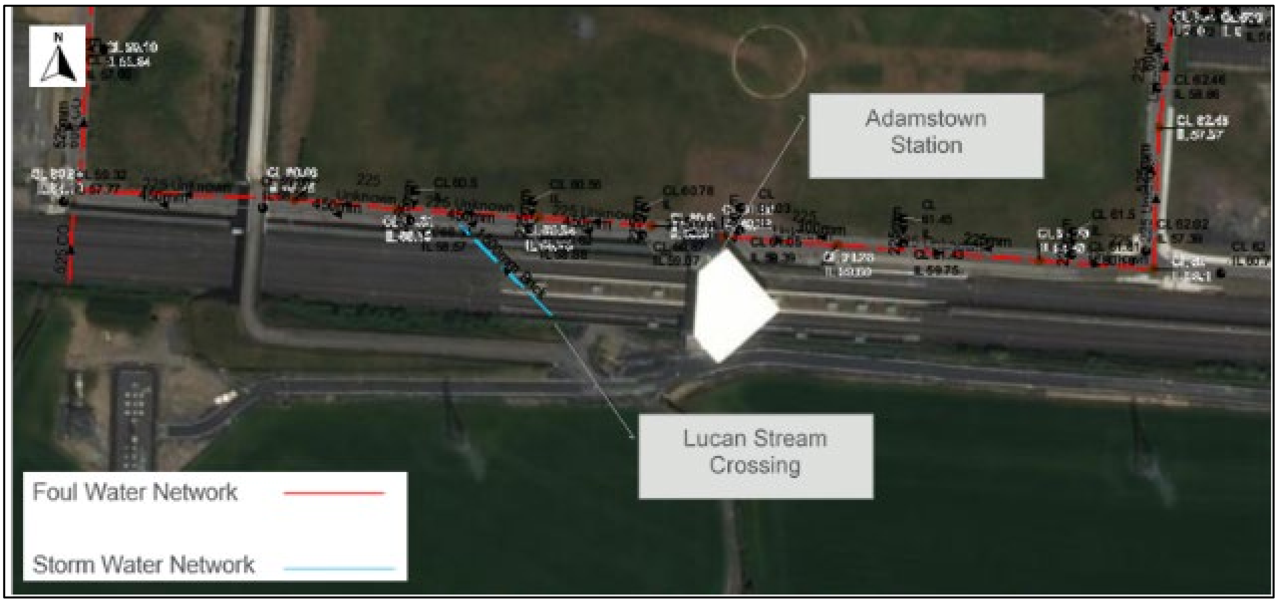

Figure 3-22 IW GIS Database – Storm and Foul Network in the vicinity of Lucan Stream Crossing the Railway

Figure 3-23 IW GIS Database – Storm and Foul Network in the vicinity of River Griffeen Crossing the Railway

3.4.5. The Proposed Development

At Adamstown Station the proposed works require modification to the existing points and crossings (P&C) to fulfil operational requirements, including the removal of an existing connection into the turnback on the central platform, as shown in Figure 3-24. Track to be removed are shown in dashed. Additionally, a new crossover will be provided to the slow lines to the east of Adamstown Station, see Figure 3-25.

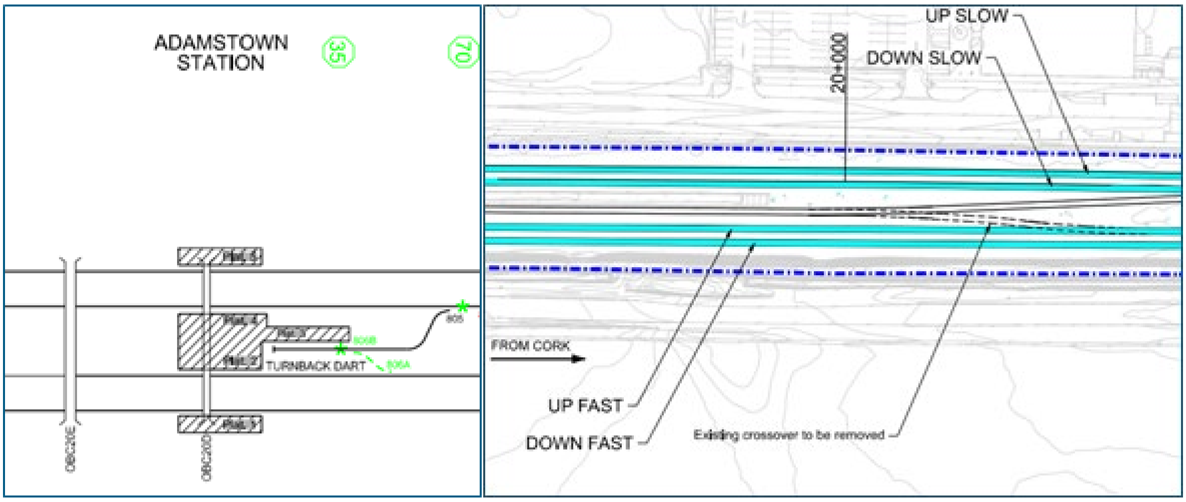

Figure 3-24 Adamstown Station – Track Plan Layout (1 of 2)

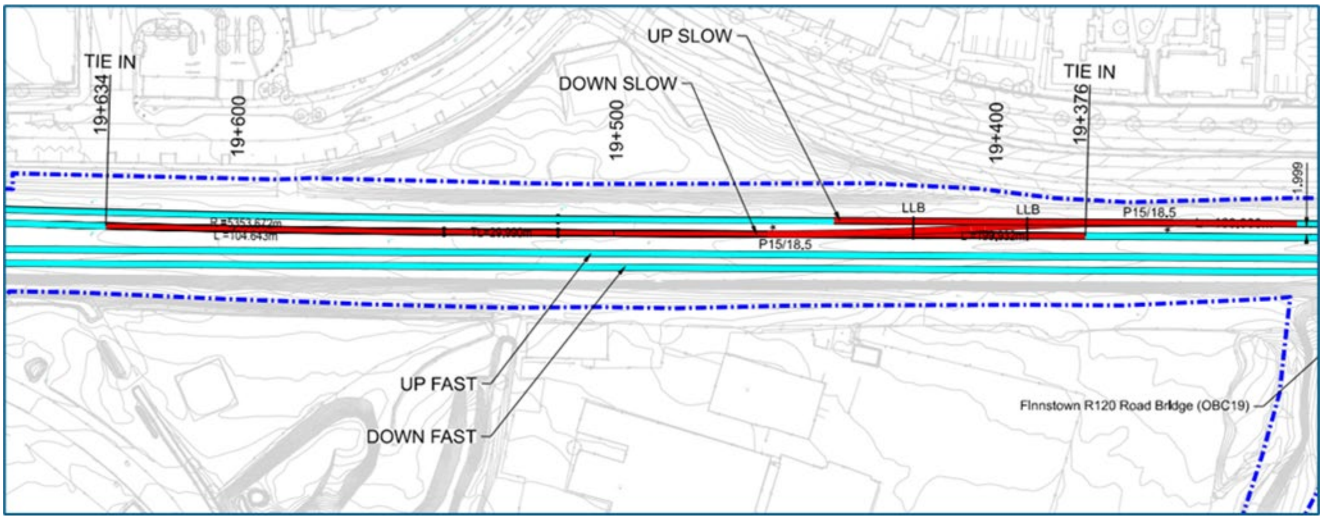

Figure 3-25 Adamstown Station – Track Plan Layout (2 of 2)

A traction power substation is proposed at Adamstown (Figure 3-26). The area is predominantly rural in nature with the exception of the ongoing residential and mixed-use development at Adamstown to the north and east of the study area. The location of the proposed Adamstown Substation is south of the railway in a greenfield site (in CIÉ ownership) and adjacent to an existing access road which joins the public road network at Stacumny Bridge. Currently this track does not have any physical separation (i.e. a fence) from the live railway.

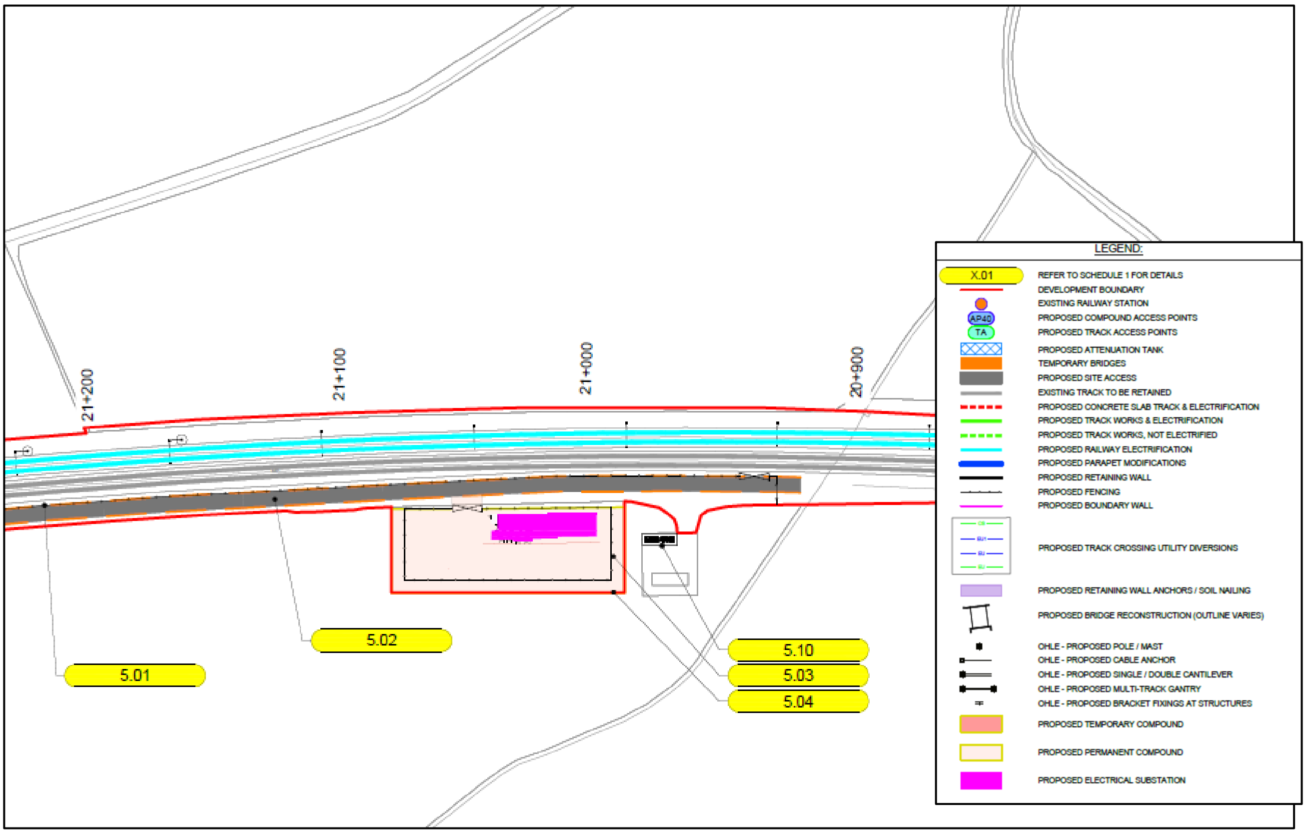

Figure 3-26 Proposed Location of the substation at Adamstown

A new Telecommunications Equipment Room (TER) room is proposed for Adamstown Station. The TER will be located as close to the station as possible and within CIÉ owned property.

3.4.6. Land Use

Lucan Village and its environs has been developed over many years. However, in the decade prior to the November 2000 event a number of major housing developments had commenced in the middle part of the Griffeen catchment. These developments include both the Old Forge and Grange Manor estates. The principal roadways which traverse the catchment are the N4 and the N7 from east to west/southwest. The Grand Canal and the Dublin-Cork rail line are other man-made features of significance.

There is a significant residential development at Adamstown, north of the existing line along Adamstown Avenue. There are several schools adjacent to the existing line on Station Road (L5787): Kishoge Community School; Adamstown Community College; Saint John the Evangelist National School; and Adamstown Castle Educate Together National School. Adamstown is also a Strategic Development Zone (SDZ), as shown in Figure 3-27. The rail corridor then traverses more open greenfield/suburban landscape.

Around the Adamstown area, the landscape character area (LCA) for SDCC indicates these green spaces are part of the Lucan LCA (Suburban South Dublin).

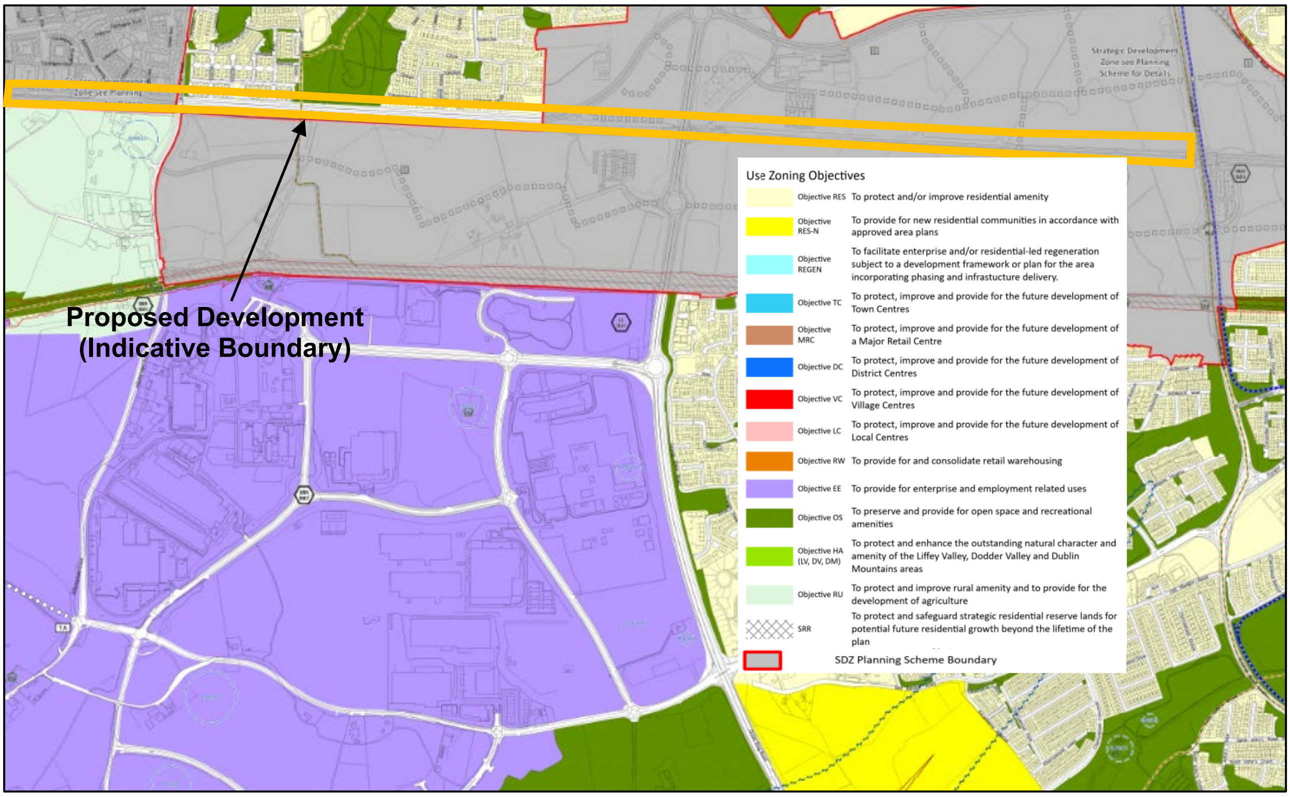

Figure 3-27 Land use map in the vicinity of Adamstown (South Dublin County Development Plan 2022-2028)

3.4.7. Existing Geology and Hydrogeology of the Area

The general superficial geology in the area is anticipated to comprise till overlying bedrock (limestone and shale). Isolated outcrops of limestone and shale at or near the ground surface is noted in places immediately to the east and west of the existing Adamstown Station between Stacumny and the R120 at Adamstown. A pocket of gravel overlying bedrock (limestone and shale) is shown underlying the track at Moorfield.

Shallow bedrock encountered at less than 1.0m bgl was generally encountered between Adamstown and Adamstown Station.

An extract from the GSI website relating to groundwater vulnerability is shown in Figure 3-28.

Figure 3-28 GSI Aquifer Vulnerability Mapping (Source Data and maps - Geological Survey Ireland https://www.gsi.ie)

As indicated, the site is within a catchment where the groundwater vulnerability is considered Extreme. The impact from any development of the subject site will need to consider the groundwater impacts at detailed design stage.

3.4.8. Existing Flood Schemes

3.4.8.1. Griffeen Flood Defence Scheme

The Griffeen River FAS involved both mid-catchment and lower catchment works and was completed in 2005. The scheme provided for the deepening and widening of the Griffeen River channel from the River Liffey to the Grand Canal and provision of culverts under Griffeen Avenue and the railway.

It was initiated in 2003 following major flooding in 2000 and was constructed from 2003 to 2004. The Scheme, that provides protection to the 1 in 100-year Standard of Protection against flooding from the Griffeen River, comprised of:

- The lowering of the river bedrock in Lucan Village,
- The lowering of the horseshoe weir at Vesey Bridge,
- Repointing and raising height of masonry pillars,
- Repointing and raising height of wall in Main Street Lucan.

3.4.8.2. Griffeen River Flood Relief Works

In addition to the works on the River Griffeen, further developer led flood relief measures were completed along the watercourse. The Griffeen River Flood Relief Works initiated in 2003 following severe flooding on 5th/6th November 2000 during which 48 newly occupied houses at Old Forge and Grange Manor were flooded. It was agreed that the developer would carry out the flood relief works. The Scheme, that provides protection against flooding from the Griffeen River, comprised of:

- Widening and deepening the Griffeen River between the Grand Canal to the outlet structure downstream of Griffeen Avenue so as to convey a flood flow of 25m3 /s.
- Installation of gabion protection along riverbank at Lucan Pitch and Putt Club.
- New culverts under Hayden’s Lane, the railway, and Griffeen Avenue.

- The construction of 1 vehicular bridge and 5 pedestrian bridges.

3.4.8.2.1. Adamstown Link Road Scheme

The Adamstown Link Road scheme included 2 offline storm water retention ponds in Griffeen Park (Figure 3-29), providing protection to the 1 in 100-year Standard of Protection against flooding from the Griffeen River.

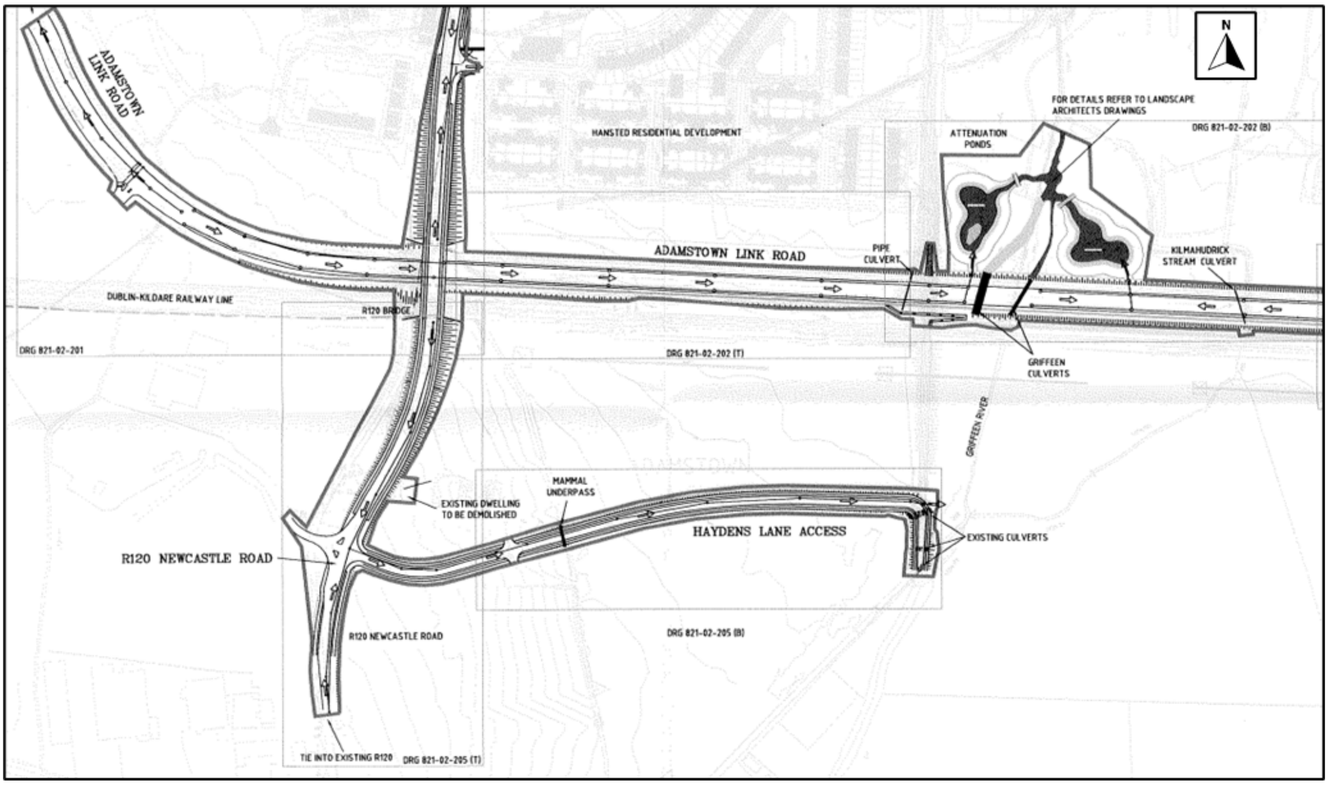

Figure 3-29 Overall Drainage Layout - Adamstown Link Road Scheme

3.4.8.3. Flood Retention Pond at Greenogue Industrial Estate

The Greenogue Industrial Estate development includes a flood attenuation pond. Flow from the Griffeen River spills into the attenuation pond which is located to the south of the railway route and the Grand Canal. The ‘Pond Outlet' was represented in the CFRAM hydraulic model as an outlet pipe linking the attenuation pond upstream of Greenogue Business Park back into the Griffeen River.

3.4.8.4. SFRA for SDCC Development Plan 2022-2028

The subject lands are zoned as ‘RES-N’ under the 2022 – 2028 Development Plan. A review of the ECFRAM flood zones shows an overlap with Flood Zone A and B extents. Climate change scenarios are not currently available for the Griffeen. Using Flood Zone B as a climate change indicator would show an increase in the 1% flood extent upstream of the railway line. RES-N is a highly vulnerable land use, and a Justification Test has been applied. A FRA of appropriate detail should accompany applications for development on this site to demonstrate that they would not have adverse flood risk impacts.

The Development Plan outlines planning requirements for this site including:

- A minimum of 14% public open space as part of a residential development
- A setback of development from the Griffeen River and

- Development of this site will be in accordance with an SD Planning Scheme or a RES-N Zoning.
- It is considered that the future development of the zoned land should be subject to a FRA in preparation of the approved plan, the application of the sequential approach in the land use strategy of the approved plan and appropriate assessment at planning application stage.

3.4.8.5. Clonburris SDZ Planning Scheme, SFRA & Surface Water Management Strategy

A small encroachment into Flood Zone B shown in Figure 3-30 is likely for the provision of attenuation to cater for Adamstown Extension. The encroachment is mitigated by a proposed flood compensation storage area located within Griffeen Park, Figure 3-31 below.

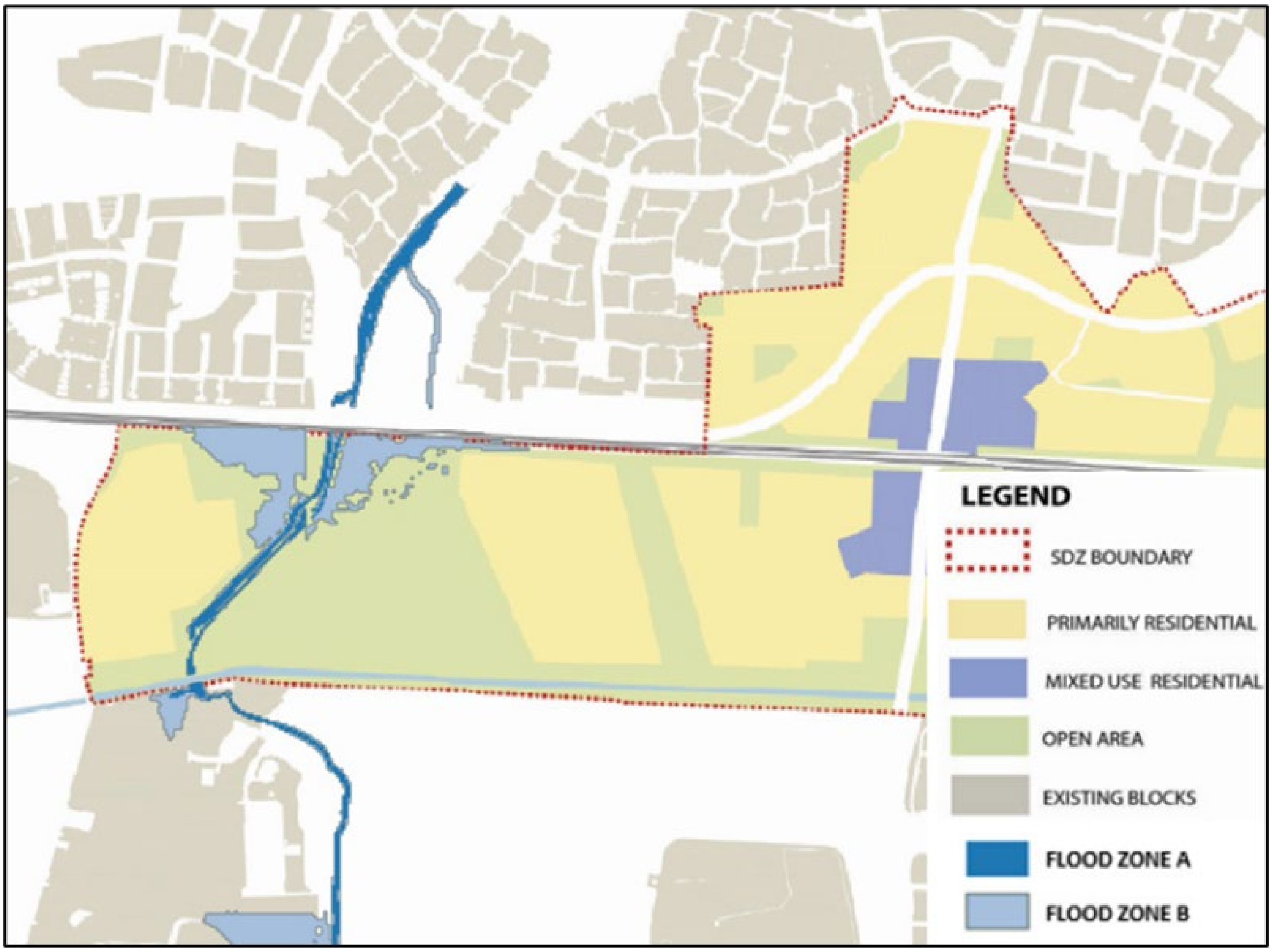

Figure 3-30 Proposed Land Uses and Flood Zones

Figure 3-31 Strategic Drainage Approach to Adamstown Extension

3.4.9. Salient Hydrological Features and Existing Flood Regime of the Area

The salient hydrological features, the impacts of which were assessed for flood risk, are the Conneyburrow Stream, the Lucan and the Griffeen. Reports and maps from the OPW Flood Hazard Mapping website (www.floodmaps.ie) have been examined as part of this FRA as presented in Figure 3-32. There are no previous flood events recorded in the vicinity of the Conneyburrow and the Lucan Streams in the vicinity of the study area.

However, there are records of two previous flood events, northwest and northeast of the site, associated with flooding from the Griffeen.

Serious flooding occurred on the 5th and 6th November 2000 in the lower reach of the Griffeen River. A considerable number of properties in the Griffeen Valley Park and Lucan Village were flooded during this event. Previous flooding in Lucan Village had occurred on the 11th and 12th June 1993 and to a lesser extent during Hurricane Charlie on the 25th/26th August 1986.

The flooding was caused by a lack of capacity in the culvert under Haydens Lane, causing flooding left of the River Griffeen. This floodwater then flowed North through a railway underpass, and onto Haydens Lane. Since the flood event of November 2000, channel capacity has been improved, a second culvert has been constructed under Haydens Lane and the Railway underpass which acted as a flow path for floodwater has been closed off. A new road has been constructed parallel to the railway line, but a second culvert to convey flow on the Griffeen River under the road and railway has been constructed. Overall, these remedial measures were found to be effective, but this flood event could not be used for model calibration due to the significant changes to the flow regime in this area.

Wet antecedent conditions preceded the flood event with 20mm of rainfall being recorded on the 2nd of November, three days prior to the flood. Such antecedent wetness conditions may have contributed to increased soil moisture levels and hence increased storm runoff (J.B. Barry & partners, 2001). The autographic rainfall recorder at Casement Aerodrome (Baldonnel Aerodrome) located in the Griffeen catchment, indicated a total rainfall depth of 84mm (70year return period) over a 24hour period and 58mm (25year) in a 12hour period. At Dublin Airport 66mm of rain fell (30yr return period) and at Glenasmole (Castlekelly) 137.2mm was recorded (approx. 100year event, 186mm was recorded at the same gauge during Hurricane Charlie).

The June 1993 event produced 108.6mm of rainfall in just over 24hours at Casement setting new records: 12hour rainfall – a return period of over 100 years 24hour rainfall – a return period of 250 years. The fact that the November 2000 storm produced greater flooding than in 1993 is probably due to the antecedent wetness conditions in the catchment leading up to the storm event.

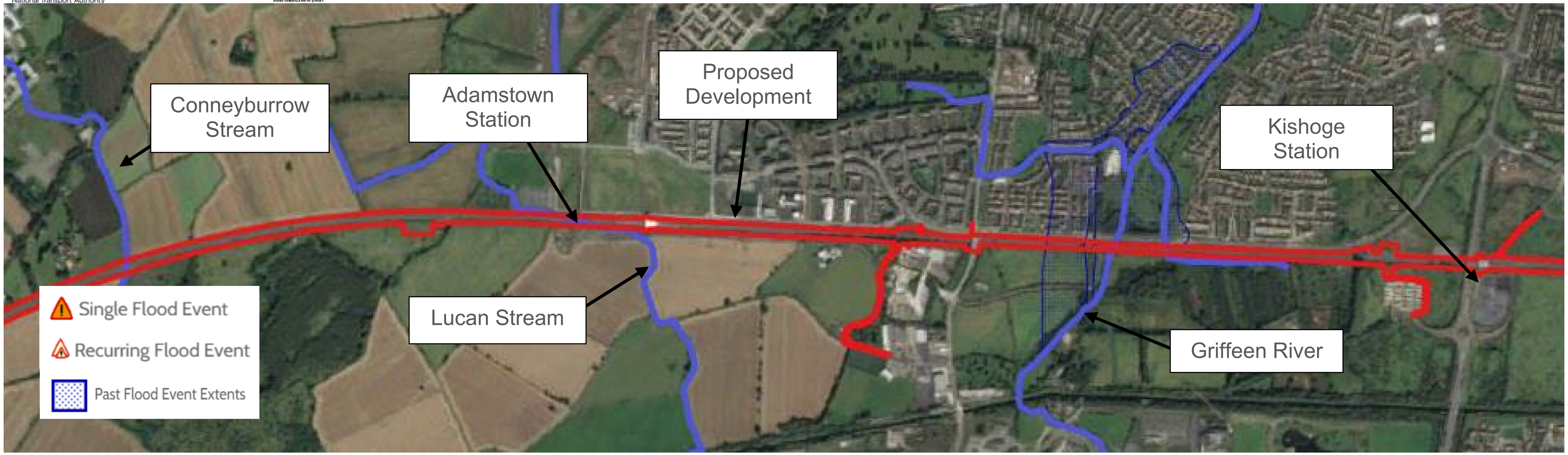

Figure 3-32 Historic flood extent from floodmaps.ie

3.4.10. Results of the previous flood studies

3.4.10.1. Fluvial Flood Risk - Eastern CFRAM Study (HA09), 2017

The Eastern CFRAM fluvial flood extent map is presented in Figure 3-33 and Figure 3-34. Flood levels are shown in Table 3.13 and Table 3.14. The predicted flood extents for three separate return period events are presented on the map: 1 in 10, 100, and 1000 year for the River Griffeen and Lucan Stream. There are no flood maps produced for the Conneyburrow Stream as part of the CFRAM Study. It can be seen on the map that the proposed works lies outside the extent of all three fluvial events of the Lucan Stream but is located with the 0.1% AEP Fluvial Event for River Griffeen.

Table 3.13: Node details – Griffeen fluvial flood extent map

Node Point	Flood Levels – Current Scenario		
	10%AEP	1%AEP	0.1%AEP
09GRIF00309	52.61	52.81	53.13
09GRIF00307D	52.50	52.71	53.04
09GRIF00305	52.43	52.62	52.92
09GRIF00376aJ	58.59	58.83	59.34
09GRIFB00009	56.38	56.54	56.88

Table 3.14: Node details – Lucan fluvial flood extent map

Node Point	Flood Levels – Current Scenario		
	10%AEP	1%AEP	0.1%AEP
09TOWN00326I	59.22	59.36	59.66
09TOWN00248	55.34	55.43	55.56
09TOWN00194J	47.37	47.49	47.61

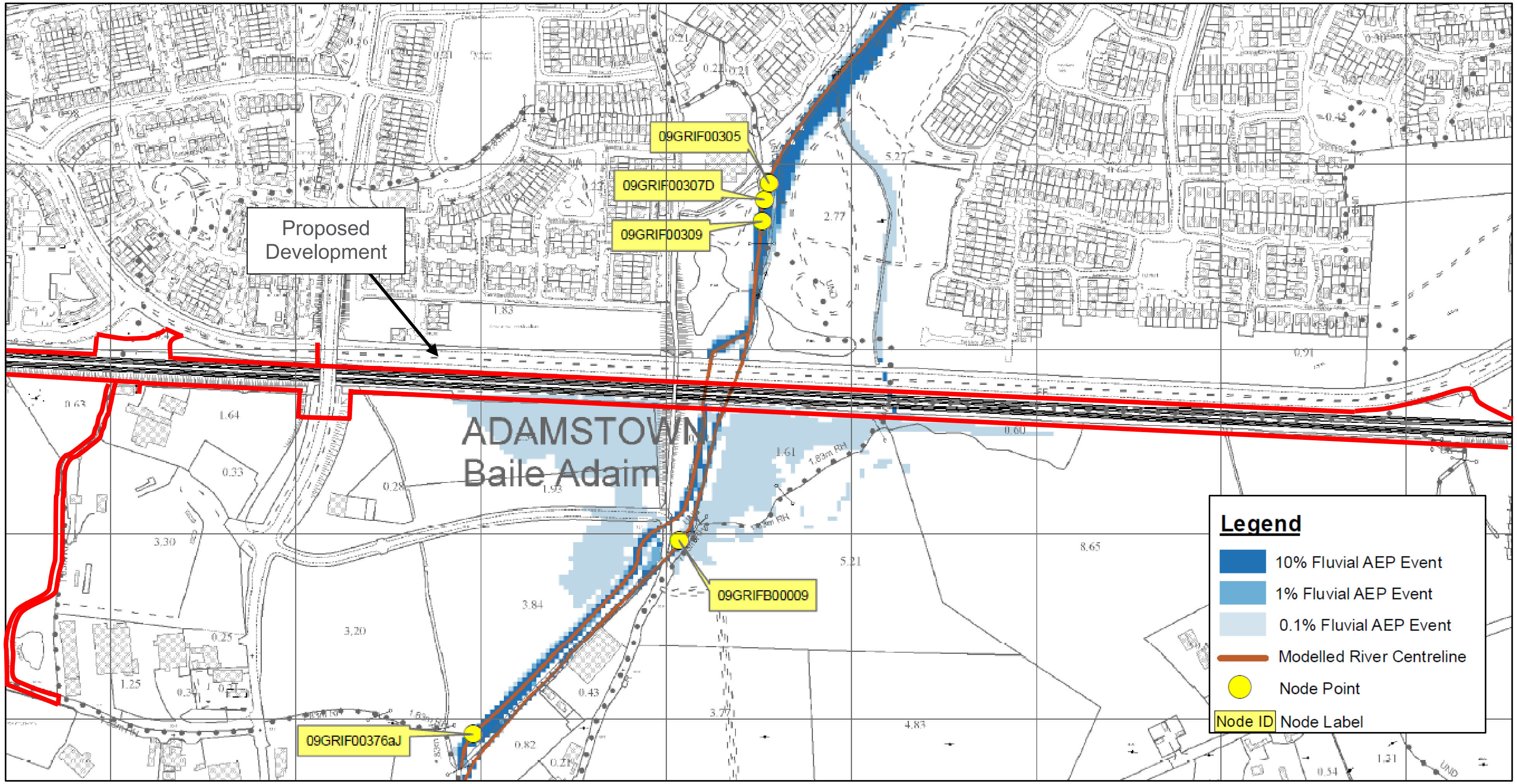

Figure 3-33 ECFRAM Study - Adamstown (West) Fluvial Flood Extents

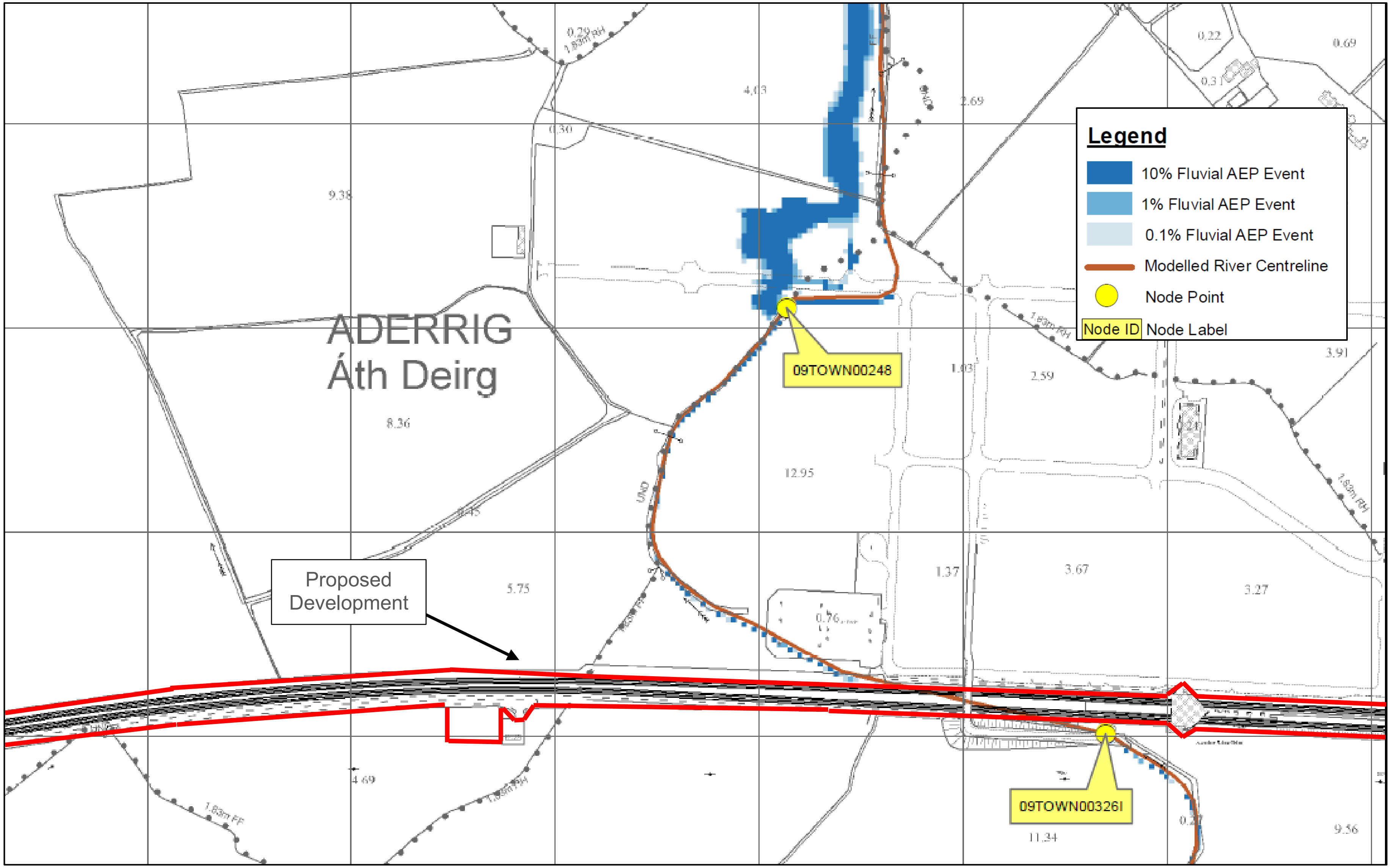

Figure 3-34 ECFRAM Study - Adamstown (East) Fluvial Flood Extents

3.4.10.2. Pluvial Flood Risk - PFRA Flood Maps

The OPW PFRA study provides a national level pluvial screening of areas that are at potential risk of pluvial flooding. The national PFRA maps can be used to identify areas that may be at risk and that may require a pluvial flooding assessment to be carried out for planning applications. The study area is not located within any of the zoning extents shown in Figure 3-35 below. As such, the risk from extreme rainfall events is considered low, which locates the site in **Flood Zone C**.

Figure 3-35 PFRA Indicative Pluvial Zone Mapping

3.4.11. Conclusion of Stage 1 – Flood Risk Identification

Records of historical flooding, the flood extent mapping generated for the study area, and other records outlined in the preceding sections indicated that the Proposed Development is potentially at risk from fluvial flooding and to a lesser extent from pluvial flooding. Therefore, the FRA was progressed to STAGE 2 – INITIAL FLOOD RISK ASSESSMENT.

3.5. Adamstown FRA: Stage 2 – Initial Flood Risk Assessment

3.5.1. Sources of Flood Risk

The purpose of the Stage 2 - Initial FRA was to appraise the availability and adequacy of the identified flood risk information, to qualitatively appraise the flood risk posed to the site and potential impacts on flood risk elsewhere and recommend possible mitigation measures to reduce the risk to acceptable level. In consideration of the above assessment, the primary flood risk to the Proposed Development was attributed to:

- Fluvial – High Risk; and
- Pluvial– Low Risk.

3.5.2. Flood Risks and Flood Zone Mapping Summary

As discussed in Section 3.4.10, the most significant source of fluvial flooding based on the ECFRAM Studies is from River Griffeen, which locates the site in **Flood Zone B,** given that the site boundaries are within the 1 in 1,000-year flood event extent.

The study area's potential for pluvial flooding based on the PFRA mapping is considered low, which locates the site in **Flood Zone C**.

3.5.3. Conclusion of Stage 2 – Initial Flood Risk Assessment

The FRA for the development should demonstrate that finished floor levels of the buildings proposed as part of the development to be designed for the 0.1% AEP (1 in 1000 year) flood level plus an allowance for climate change and a minimum freeboard of 500mm. The new Adamstown Substation and the new TER are proposed in the vicinity of the Lucan Stream crossing where a 1D hydraulic model will be built to investigate the flood and protection levels.

The FRA shall also examine residual risk associated with culvert blockages at the watercourse crossing locations and ensure development does not block flow paths and increase flood risk elsewhere. This is mostly relevant to the Griffeen River location, where the site boundaries of the proposed Development were identified to be within the extents of Flood Zone B, susceptible to a fluvial flood risk and hence a further assessment of the implications to the proposed site and surrounding areas is necessary.

Therefore, a 1D/2D hydraulic model was built to assist the quantitative assessment of the flood levels and the impact of the mitigation measures (if required) along the Griffeen flood extents in the study area.

The protection levels proposed have not been investigated using hydraulic modelling therefore, the FRA was progressed to Stage 3 – Detailed Flood Risk Assessment to improve the accuracy of these levels and to assess the residual impact of the proposed mitigation measures on the predicted 0.1% AEP event flood extents in the surrounding area.

3.6. Adamstown FRA: Stage 3 – Detailed Flood Risk Assessment

3.6.1. Overview

The objective of the detailed assessment is to identify locally predicted flood levels for the proposed Development and also to assess the potential impact of the proposed mitigation measures. The proposed measures may displace flood waters and adversely impact the site itself or the surrounding area.

3.6.2. Hydrology

3.6.2.1. Existing Study

A previous hydrological analysis for the study area was undertaken as part of the Eastern CFRAM Study. The Eastern CFRAM employed statistical analysis of gauged AMAX flows, supplemented by the OPW FSU techniques, as the hydrological methodology for developing peak design flows. This selected hydrological methodology relies on analysis of recorded flow and level data, and the FSU regression equation for Qmed where no such recorded data is available (adjusted by recorded data from representative gauged catchments where appropriate).

A more comprehensive description of the CFRAM hydrological methodology for the study area and the FSU hydrological methodologies area presented in the Eastern CFRAM Study Hydrology Report Unit of Management 9 Final Report[7] and the FSU Technical Research Reports[8] respectively.

The CFRAM Study identified flood extents and flood levels will be used to calibrate the hydraulic model of this FRA.

3.6.2.2. Catchment Review

The catchments were reviewed and updated using GIS based tools as previously detailed in Section 2.6.1. The updates were checked against aerial imagery and historical OSI mapping. The updates were checked against aerial imagery and historical OSI mapping. The defined catchments are shown in Figure 3-36.

3.6.2.3. Peak Flows Estimation

The design flows estimation employed FSU and UK IH techniques to predict flood discharges at various locations across the modelled extents. These methodologies are previously detailed in Section 2.6.2.2.

3.6.2.3.1. Pivotal Site Adjustment

Analysis was undertaken to identify the adjustment factor for both the Lucan Stream and Griffeen River. For the Adamstown FRA the Lucan gauging station (9002) is located downstream of the model extents along the Griffeen River. For the Lucan stream there is no gauging station along its length. Station details are shown in Table 3.15 and a plot of the AMAX data is shown in Figure 3-37 below. Adjustment factors for each HEP in the FRA were also calculated using the mean value of adjustment factors of five hydrological similar gauged catchments using method of which is previously described in Section 2.6.2.2.

All HEPs in the Adamstown FRA have been adjusted by the mean value of adjustment factors of five hydrological similar gauged catchments. The HEPs along the Griffeen River have not been adjusted by the Lucan gauge as the mean adjustment factor from hydrological similar stations is more conservative.

[7] Eastern CFRAM Study Hydrology Report Unit of Management 9 Final Report available at https://www.floodinfo.ie/
[8] Flood Studies Update Technical Research Report Volumes available at https://opw.hydronet.com/default.aspx?page=1

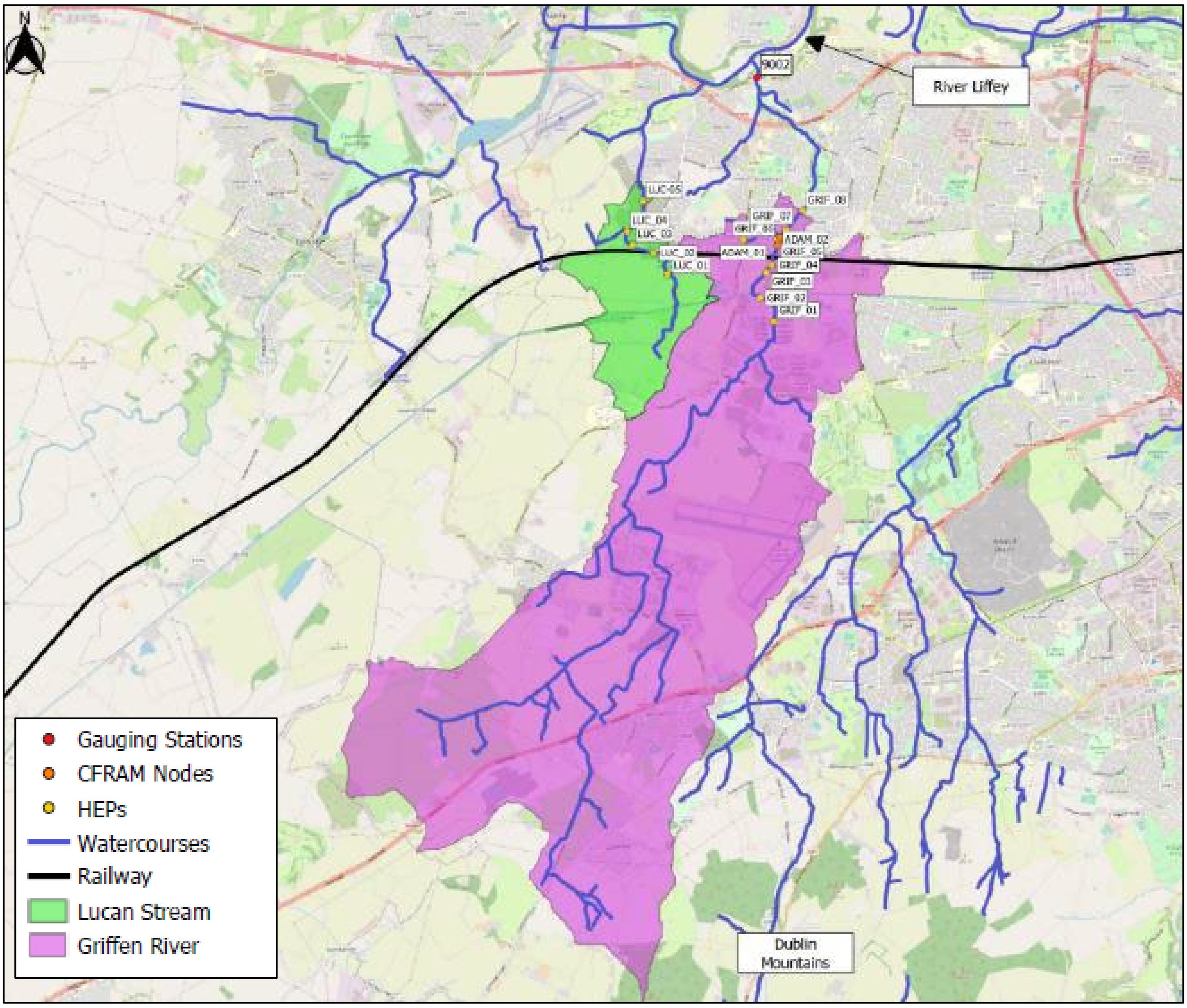

Figure 3-36 Adamstown FRA Catchments and HEP locations

Table 3.15: Hydrometric Gauging station record considered for hydrological analysis

Station No.	Station Name	Catchment Area (km^2)	Operator	Record Length	Record End	Data	FSU Quality Rating
9002	Lucan	35	EPA	38 years (1977 – 2018) (Data missing 1999, 2002, 2003 & 2013)	-	WL & Flow	-

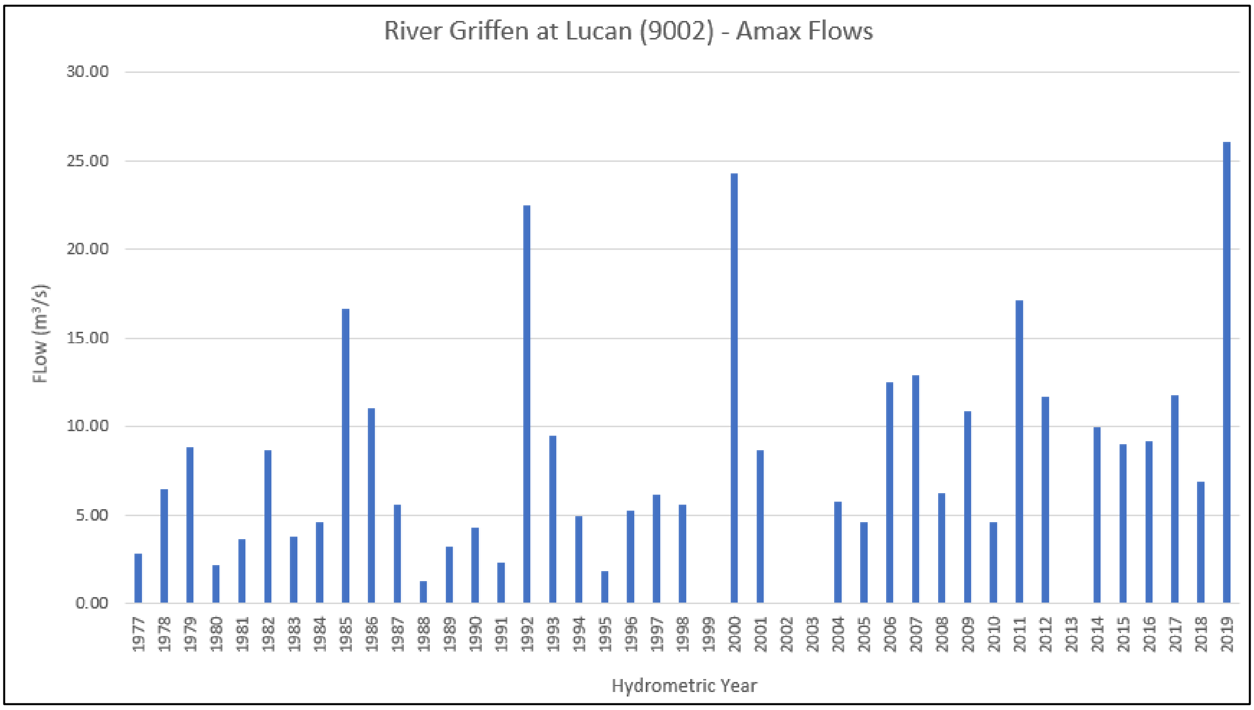

Figure 3-37 Frankfort Bridge (9011) – AMAX Record

3.6.2.3.2. Urban Adjustment

UAFs were applied using the same methodology as shown in Section 2.6.2.2.

3.6.2.3.3. Growth Factor/Curve Development

Growth curves and growth factors were defined as per the methodology described in Section 2.6.2.3.

3.6.2.3.4. Design Hydrographs

Growth curves and growth factors were defined as per the methodology described in Section 2.6.2.4. HEPs in this study were adjusted using the observed flood hydrographs at the stations listed in Table 3.16.

Table 3.16: Design Hydrograph Method Pivotal Sites Adjustment

Watercourse	Gauging Station
Griffeen River	Whitebridge (22009)
Adamstown Stream	Johns Bridge (15002)
Lucan Stream	Ballinaclogh (16006)

3.6.2.4. Physical Catchment Descriptors

Table 3.17 shows the PCD values associated with all HEPs identified in the study area, as shown in Figure 3-36.

Table 3.17: PCD values for HEPs

Watercourse	HEP	AREA (km^2)	SAAR (mm)	URBEXT	SOIL	BFISOIL	DRAIND (km/km^2)	S1085 (m/km)	ARTDRAIN2
Griffeen	GRIF_01	23.396	766	0.290	0.321	0.674	1.088	11.694	0.000
Griffeen	GRIF_02	25.382	762	0.317	0.320	0.635	1.020	11.157	0.000
Griffeen	GRIF_03	25.599	762	0.318	0.319	0.635	1.030	10.867	0.000
Griffeen	GRIF_04	25.934	761	0.318	0.319	0.636	1.022	10.768	0.000
Griffeen	GRIF_05	26.027	761	0.320	0.319	0.636	1.032	10.623	0.000
Griffeen	GRIF_06	26.430	761	0.329	0.319	0.638	1.057	10.643	0.000
Griffeen Trib	GRIF_06a	0.855	720	0.373	0.300	0.639	0.788	4.740	0.000
Griffeen	GRIF_07	27.333	760	0.331	0.318	0.639	1.053	10.571	0.000
Griffeen	GRIF_08	27.476	760	0.333	0.318	0.639	1.060	10.392	0.000
Adamstown	ADAM_01	0.286	741	0.829	0.300	0.539	1.699	2.363	0.000
Adamstown	ADAM_02	0.404	741	0.873	0.300	0.624	2.651	0.682	0.000
Lucan	LUC_01	1.535	723	0.089	0.300	0.623	0.943	6.663	0.000
Lucan	LUC_02	2.509	725	0.059	0.300	0.623	0.753	7.269	0.000
Lucan	LUC_03	2.600	725	0.101	0.300	0.623	0.850	6.214	0.000
Lucan	LUC_04	2.753	725	0.099	0.300	0.594	1.162	5.656	0.000
Lucan	LUC_05	3.067	726	0.150	0.300	0.624	1.227	5.379	0.000

3.6.2.5. Design Peak Flows

3.6.2.5.1. Index Flood Flows

Qmed Estimates

The Index-floods, Qmed, for all HEPs have been estimated in accordance with the methodology discussed in Section 2.6.2.2.1. Table 3.18 below presents the estimated Qmed & Qbar values.

Table 3.18: HEPs – PCD based Qmed & Qbar estimates

HEP	FSU PCD Qmed-rural (m^3/s)			IH124 Qbar (m^3/s)	FSU PCD -Qmed-urban (m^3/s)			IH124 Qbar Urban (m^3/s)
	7-Var	5-var	3 Var		7-Var	5-var	3 Var	
GRIF_01	3.23	4.69	2.94	3.60	4.72	6.84	4.29	7.46
GRIF_02	3.56	5.24	3.44	3.80	5.35	7.89	5.17	8.39
GRIF_03	3.58	5.25	3.46	3.83	5.38	7.90	5.21	8.45
GRIF_04	3.60	5.29	3.49	3.86	5.41	7.96	5.25	8.53
GRIF_05	3.61	5.29	3.50	3.87	5.45	7.98	5.28	8.59
GRIF_06	3.68	5.34	3.52	3.92	5.60	8.14	5.36	8.85
GRIF_06a	0.11	0.17	0.19	0.15	0.17	0.27	0.31	0.40
GRIF_07	3.78	5.49	3.61	4.01	5.77	8.38	5.51	9.11
GRIF_08	3.79	5.49	3.63	4.02	5.80	8.40	5.55	9.20
ADAM_01	0.05	0.06	0.10	0.06	0.13	0.15	0.26	0.34
ADAM_02	0.06	0.06	0.11	0.08	0.15	0.14	0.28	0.50
LUC_01	0.21	0.33	0.33	0.26	0.24	0.37	0.37	0.34

HEP	FSU PCD Qmed-rural (m^3/s)			IH124 Qbar (m^3/s)	FSU PCD -Qmed-urban (m^3/s)			IH124 Qbar Urban (m^3/s)
	7-Var	5-var	3 Var		7-Var	5-var	3 Var	
LUC_02	0.32	0.53	0.50	0.40	0.35	0.57	0.54	0.48
LUC_03	0.34	0.52	0.51	0.41	0.39	0.60	0.59	0.56
LUC_04	0.41	0.56	0.58	0.43	0.47	0.65	0.66	0.58
LUC_05	0.43	0.59	0.59	0.48	0.53	0.72	0.72	0.74

Table 3.19 presents the PCD details and observed Qmed for the pivotal site 9002 which is the closet gauged catchment to the study area. The adjustment factor for this station based on the FSU 7variable equation is 1.06, however as detailed in Section 3.6.2.3.1 it has not been selected as the pivotal site for HEPs.

Table 3.19: HEPs - Pivotal Site PCD values

Pivotal Site	Area (km2)	SAAR (mm)	URBEXT	BFIsoil	DRAIND (km/km2)	S1085 (m/km)	ARTDRAIN2	Obs Qmed (m^3/s)	Obs Qbar (m^3/s)
9002	32.67	796	0.475	0.672	1.177	13.82	0.000	6.34	8.09

Table 3.20 presents the estimated adjustment factors for the HEPs based on the mean values of adjustment factors from five hydrological similar gauged catchments.

Table 3.20: Mean Adjustment Factor from Hydrological Similar Gauged Catchments

HEP	Best Performing Hydrological Equation	Recommended Adjustment Factor
GRIF_01	QMED (m3/s) 7 Variable	1.121
GRIF_02	QMED (m3/s) 7 Variable	1.121
GRIF_03	QMED (m3/s) 7 Variable	1.121
GRIF_04	QMED (m3/s) 7 Variable	1.121
GRIF_05	QMED (m3/s) 7 Variable	1.121
GRIF_06	QMED (m3/s) 7 Variable	1.121
GRIF_06a	3 Var	1.036
GRIF_07	QMED (m3/s) 7 Variable	1.121
GRIF_08	QMED (m3/s) 7 Variable	1.121
ADAM_01	3 Var	1.036
ADAM_02	3 Var	1.036
LUC_01	3 Var	1.036
LUC_02	IH124 Qbar	0.918
LUC_03	IH124 Qbar	0.918
LUC_04	3 Var	1.068
LUC_05	IH124 Qbar	0.918

Design Index Floods

Table 3.21 presents the adjusted Qmed values for all the HEPs selected on the proposed model watercourse.

Table 3.21: Estimated Design Index-floods

HEP	Method	Qmed (m^3/s)
GRIF_01	QMED (m3/s) 7 Variable	5.288
GRIF_02	QMED (m3/s) 7 Variable	5.994
GRIF_03	QMED (m3/s) 7 Variable	6.033
GRIF_04	QMED (m3/s) 7 Variable	6.067
GRIF_05	QMED (m3/s) 7 Variable	6.106
GRIF_06	QMED (m3/s) 7 Variable	6.279
GRIF_06a	3 Var	0.322
GRIF_07	QMED (m3/s) 7 Variable	6.460
GRIF_08	QMED (m3/s) 7 Variable	6.502
ADAM_01	3 Var	0.265
ADAM_02	3 Var	0.292
LUC_01	3 Var	0.387
LUC_02	IH124 Qbar	0.438
LUC_03	IH124 Qbar	0.510
LUC_04	3 Var	0.709
LUC_05	IH124 Qbar	0.678

3.6.2.5.2. Growth Factors / Curves Estimation

Using the selection guidelines for growth curves as detailed in Section 2.6.2.3, it is recommended to use a pooled analysis growth curve. A GEV distribution was chosen as it produced the most appropriate curve. The selected growth factors are shown in Table 3.22.

Table 3.22: Design Growth Factors

HEP	Growth Factors	
	1%AEP	0.10%AEP
GRIF_01	2.574	2.988
GRIF_02	2.583	2.988
GRIF_03	2.583	2.988
GRIF_04	2.583	2.988
GRIF_05	2.583	2.988
GRIF_06	2.583	2.988
GRIF_06a	2.543	3.340
GRIF_07	2.583	2.988
GRIF_08	2.583	2.988
ADAM_01	2.775	3.620
ADAM_02	2.775	3.328
LUC_01	2.543	3.284
LUC_02	2.543	3.284
LUC_03	2.543	3.284
LUC_04	2.543	3.342
LUC_05	2.543	3.284

3.6.2.6. Estimated Peak Flows

Table 3.23 presents the estimated design peak flows for all HEPs selected on the proposed model watercourse for a 1% and 0.1% AEPs. This has been estimated as the product of Qmed (Index-flood) and the value of the growth factor associated with any of the AEPs.

Table 3.23: Estimated Design Peak Flows

HEP	Peak Flows (m³/s)	
	1% AEP	0.10 % AEP
GRIF_01	20.721	24.054
GRIF_02	23.822	27.557
GRIF_03	23.982	27.742
GRIF_04	24.120	27.902
GRIF_05	24.293	28.101
GRIF_06	25.059	28.988
GRIF_06a	1.287	1.690
GRIF_07	25.803	29.849
GRIF_08	25.993	30.068
ADAM_01	1.293	1.687
ADAM_02	1.437	1.724
LUC_01	1.360	1.756
LUC_02	1.390	1.800
LUC_03	1.654	2.142
LUC_04	2.503	3.290
LUC_05	2.245	2.908

3.6.2.6.1. CFRAM & FRA Design Flow Comparisons

Table 3.24 shows a comparison between the CFRAM and FRA derived design flows. The FRA design flows for 1% AEP are slightly lower but for the 0.1% AEP they are much lower. The CFRAM nodes can be seen on Figure 3-36.

Table 3.24: CFRAM & FRS Design Flow Comparisons

CFRAM Node	CFRAM 1% AEP (m³/s)	CFRAM 0.1%AEP (m³/s)	FRA 1% AEP (m³/s)	FRA 0.1% AEP (m³/s)
09GRIF00309	13.36	23.55	15.77	18.24
09GRIF00305	16.96	31.59	16.69	19.3

The decrease in flows is due to the difference in growth factors used. The CFRAM study used generalised regional growth factors based on the catchment size for the entirety of the River Liffey Hydrometric Area. This approach was a conservative. The FRA has used site specific calculations which is considered to be more appropriate under this current study.

3.6.2.7. Design Flood Hydrographs

3.6.2.7.1. Characteristic Flood Hydrographs

The characteristic flood hydrograph for the modelled watercourses were generated using the methodology as described in Section 2.6.2.4.3. Figure 3-38 illustrates the estimated characteristic flood hydrograph for the Griffeen River having been adjusted by hydrologically similar station.

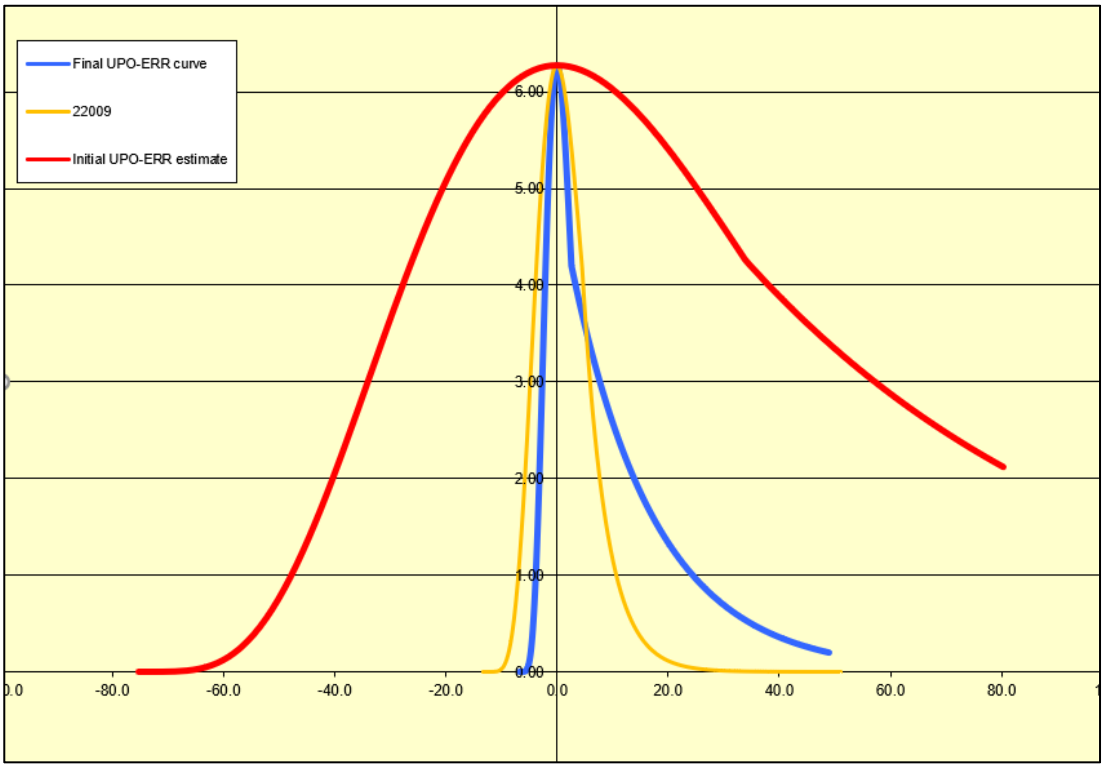

Figure 3-38 Characteristic flood hydrograph for the Griffeen River

3.6.2.7.2. Design Flood Hydrographs

The design flood hydrograph associated with any AEP has been estimated by scaling up the characteristic hydrograph ordinates by the relevant peak flow. Figure 3-39 illustrates the estimated 0.1% AEP flood hydrographs for the for the modelled watercourse.

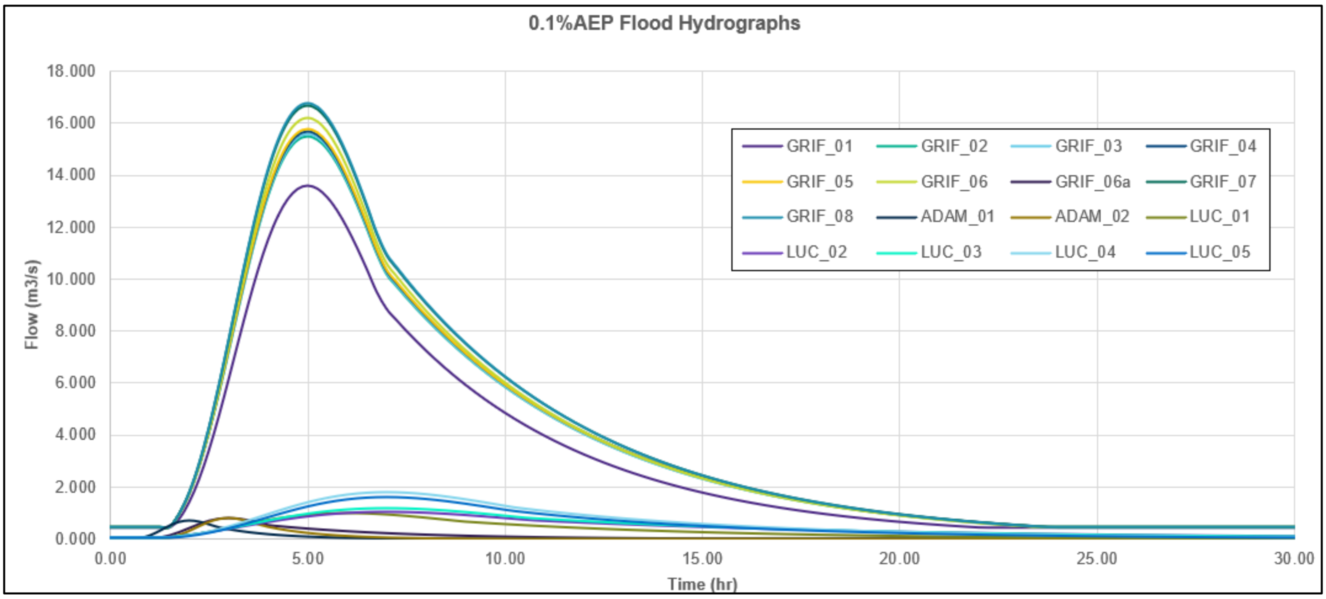

Figure 3-39 Design Flood Hydrographs for 0.1% AEP

3.6.2.8. Future Conditions

Future Condition peak flows were defined taking into consideration all parameters discussed in Section 2.6.5.

3.6.3. Hydraulic Modelling

3.6.3.1. Existing Scenario

3.6.3.1.1. Flood Zone Mapping

Figure 3-40 shows that the proposed Development site is not impacted by the 1% and 0.1% AEP fluvial flood events for the existing scenario. The flood zone map is also shown in Appendix A. Table 3.25 shows the flood levels across the model extents. The mapping shows that there is no flooding on the track or at proposed substation location from either watercourse during the existing scenario.

Table 3.25: CFRAM and FRA flood level comparisons

River	Monitoring Points	CFRAM Study Existing 1% AEP (m)	FRA Existing 1% AEP (m)	Difference (m)	CFRAM Study Existing 0.1% AEP (m)	FRA Existing 0.1% AEP (m)	Difference (m)
Lucan	09TOWN00326I	59.36	60.11	0.75	59.66	60.33	0.67
Lucan	Mon 04a	-	59.49	-	-	59.45	-
Lucan	Mon 04b	-	58.85	-	-	58.86	-
Griffeen	09GGRIFB00009	56.54	57.02	0.48	56.88	57.2	0.32
Griffeen	Mon 05a	-	56.87	-	-	56.96	-
Griffeen	Mon 05b	-	54.4	-	-	54.59	-
Griffeen	09GRIF00309	52.81	52.7	-0.11	53.13	52.75	-0.38
Griffeen	09GRIF00305	52.62	52.2	-0.42	52.92	52.3	-0.62

3.6.3.1.2. CFRAM Comparison

Comparing Figure 3-33 and Figure 3-34 with Figure 3-40 it can be seen that for the Lucan stream the extents are broadly similar. However, the extents for the Griffeen are larger for this FRA upstream of the railway for both the 1% AEP and 0.1 % AEP events when compared than the CFRAM mapping. The flood levels shown in Table 3.25 correlate with the mapping showing increased water levels upstream of the railway and lesser downstream of the railway for the FRA when compared to the CFRAM. The level differences are due to the larger flooding extents upstream of the railway.

This was not expected initially, in particular for the 1% AEP as the flows for the FRA are broadly similar the CFRAM as discussed in Section 3.6.2.6.1. However, upon review of the LiDAR surface (Figure 3-41) and CFRAM topographical information (Figure 3-42 and Figure 3-43) it was found that there is a lower section of the right riverbank upstream of the railway which does not appear to have been accounted for in the CFRAM modelling. Thus flood waters could overtop this in the FRA and produced larger flooding extents on the right bank.

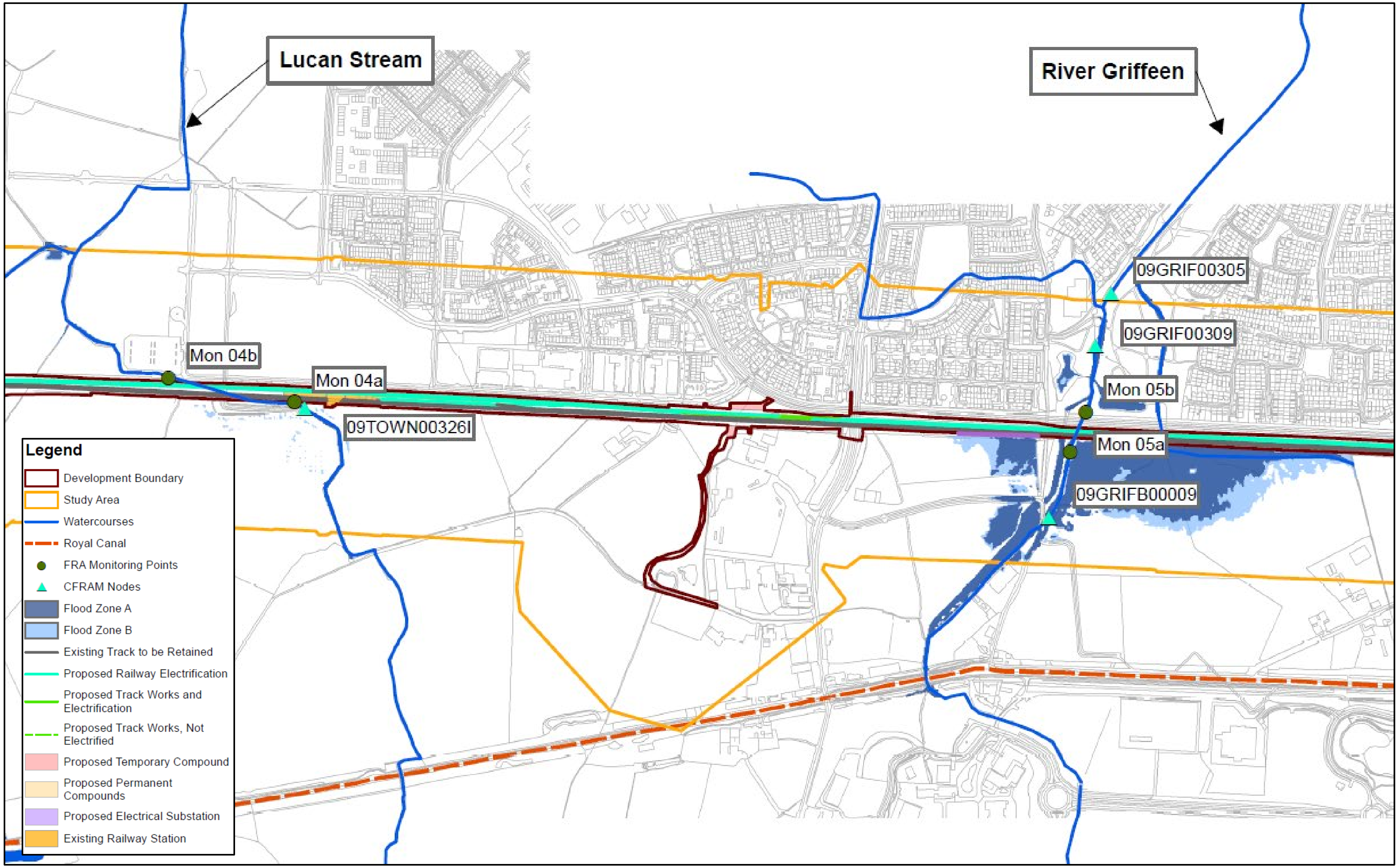

Figure 3-40 Flood Zones for the Lucan and Griffeen Streams

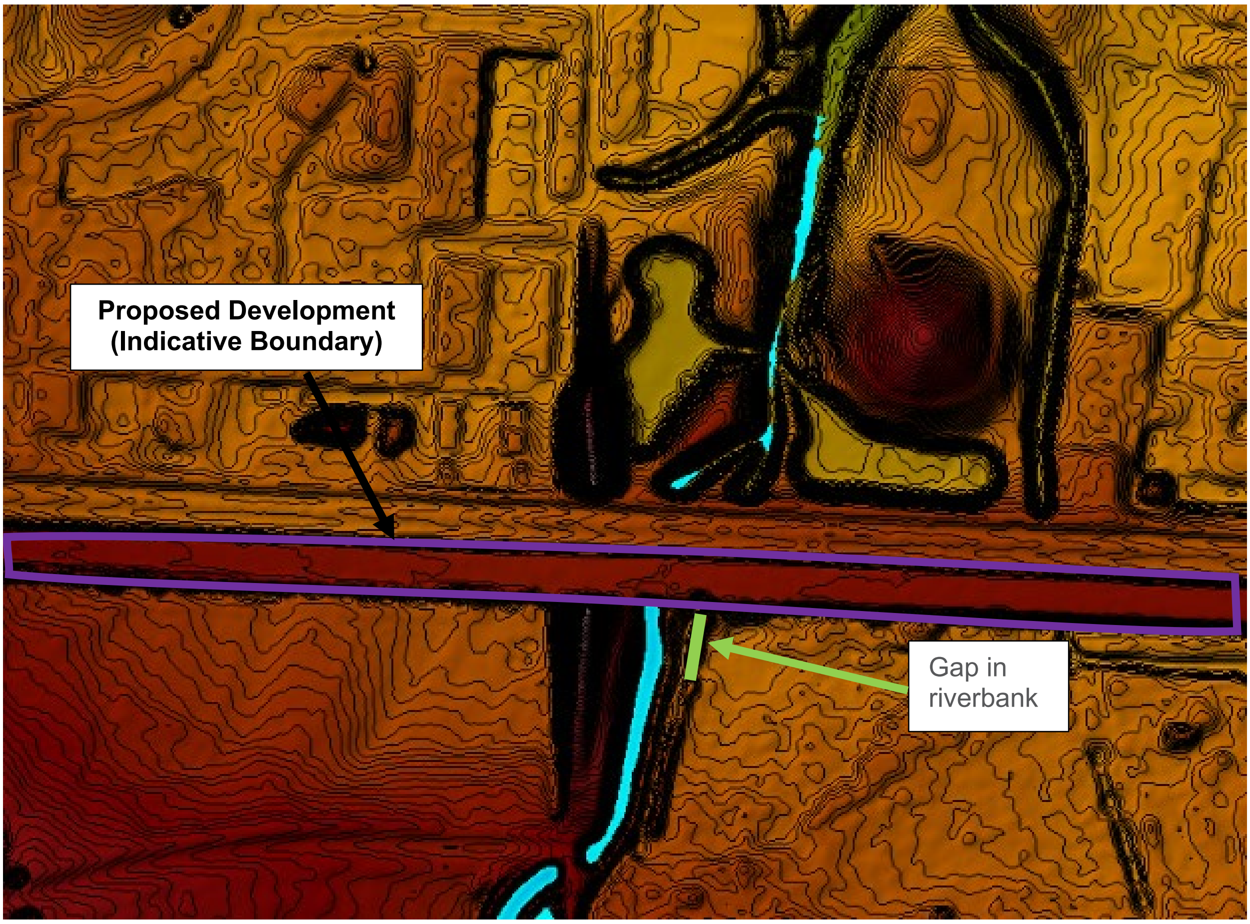

Figure 3-41 LiDAR surface for Adamstown FRA with a gap highlighted on the right riverbank

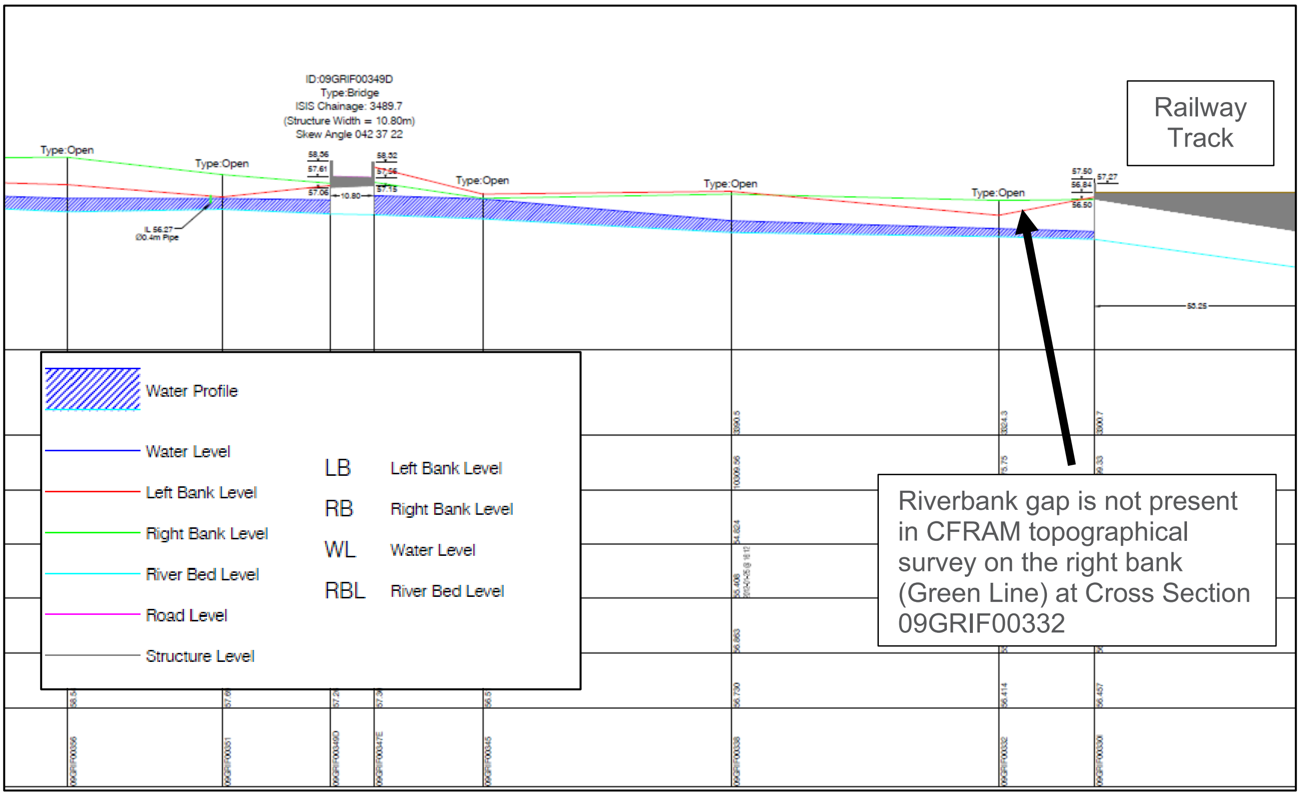

Figure 3-42 Longitudinal profile of the Griffeen River upstream of the railway

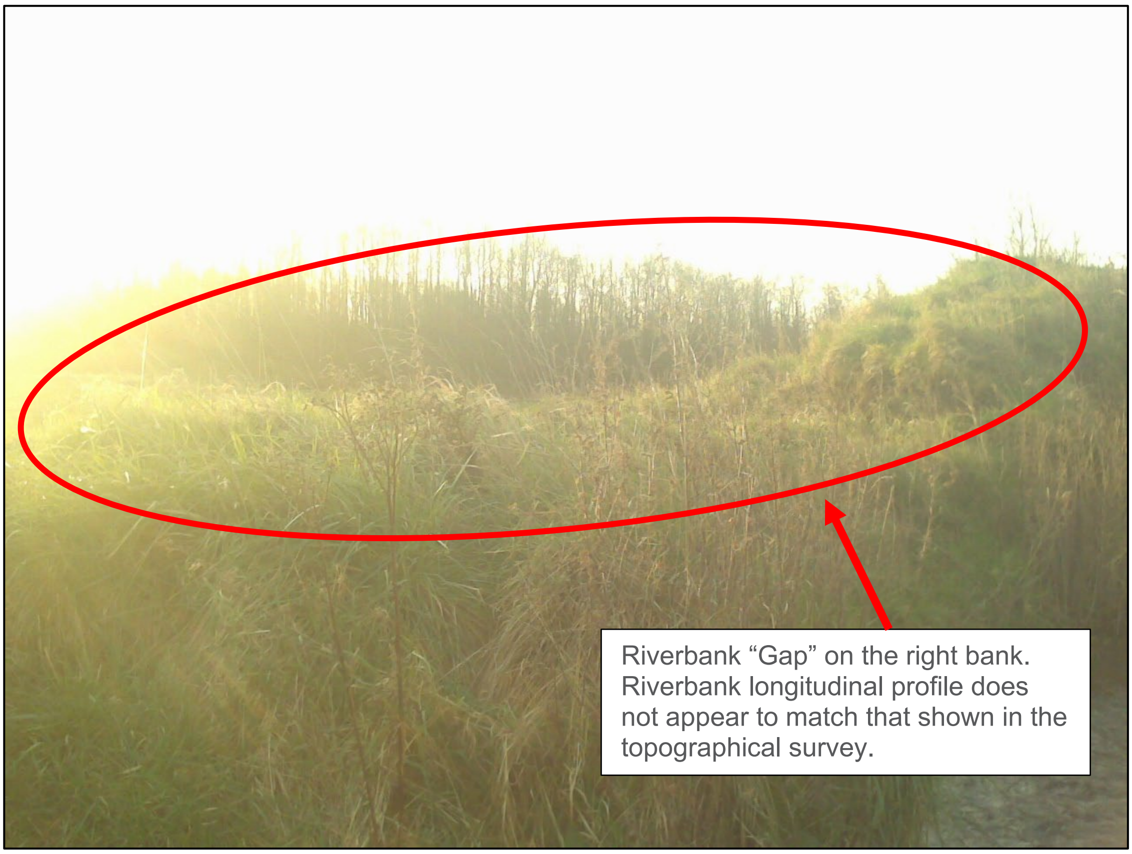

Figure 3-43 Photograph of right riverbank at Cross Section 09GRIF00332

3.6.3.2. Climate Change Scenario

Model runs inclusive of climate change parameters, were generated to appraise any potential flood risk to the development site. Results for the worst case HEFS scenario are shown in Figure 3-44. During this event, flooding occurs at the Haydens Lane culvert. The culvert is unable to convey the 0.1% AEP HEFS flows and causes the water to overtop the river bank along the left bank just upstream of the culvert. This flood water encroaches on the railway line causing flooding of approximately 120mm depth above for an approximate duration of 12 hours. There is no predicted flooding to the proposed substation to the west of the Lucan Stream. The HEFS flood extent map is shown in Appendix A.

3.6.3.3. Proposed Scenario

3.6.3.3.1. Flood Zone Mapping

Potential mitigation measures to alleviate flooding along the railway track were investigated. Two alternative mitigation measures were proposed which included:

- Approximately 1m high flood embankment to a level of 57.7mOD, providing 300mm freeboard to the railway track, along the southern boundary of the railway line extending west from the Griffeen for approximately 145m.; and
- Upgrading Culvert at Hayden's Lane from 1.86m (H) x 2.9m (W) to 2.0m (H) x 5.0m (W).

These measures were modelled independently of each other. Figure 3-45 shows the HEFS flooding extents.

3.6.3.3.2. Comparison of Existing and Proposed Scenarios

By comparing Figure 3-44 with Figure 3-45 it shows that the inclusion of the embankment would increase the flooding extent marginally, however by including the upsized culvert at Hayden's Lane the flooding was reduced, no longer the overtopping of the left bank and eliminated the flooding on the railway line. In both scenarios flooding extents downstream are not increased.

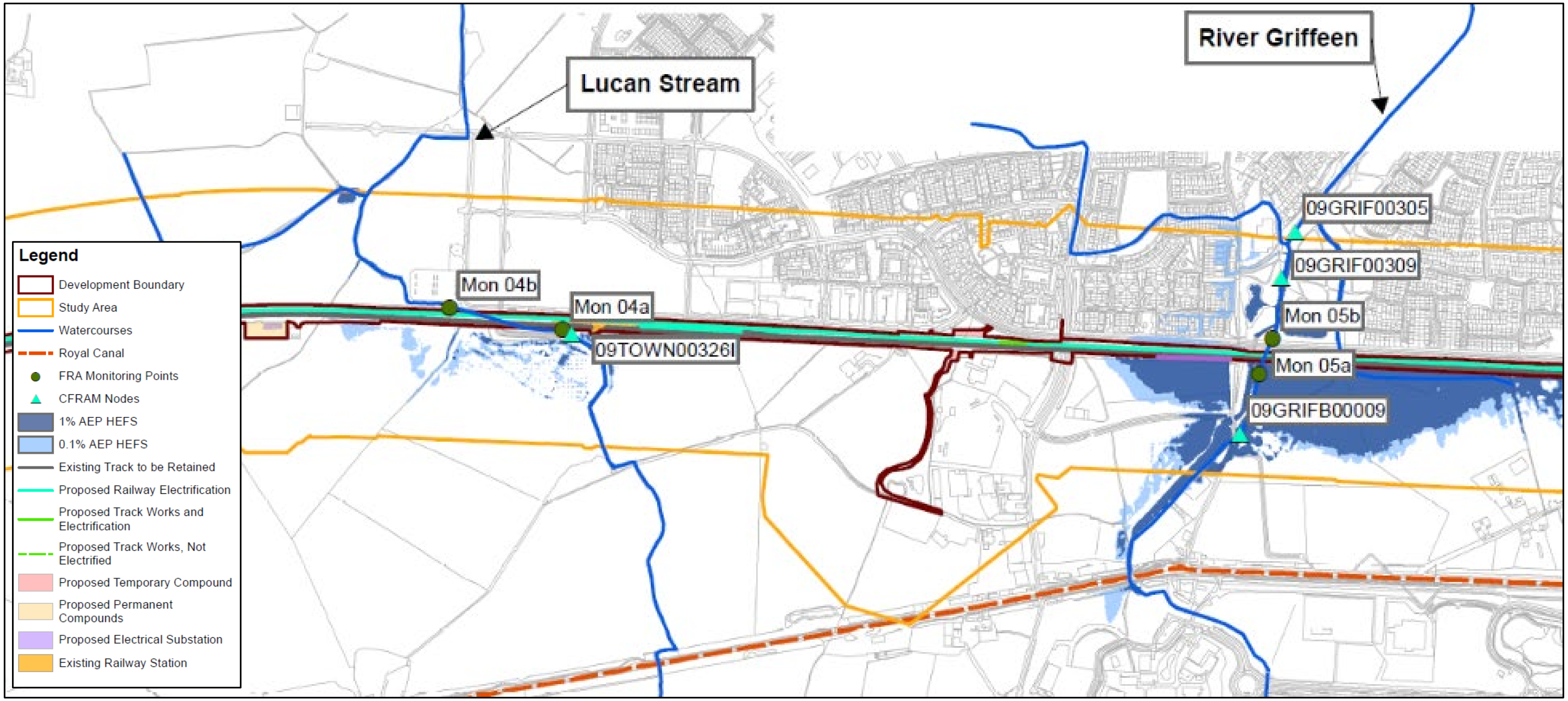

Figure 3-44 HEFS flood extents for the Lucan and Griffeen Streams

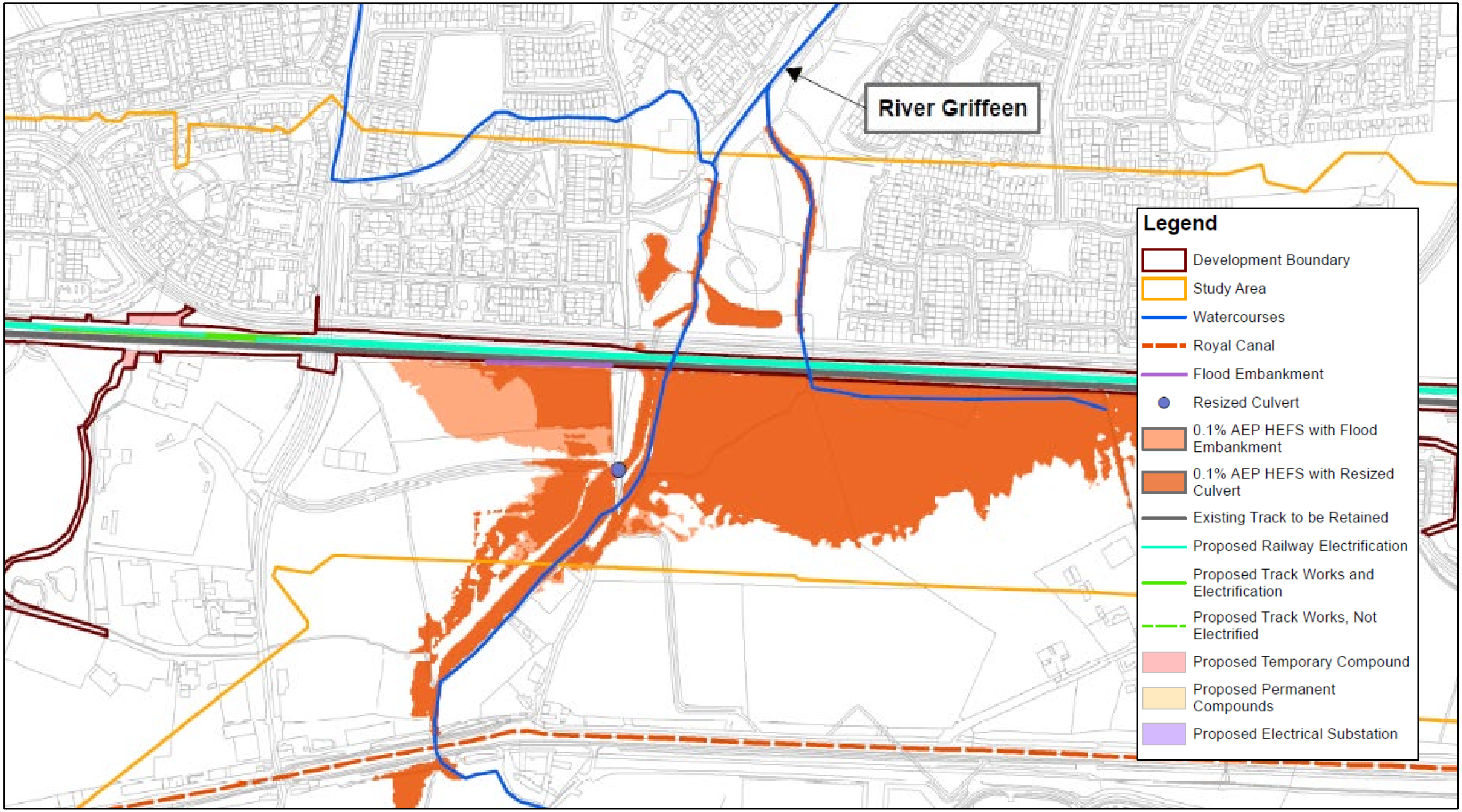

Figure 3-45 Flood extents for the Lucan and Griffeen Streams with proposed mitigation measures in place

3.7. Conclusion of Zone A Stage 3 – Detailed Flood Risk Assessment

3.7.1. Overview

1D/2D combined hydraulic models were built to assess the existing and proposed flood risk to the railway in Zone A at Hazelhatch Co. Kildare and Adamstown Co. Dublin. The primary rivers in the Hazelhatch are the Shinkeen and Hazelhatch while in Adamstown they are the Lucan and Griffeen. The design flood flows were estimated using the FSU and IH recommended flood estimation methodologies. The models were calibrated against the results from the relevant Eastern CFRAM Study flood extent mapping. The analysis of the existing scenario found that the railway at Hazelhatch is at risk of flooding from both the 1% AEP and 0.1% AEP flooding events while the Adamstown area is not at risk. However, the railway is at risk at Adamstown during the 0.1% AEP HEFS climate change scenario. The proposed compound and substation at Hazelhatch are also at risk of flooding from the 1% AEP and 0.1% AEP flooding events. To mitigate against flooding along the railway mitigation measures were proposed and modelled. The measures included additional culverts at Hazelhatch while at Adamstown options included a flood embankment or upsizing a culvert.

3.7.1.1. Conclusion Stage 3 Hazelhatch FRA

Hydraulic modelling of possible mitigation measures included at Hazelhatch would increase flood risk to the surrounding area and would not reduce flooding below the Iarnród Éireann flood depth operational limits. Therefore it is recommended that no mitigation measures are included with the application for a Railway Order (RO) and that Iarnród Éireann engage with the OPW who is currently progressing a FRS for the wider Hazelhatch area. This scheme could reduce flooding to the railway station and its infrastructure. Mitigation measures developed solely for the railway station would increase flood risk to the surrounding area and therefore would not pass the FRM Guidelines Justification Test.

The upgrading of infrastructure at Hazelhatch to facilitate the electrification will not increase flood risk to the surrounding area as the proposed ground levels will be maintained at the current levels to ensure that displacement of floodwaters does not occur and cause a residual risk. The predicted flooding for the HEFS 0.1% AEP event at the location of the proposed substation is 57.559 mOD. All critical equipment can be set at a level above this flood level while the substation site ground level can be maintained at existing levels.

Noise barriers are proposed at a number of locations within Zone A to mitigate operational noise impact (Refer to Chapter 14 Noise & Vibration of Volume 2, EIAR for further details). The proposed noise barriers in the Hazelhatch area are located within the 1% AEP and 0.1% AEP flood extents. A hydraulic model simulation showed that these proposed noise barriers would cause a slight increase in flood level, particularly in the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. The causes of this flood level rise can mainly be attributed to the obstruction to flood water flow paths caused by the proposed noise barriers. In order to mitigate this impact to the flood level, an 83m long and 2m wide conveyance channel was proposed along the railway track along the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. This channel will help in conveying the increased flood volume from the adjacent flooded land areas into the Shinkeen river and maintain the status quo flooding regime.

It is also recommended that Iarnród Éireann should update its operational procedures, as listed in Section 2.9, which would ensure that Hazelhatch is not utilised during an extreme flooding situation. The EMU rolling stock would be able to access part of the station during a flood as the flooding depths at the monitoring point - Mon 03a/b are below 170mm but there is no safe access or egress from the station itself during an extreme flooding event.

3.7.1.2. Conclusion Stage 3 Adamstown FRA

The analysis of the existing scenario found that the railway at Adamstown is not at risk of flooding from both the 1% AEP and 0.1% AEP flooding events.

The railway is not at risk at during the 1% AEP HEFS climate change scenario, however the railway is at risk at Adamstown during the 0.1% AEP HEFS climate change scenario. To mitigate against flooding along the railway mitigation measures were proposed and modelled. These proposed mitigation measures have been presented in Section 3.6.3.3.

Hydraulic modelling of the proposed mitigation measures included at Adamstown showed that they remove flooding from the railway track during the HEFS 0.1% AEP event. However, depending on the mitigation solution employed, it increases (flood embankment) or reduces (culvert upgrade) flooding depths and extents upstream of the railway line. There are no increases for either mitigation measure downstream of the railway.

Having considered the hydraulic analysis of the existing scenario for the HEFS 0.1% AEP event, which identified the approximate depth of flood water on the track as 120mm for an approximate duration of 12 hours, the EMU (the rolling stock of primary concern) is within the recommended operating limits passing over flooded track as outlined within Iarnród Éireann's operating procedure.

The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. TTA have presented the analysis of the modelling to Iarnród Éireann and Iarnród Éireann has determined that hard mitigation measures are not warranted at this time. Risk reduction associated with the HEFS 0.1% AEP could be achieved in the future by implementation of the proposed mitigation measures by Iarnród Éireann if warranted.

Noise barriers are proposed at a number of locations within Zone A to mitigate operational noise impact (Refer to Chapter 14 Noise & Vibration of Volume 2, EIAR for further details). No impacts on the existing flooding regimes of the Lucan and Griffin Rivers in the Adamstown areas, due to the installation of the proposed noise barriers, are expected, since the proposed noise barriers are not located within the design flood extents.

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4. Zone B - Park West & Cherry Orchard Station to Heuston Station (incorporating Inchicore Works) FRA

4.1. Stage 1 – Flood Risk Identification

4.1.1. Overview

The section from Park West & Cherry Orchard Station to Heuston Station, shown in Figure 4-1, requires electrification and the provision of four tracks. Expanding from two tracks to four tracks will require a horizontal width extension across the railway corridor, including potential infringement of property rights (on a permanent and / or temporary basis) outside the rail corridor / CIÉ's property boundary.

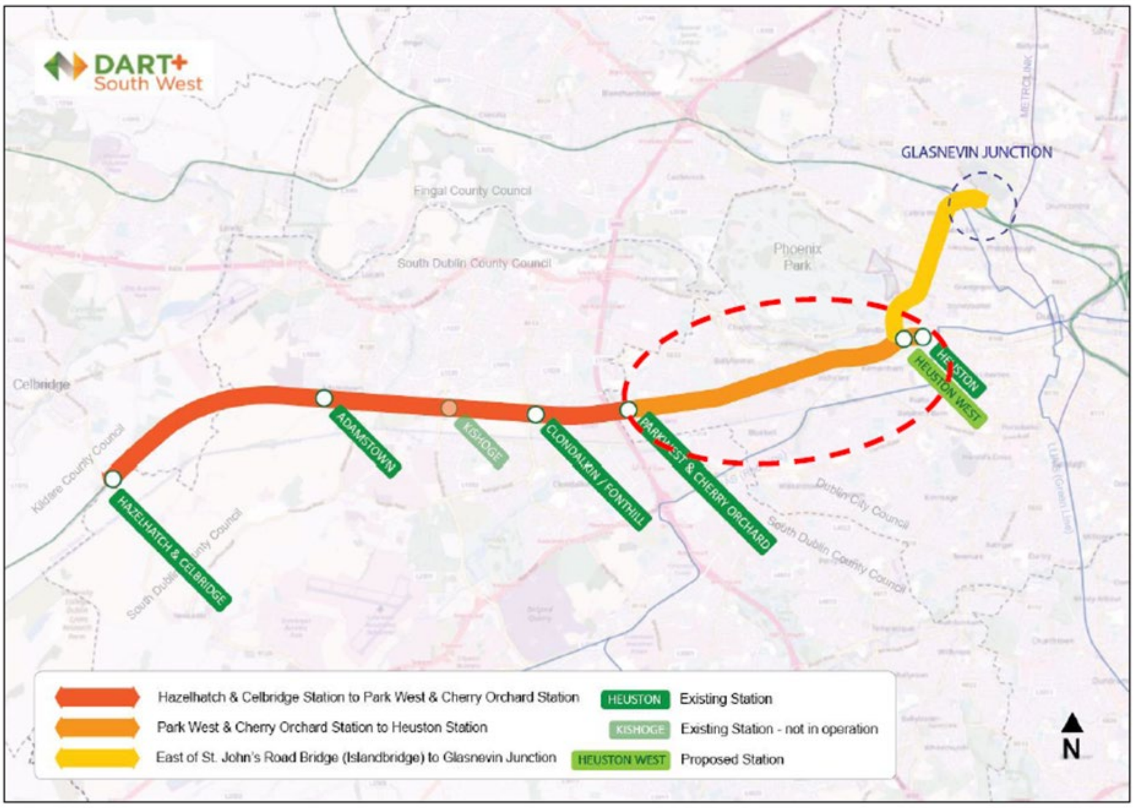


Figure 4-1 Park West & Cherry Orchard Station to Heuston Station

4.1.1. Site Topography

The general topography of the subject area is flat and sloping gently towards the north. To the east of the existing Park West & Cherry Orchard Station the railway is in a cutting (i.e. the rail level is below the surrounding ground level). To the west of Park West & Cherry Orchard Station, the height of the cutting gradually decreases and thereafter the railway is generally at grade or minor cutting throughout the study area.

4.1.2. Existing Site Drainage

The majority of the lands within the study area are located within the catchment of the River Camac, which rises in the Dublin Mountains, and runs in close proximity to the southern boundary of the lands. A small area near the northern boundary of the Local Area Plan (LAP) lands (mainly the Cherry Orchard Hospital lands), and another small area near the eastern boundary of the lands north of the railway line and adjacent to Killeen Road are located within the Lower Liffey Lyreen Ryewater catchment.

A network of surface water sewers feed into this strategic network which is well developed in the built-out areas of the Park West Industrial Estate and Business Campus and the Cherry Orchard residential area, however there is a lack of existing drainage infrastructure in the vicinity of some of the proposed development sites, in particular in the vicinity of the M50 at the western boundary of the LAP lands.

4.1.3. The Proposed Development

The elements which form the design for this section of the Project are outlined in Table 4.1 below. For the purpose of describing the proposed works, this area has been summarised into sections as outlined in the table below.

Table 4.1: Proposed Development

Section	Proposed Development
Park West & Cherry Orchard Station to Le Fanu Road Bridge (OBC7)e	• Two northern tracks through this area (Slow Tracks) will be electrified • Retaining Structures to limit the impact of the construction works • Permanent Way re-alignment • Le Fanu Road Bridge Replacement (OBC7) • Construction Compounds • New Proposed Park West Substation
Le Fanu Road Bridge (OBC7) to Kylemore Road Bridge (OBC5A)	• Two northern tracks through this area (Slow Tracks) will be electrified • Retaining Structures to limit the impact of the construction works • Permanent Way re-alignment • Kylemore Bridge Replacement (OBC5A) • New Proposed Kylemore substation • Compounds are required at Kylemore Road Bridge
Kylemore Road Bridge to Sarsfield Road Underbridge (including Inchicore Works)	• Two northern tracks through this area (Slow Tracks) will be electrified • Retaining Structures to limit the impact of the construction works • Permanent Way to accommodate the increase from three tracks to four tracks

Section	Proposed Development
	• Demolition of several structures and buildings within the Inchicore Works complex • Khyber Pass Footbridge (OBC5) Replacement • New drainage system with attenuation tank west of Inchicore Depot • A construction compound is required at Inchicore Depot & new Khyber Pass Footbridge • Proposed attenuation tank east of Inchicore depot • New track drainage system to a proposed attenuation facility located near New Heuston West Station • Sarsfield Road Under-Bridge (UBC4) Deck Replacement • Memorial Road Bridge (OBC3) Replacement • Construction compounds required in the area of Sarsfield Road Bridge (UBC4)
Memorial Road Bridge to South Circular Road Junction	• Two northern tracks through this area (Slow Tracks) will be electrified • Permanent way to be increased from three to four tracks • Retaining Structures to limit the impact of the construction works • New structure to the north of the existing South Circular Road Bridge • Construction compounds required in the area between Memorial and South Circular Road

4.1.4. Land Use

The line runs through a relatively dense urban environment with a mix of residential and commercial properties bordering the rail corridor.

4.1.5. Existing Geology and Hydrogeology of the Area

Shallow bedrock close to the existing permanent way formation-level may be present. Appropriate groundwater management/drainage design may be required should the upcoming detailed ground investigation encounter groundwater at similar depth.

4.1.6. Salient Hydrological Features and Existing Flood Regime of the Area

The salient hydrological feature for the study area between Park West & Cherry Orchard Station and Heuston Station is the Blackditch and Creosote Streams (Figure 4-2 and Figure 4-5).

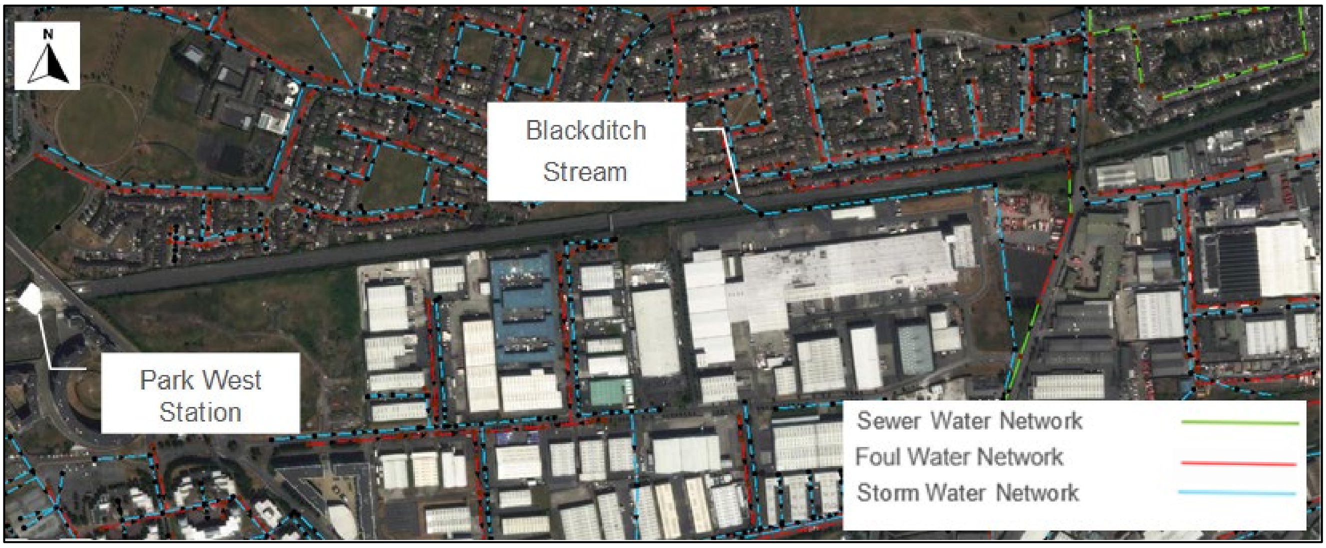


Figure 4-2 Blackditch Stream Crossing: IW GIS Database – Storm and Foul Network in the vicinity of Park West and Cherry Orchard

The majority of the Cherry Orchard area, north of the railway line, drains to the piped Blackditch stream, which also exits the LAP lands at their south-east corner (Outfall A) and eventually drains to the Camac River. As previously alluded to, a small portion of the Cherry Orchard area drains to Le Fanu Road, exiting the LAP lands at Outfall C. The area in the vicinity of the Cherry Orchard Hospital and the Ballyfermot Primary Care Centre drain to a 1.5m sewer which runs along the southern boundary of the hospital and exits the LAP lands at Outfall B (Figure 4-3 and Figure 4-4).

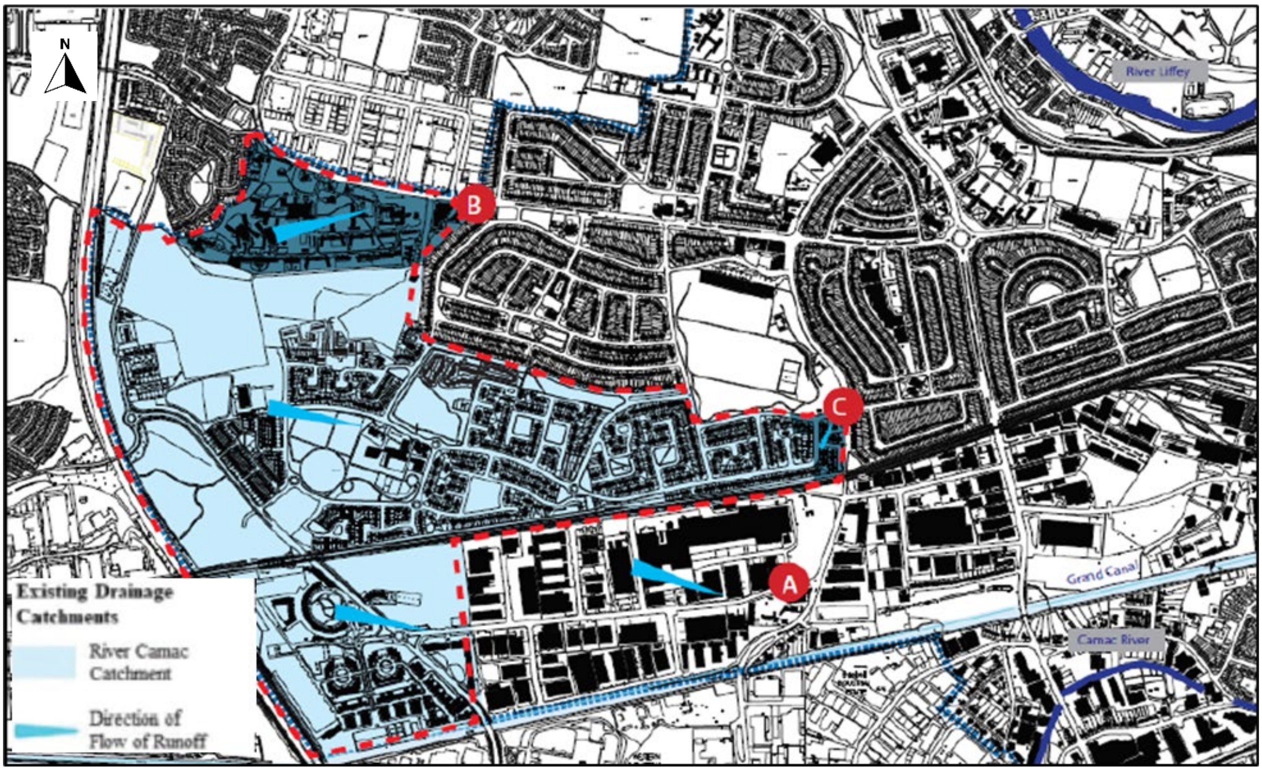


Figure 4-3 Existing Surface Water Catchments, (Source: Draft Park West – Cherry Orchard LAP 2019, SFRA)

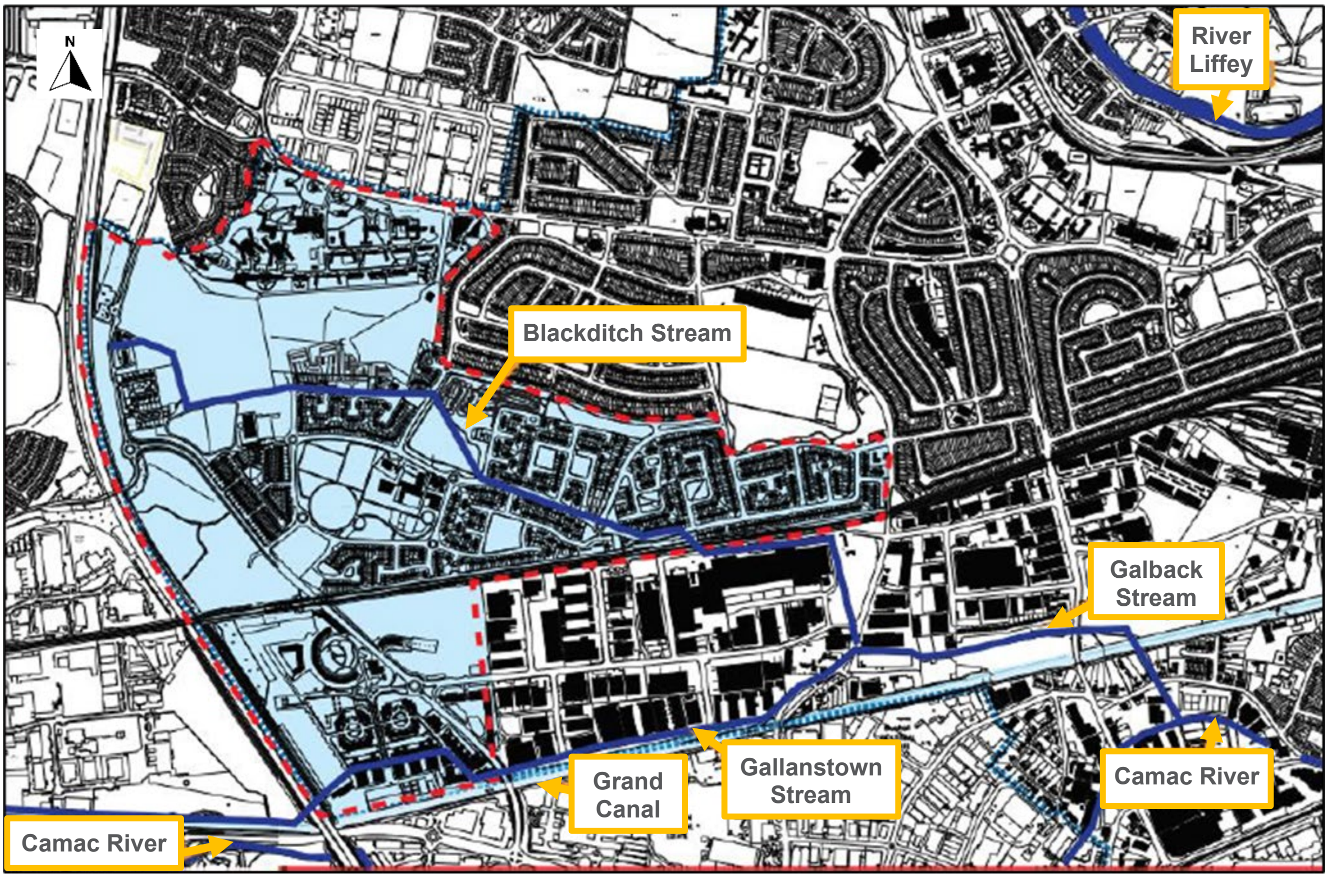


Figure 4-4 Blackditch Stream crossing

Figure 4-5 Creosote Stream crossing Sarsfield Road Bridge (UBC4)

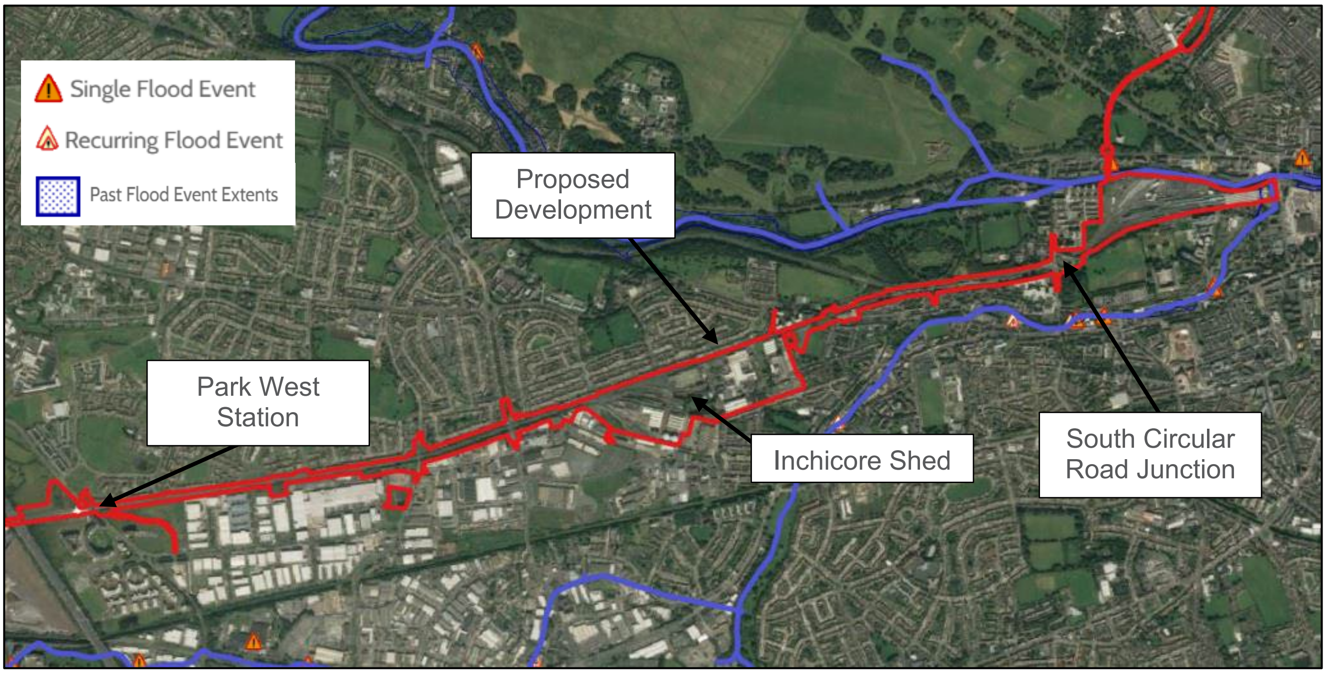


Figure 4-6 Past Flood Events along the DART+ South West Route – Park West & Cherry Orchard Station to South Circular Road Junction (Source: OPW National Flood Hazard Mapping)

There are no recorded Past Flood Events available in the OPW's database (Figure 4-6). However, information received from IE noted that following periods of significant and sustained heavy rainfall, the running shed at Inchicore has experienced flooding. On average, it has resulted in 2 periods of flooding per year, and it is believed that it is a legacy issue of poor drainage. However, no detailed records were available.

4.1.7. Interreg IVB FloodResilienCity Project

DCC is one of eleven partner organisations, drawn from eight European cities, which form the Interreg IVB flood risk management good practice project known as the Flood Resilient City (FRC).

DCC's involvement and interest in the project was impelled by a necessity to develop sustainable flood risk management in the urban environment to deal specifically with Pluvial Flood Risk, pluvial flooding being the key component of surface water flooding.

Figure 4-7 presents a map of the modelled area. The layers show the modelled extent of land that might be directly flooded by rainfall under existing (Do-minimum) conditions. The proposed development is susceptible to pluvial flooding under all probabilities.

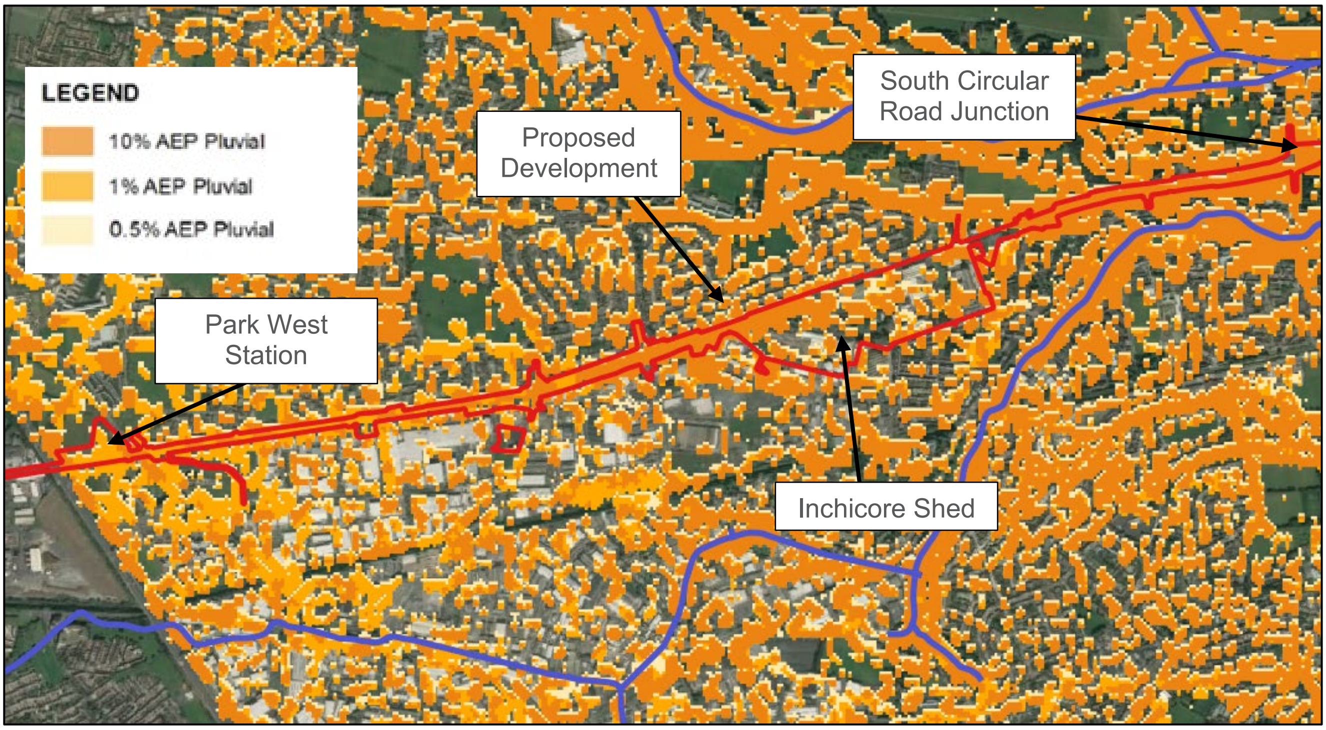


Figure 4-7 Rainfall Flood Extents – Dublin City Area (Source: https://www.floodinfo.ie/map/floodmaps/)

4.1.8. Conclusion of Stage 1 – Flood Risk Identification

Records of historical flooding, the flood extent mapping generated for the study area, and other records outlined in the preceding sections indicated that the proposed Development is potentially at risk from pluvial flooding and to a lesser extent from groundwater. Therefore, the FRA was progressed to STAGE 2 – INITIAL FLOOD RISK ASSESSMENT.

4.2. Stage 2 – Initial Flood Risk Assessment

4.2.1. Sources of Flood Risk

The purpose of the Stage 2 - Initial FRA was to appraise the availability and adequacy of the identified flood risk information, to qualitatively appraise the flood risk posed to the site and potential impacts on flood risk elsewhere and recommend possible mitigation measures to reduce the risk to acceptable level. In consideration of the above assessment, the primary flood risk to the proposed Development was attributed to:

- Pluvial– High Risk.

4.2.2. Flood Risks and Flood Zone Mapping Summary

As mentioned above, the most significant source of flooding based on the Studies is pluvial, which locates the site in **Flood Zone A**.

4.2.3. Conclusion of Stage 2 – Initial Flood Risk Assessment

The freeboard levels proposed have not been investigated using hydraulic modelling. This will be carried out as part of the standard drainage design following the criteria set out by DCC, which should limit the risk of pluvial flooding to being low.

An assessment of the surface water discharge should be undertaken to assess any risk of flooding to the development site. Storm water infrastructure (including attenuation tanks, pipes and Sustainable Urban Drainage Systems (SuDS) features) shall be adequately designed to the requirements of DCC to prevent pluvial flooding on the site. As part of the STAGE 3 – DETAILED FLOOD RISK ASSESSMENT the drainage design was reviewed in terms of adequacy of the proposed drainage system and residual risks associated with this design to the proposed development and/or to any properties located adjacent to the development site.

4.3. Stage 3 – Detailed Flood Risk Assessment

A new drainage system is proposed for the zone in order to meet the increased runoff volumes generated by the new four-tracking layout, as well as the attenuation requirements needed to comply with the allowable discharge rates.

The new drainage system is based on three independent drainage networks (Network 1, Network 2 and Network 3, shown in Figure 4-8) with three outfall locations and the existing open areas along the track that are suitable for locating the required attenuation structures (Figure 4-9 to Figure 4-11).

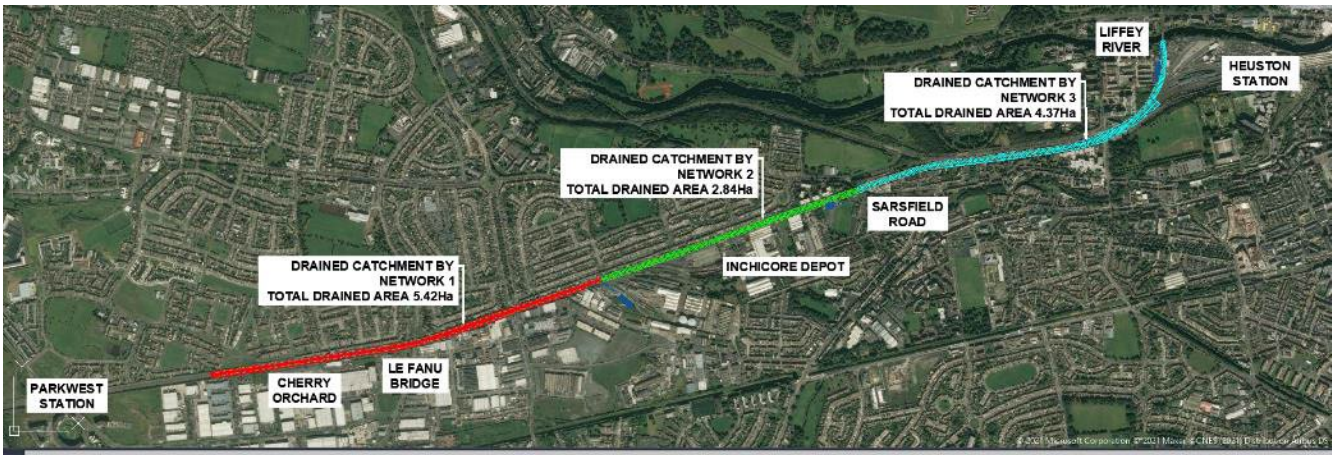


Figure 4-8 Proposed Network Delimitation

The proposed drainage network consists of two main branches running parallel to the track with filter drains above carrier pipes. Runoff water percolates through the ballast up to the low points of the ballast layer where the filter drains are placed. Water is then collected by the perforated drains and discharged into the carrier pipes that convey runoff flows through the drainage network. The collected runoff is attenuated in the attenuation ponds before discharging to outfalls (existing storm sews or surface watercourses). The attenuation systems have been designed to retain storm water volumes up to 1 in 100-year return period plus 30% climate change allowance. Table 4.2 below provides a summary of the proposed drainage systems for Zone B.

Table 4.2: Summary of the proposed drainage systems for Zone B

	Network 1 **Cherry Orchard to Inchicore Works**	**Network 2** **Inchicore Depot to Sarsfield Road**	**Network 3** **Sarsfield Road Underbridge to Heuston Station**
System description	Network 1 drains the track length from Cherry Orchard up to Inchicore Depot and conveys collected runoff waters up to a proposed attenuation tank located west of Inchicore Depot by pumping. A new pumping system is proposed downstream of the attenuation tank to pump surface water flows up to the discharge level and into the existing SW sewer. The proposed pump rate to comply with DCC requirements and is set at a maximum flow of 14.3 l/s.	Network 2 also drains the track section from Sarsfield Road up to ch.10+650 The proposed attenuation tank is located east of Inchicore Depot at Ch. The discharge point for Network 2 is at the existing storm water sewer that crosses the track south to north at Sarsfield Road.	The third network drains the new track arrangement from Sarsfield Road Underbridge to Heuston West by following the vertical profile of proposed track. The drainage network downstream of the attenuation tank will discharge by gravity to the outfall location at the Liffey (next to Heuston West Station) and will include a flow control unit to restrict outgoing flows to the agreed rate.
Drainage Area (m^2)	52,180	27,705	44,623
Attenuation pond Volume (m^3)	4172.16	1780.8	3222.4
Outfall Invert Level (mOD)	The invert level of the attenuation tank is approximately 31.9mOD and the invert level of the existing sewer at the proposed connection point of 33.8mOD. In order to save this level difference a storm water pumping station is required.	-	3.528mOD (1% AEP Flood level in River Liffey)

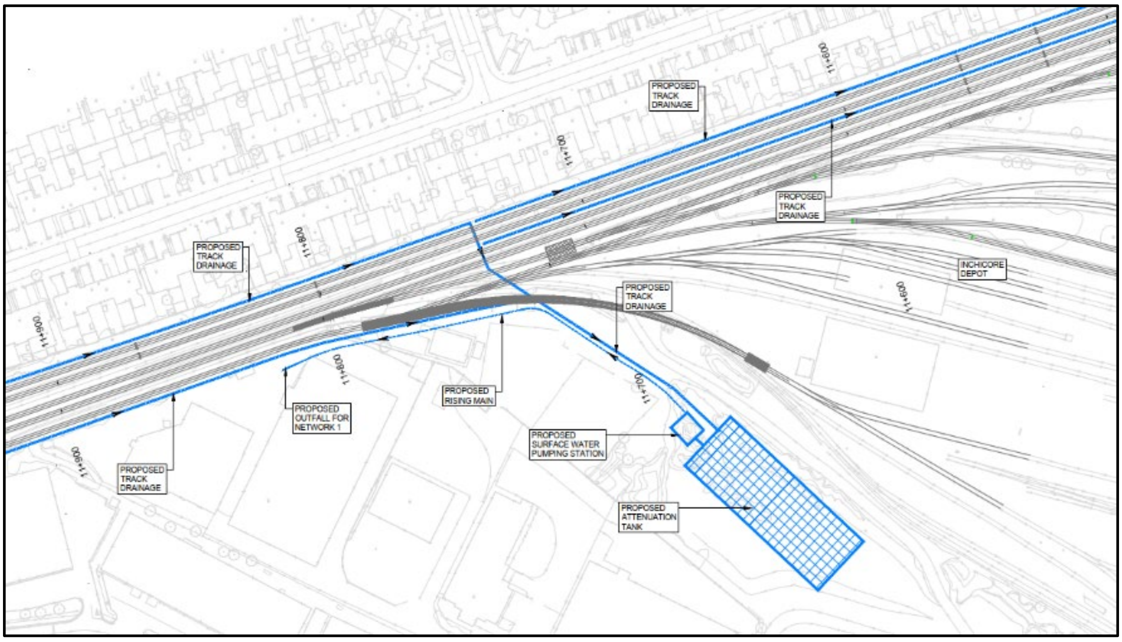


Figure 4-9 Network 1 Location of Underground Attenuation Tank

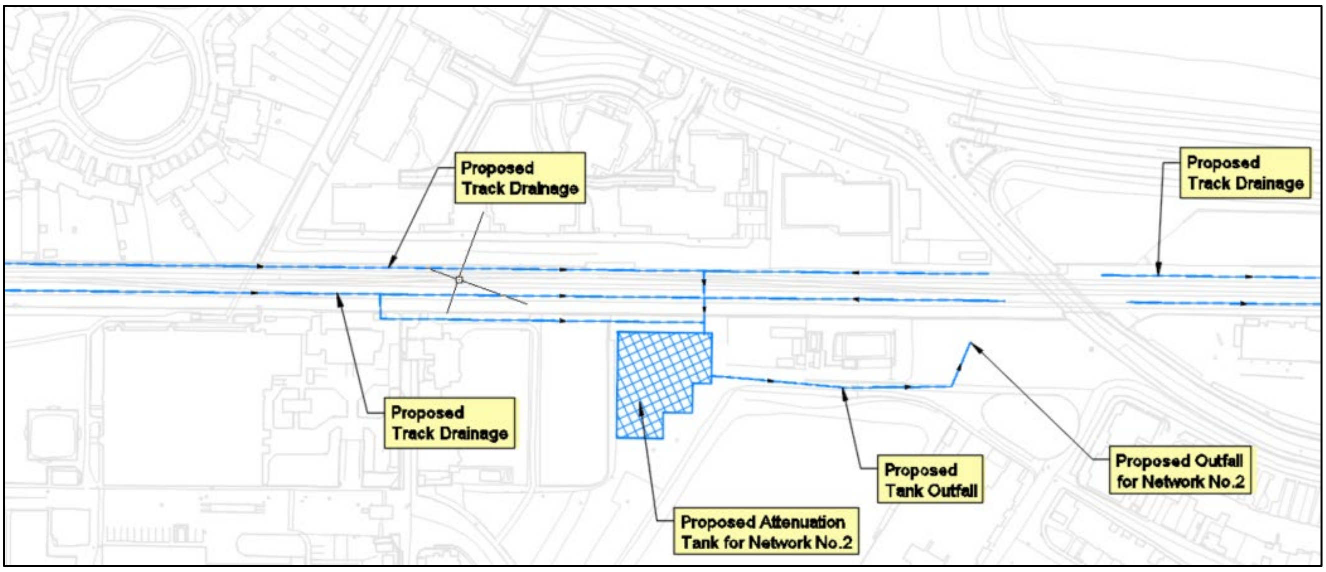


Figure 4-10 Network 2 Location of Underground Attenuation Tank

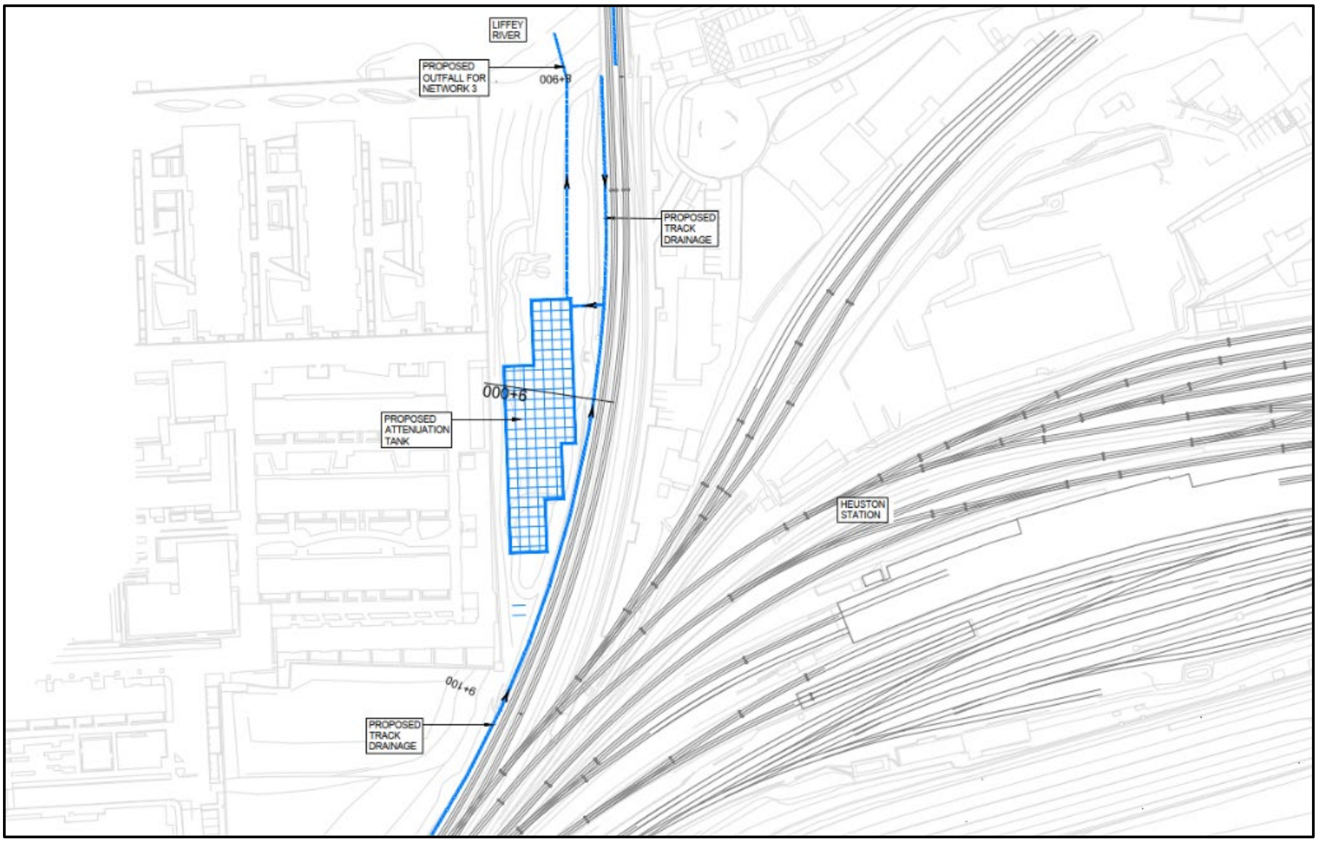


Figure 4-11 Network 3 Location of Underground Attenuation Tank

The above mentioned drainage system will be adequate to avoid any pluvial flooding on the railway track in Zone B.

5. Zone C – Heuston Yard & Station (incorporating New Heuston West Station) FRA

5.1. Stage 1 – Flood Risk Identification

5.1.1. Overview

This area encompasses Heuston Station and Heuston Yard including the site for the proposed Heuston West Station. The area extends west to east from St John's Road Bridge (OBC0A) eastwards to include the existing Heuston Station and from the CIÉ boundary along the Chapelizod Bypass northwards to the CIÉ boundary on the banks of the River Liffey.

This zone features the main Heuston Station building and an extensive railway yard area located to the west of this building. The station and yard area features various ancillary buildings, platforms, track areas, car parks and maintenance facilities. The site for the proposed new Heuston West Station is located in the north western part of this zone, adjacent to the existing Clancy Quay Development and the new National Train Control Centre (NTCC) site currently under construction.

There is existing pedestrian and vehicle access which extends from the proposed site, along the existing access road to the main Heuston Station and the LUAS Red Line stop which is located at the front entrance to Heuston Station.

5.1.2. Existing Structures and Facilities

The existing Heuston Station comprises nine (9 no.) Platforms, Platforms 1 to 8 are formed in a block of parallel tracks at the terminus end of the mainlines, and Platform 10 situated alongside the Down Loop on the Phoenix Park Tunnel Branch Line. Platform 10 which, due to current operational constraints at Heuston, is not used for passenger services. To the south of Platform 1, there are multiple sidings, as well as further sidings around the Valeting Depot and the Wash Road. Numerous Points & Crossings (P&C's) provide the operational capability necessary to access all of the platforms and train servicing facilities. Additionally, to the north of Platform 8 there are the Guinness Sidings and the Carriage Sidings. All tracks fall in level from west to east towards Heuston Station, platforms being on flat gradients.

There are a number of signalling structures controlling all of the passenger services and operational/ service requirements in the station area. The area does not currently provide for electrification. There are a number of retaining walls in this area.

There is a subway structure (UBC1A), providing access for Iarnród Éireann personnel to the valeting plant at Heuston Yard. A new National Train Control Centre (NTCC) at Heuston Station is currently under construction.

5.1.3. Site Topography

All tracks fall in level from west to east towards Heuston Station, platforms being on flat gradients. The topography of the site is flat, sloping gently to the north towards the River Liffey (Figure 5-1). St Johns Road is at an elevated level immediately adjacent and slopes east towards Heuston Station. The western approach of the railway into Heuston Yard is in cutting and this cutting reduces on entry into the yard. All rail lines within the yard are at similar elevations. To the west of the site, the ground level of the existing Clancy Quay development is approximately 4m to 5m below the existing track level.

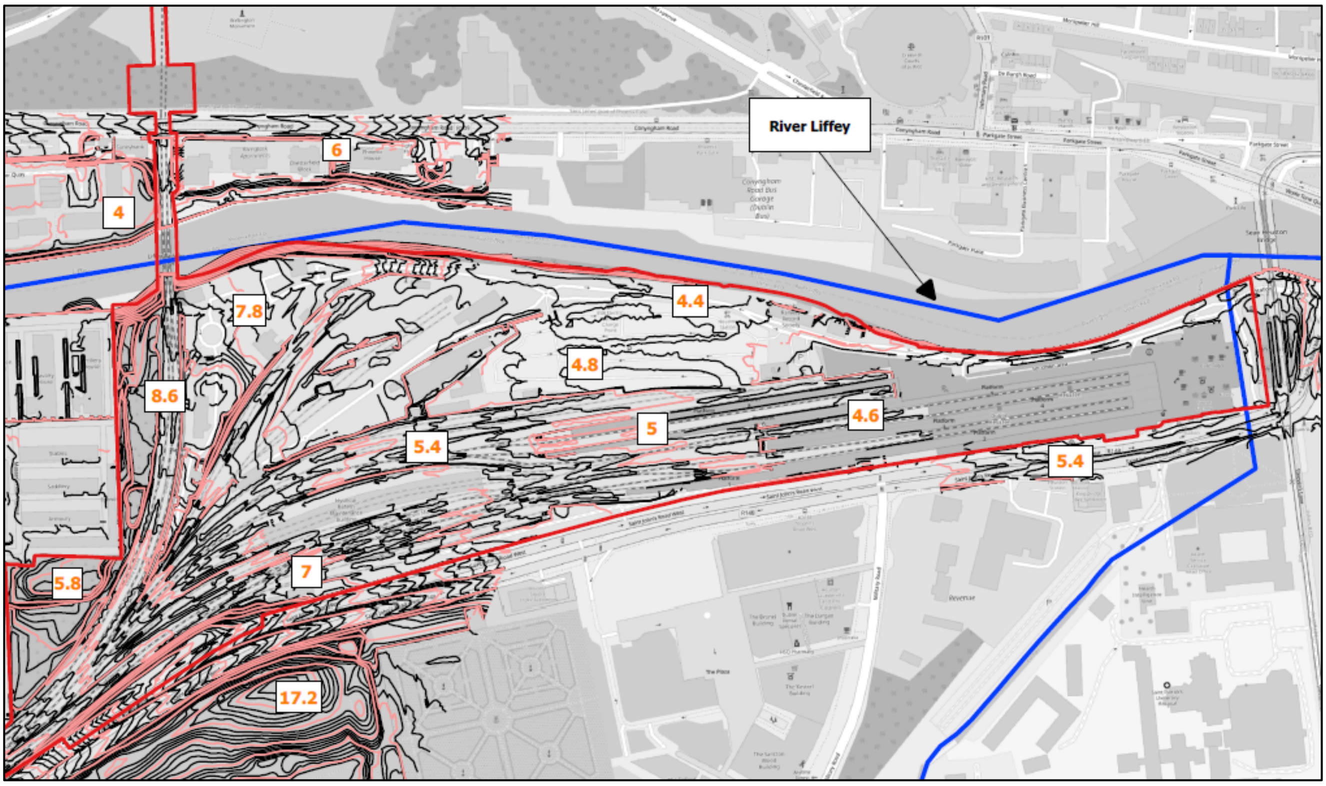


Figure 5-1 Existing ground levels

5.1.4. Existing Site Drainage

Foul and surface water drainage from the existing buildings on the Heuston Station site discharge by gravity to the existing combined sewer, which runs from the southwest corner of the site, around the west and north boundary and to the northeast end of Heuston Station. Figure 5-2 illustrates the existing surface and foul sewers network in the vicinity of the proposed development site.

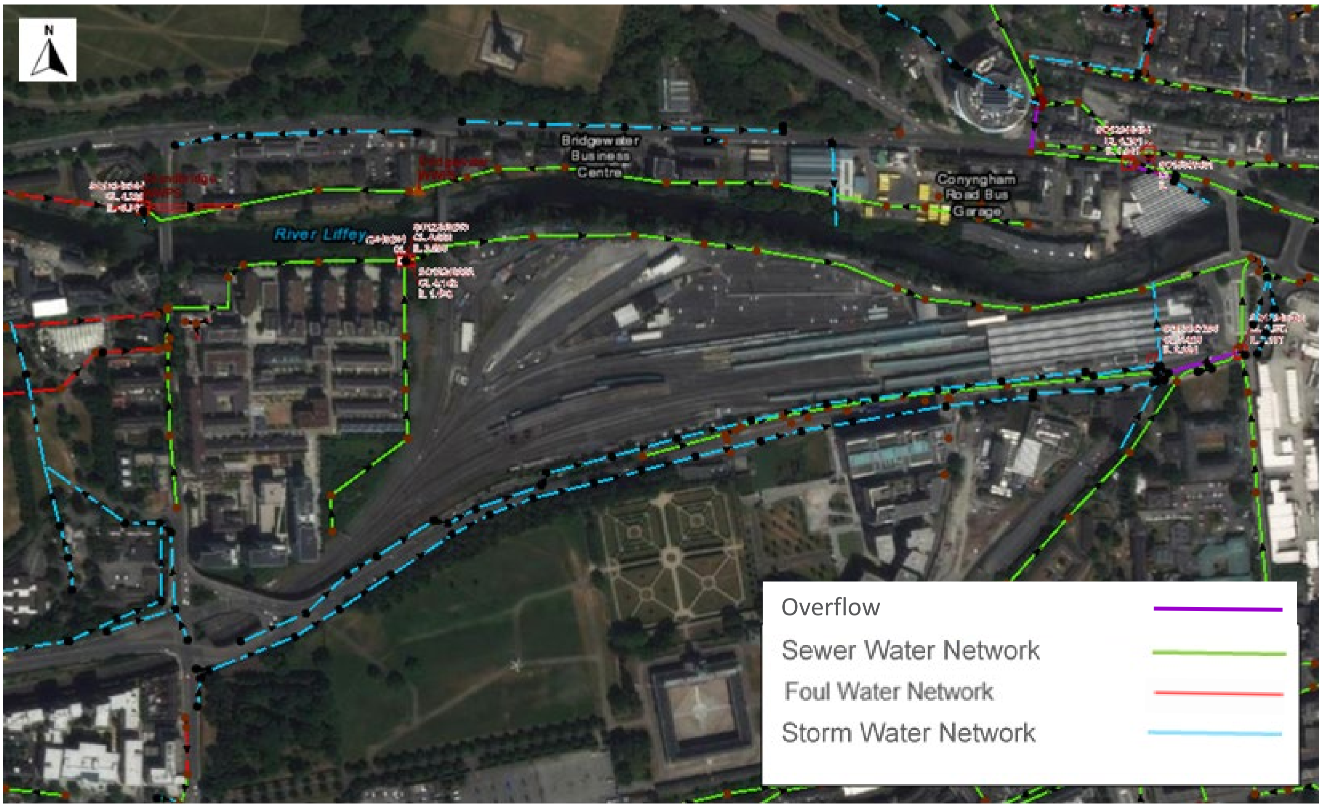


Figure 5-2 IW GIS Database – Storm and Foul Network in the vicinity of Heuston Station and Yard

5.1.5. The Proposed Development

The proposed design is to adjust the existing Heuston Yard to the new four tracking layout and to provide a direct access from the slow tracks while keeping the existing functionality of the station and depot. Tracks are to be rearranged and platform 10 is to be removed. The proposed design allows for a track access point north of the platforms for the maintenance services access.

The proposed Development includes for the provision of a new station at Heuston West, located to the west of the main Heuston Station. A new platform and station access will be built; requiring a new pedestrian and cycle access route to be provided between the lower ground level of the Clancy Quay residential area and the new station, a new segregated pedestrian / cycle bridge will provide access to both platforms and the public areas to the east and west of the station. The new station design comprises two open platforms, each 174m long, finished with ramps for maintenance and emergency access to the tracks. Pedestrian and cyclist access is to be provided – connecting both platforms and the public areas to east and west of the station by a segregated pedestrian/cyclist bridge. Access to the footbridge will be via stairs and ramps in accordance with accessibility requirements. 3 no. construction compounds are required to the west of Heuston Station for works to be undertaken to the Phoenix Park Tunnel (PPT) and the construction of the new Heuston West Station. These compounds will be also be used for the Heuston Yard works

The drainage network for this track section consists of a single pipe branch running parallel to the track beneath the ballast layer.

The proposed track drainage system includes filter drains to collect runoff waters ballast and surrounding areas runoff. The proposed filter drains discharge into the collector pipes through manholes, which are to be spaced between 30 to 50 metres which in turn convey the runoff t othe proposed attenuation structure.

A proposed outfall for the new attenuation tank is to be located between Heuston West Station and Clancy Quay. The attenuated flows will discharge to the Liffey River, at controlled discharge rates.

The proposed location of the Islandbridge Substation is located within the Heuston Yard area along the R148 (St. John’s Road). It is a brown field site in the possession of CIÉ on the southern side of the railway yard. The location can be accessed via a CIÉ-owned track. A construction compound is required at Islandbridge to facilitate the construction of the new electrical substation. Following completion of construction activities, the area will be used for the permanent substation compound.

All the elements of the proposed works for Zone C including the Heuston Station and Yard are presented in Figure 5-3.

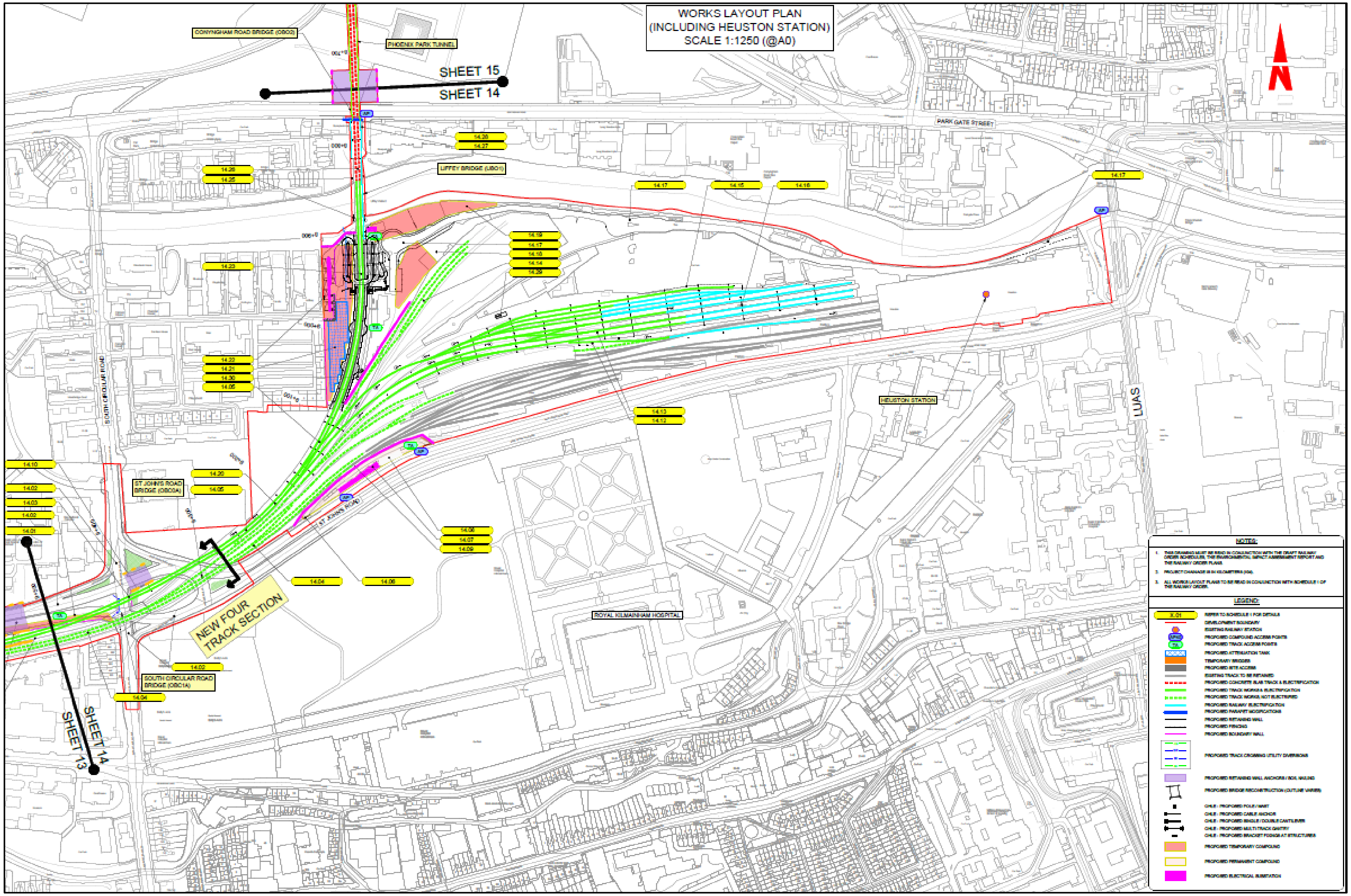


Figure 5-3 Schematic Layout of the proposed development in the environs of Heuston Station

5.1.6. Land Use

Since the preparation of the Draft Development Plan and the making of the Plan by DCC, there have been several significant new sources of information and changes to the Government policy. DCC is reviewing the current Dublin City Development Plan 2016-2022 and preparing a new City Development Plan up to 2028 (Land Zones are shown in Figure 5-4).

High numbers of residential properties in terms of apartment blocks are considered in the area along with the commercial core of the city, mainly zoned as Z5 – City Centre and Z10 – Sustainable Mixed Use.

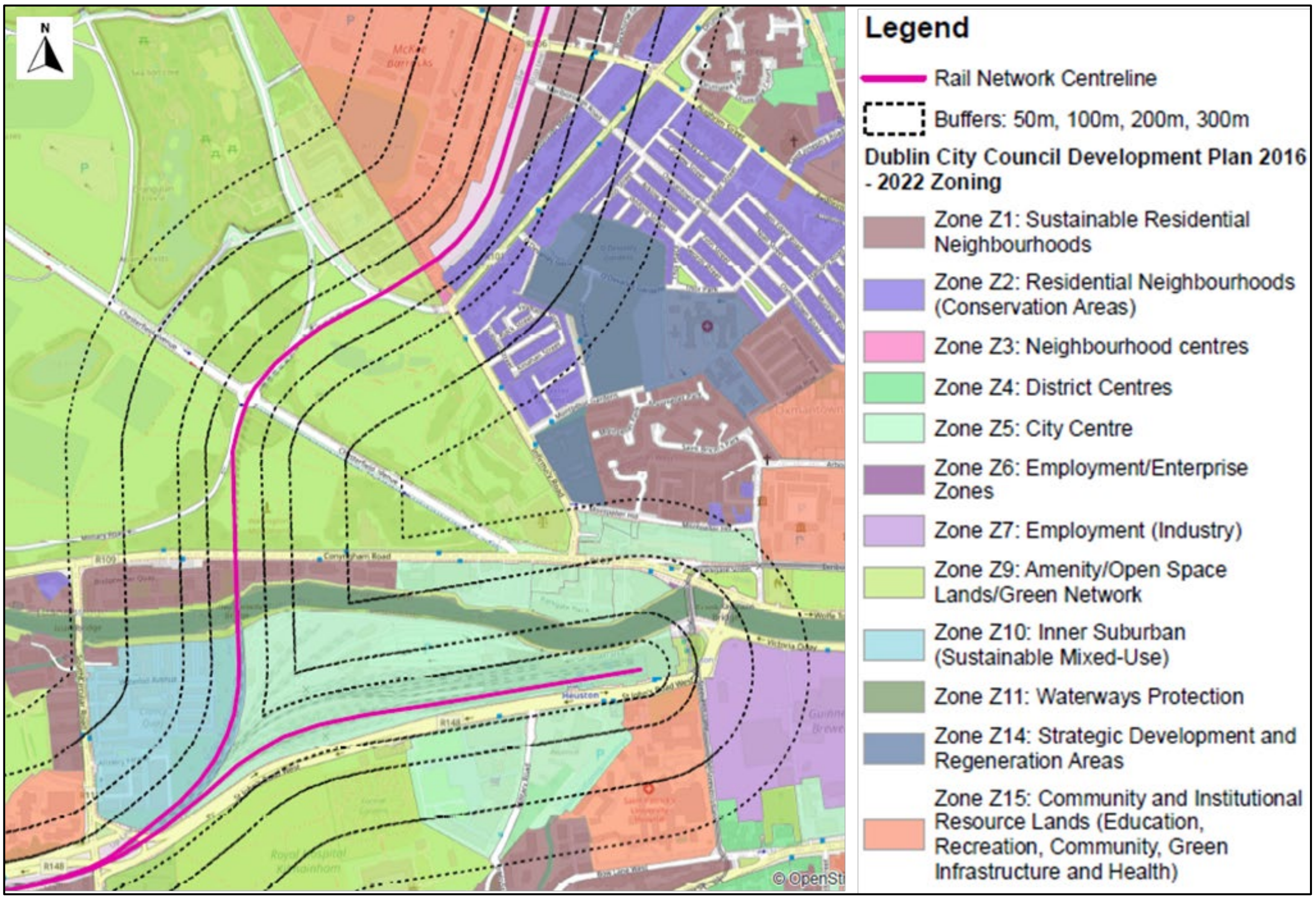


Figure 5-4 Land use map in the vicinity of Heuston Station

5.1.7. Existing Geology and Hydrogeology of the Area

The general superficial geology in the area is anticipated to comprise urban (made ground) deposits (Figure 5-5). It is expected that a layer of till will exist below the made ground deposits overlying bedrock (limestone and shale). Historical ground investigation records show the ground conditions at Heuston Station generally consist of significant thicknesses of made ground, silt, clays and gravels underlain limestone.

From the historical ground investigation information, made ground was described as sandy gravely clay with gravels or cobbles of brick, concrete or slate, to maximum depth of 6.10m bgl. The superficial deposits underlying the made ground are variable and were generally recorded as firm to stiff gravelly clay and silt, above dense to very dense gravels and occasional sand and gravel layers. However, in the north east of this area, a local pocket of soft to firm silt was recorded.

Bedrock was recorded as moderately strong to very strong limestone with thinly laminated mudstone and shale. Rockhead was encountered at depths between 17.5m bgl (12.97m AOD) and 22.65m bgl (16.92m AOD). Bedrock was not proven within any of the exploratory holes in the previous investigations.

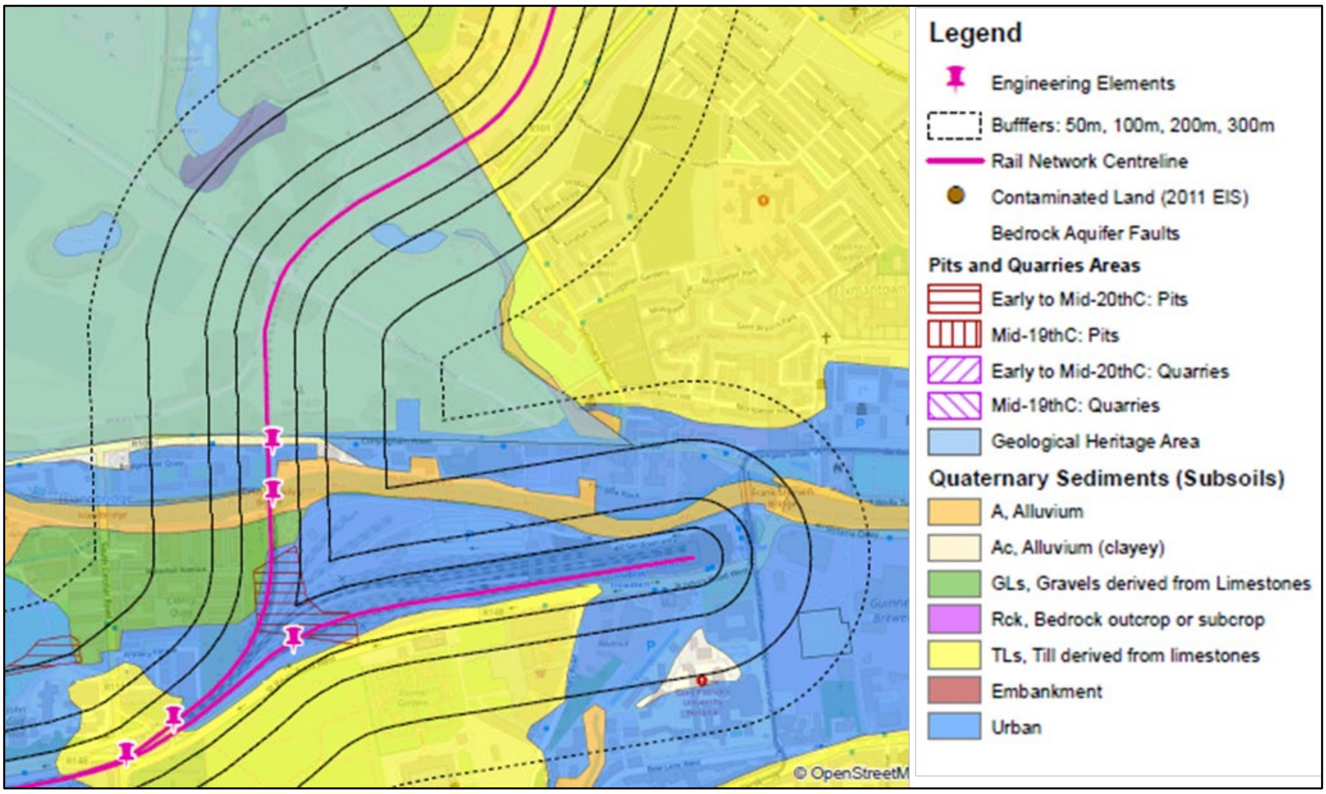


Figure 5-5 GSI Subsoil Mapping (Source Data and maps - GSI https://www.gsi.ie)

The majority of exploratory holes in this area were recorded as being dry or contained no groundwater information. Where groundwater was recorded in exploratory holes, it ranged from between 4.4m bgl to 9.8m bgl.

Groundwater strikes were recorded at 7.50m bgl and 13.50m bgl with no rises was recorded.

To the east, historical ground investigation records show the ground conditions at Heuston Yard to generally consist of similar sequences of strata with significant thicknesses of made ground, silt, clays and gravels underlain by bedrock. Groundwater levels recorded during these investigations to the east ranged from 4.40m bgl to 9.8m bgl.

Hazardous and non-hazardous material within soil samples was identified near to the current location of the proposed NTCC in 2019, which is now under construction and due for completion in early 2022.

The GSI Website classifies the aquifer vulnerability in this region as having moderate vulnerability rating (Figure 5-6). Observation of Table 5.1 below shows that the existing hydrogeological conditions possess a moderate subsoil permeability over a depth greater than 5m. An aquifer with moderate vulnerability means that the fundamental geological and hydrogeological characteristics which determine the ease at which groundwater may get contaminated by human activities.

Table 5.1: GSI vulnerability classification criteria (Source Data and maps – GSI https://www.gsi.ie)

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness			Unsaturated Zone	Karst Features
	High permeability (sand/gravel)	Moderate permeability (e.g. Sandy subsoil)	Low permeability (e.g. Clayey subsoil, clay, peat)	(Sand/gravel aquifers only)	(<30 m radius)
Extreme (E)	0 - 3.0m	0 - 3.0m	0 - 3.0m	0 - 3.0m	-
High (H)	>3.0m	3.0 - 10.0m	3.0 - 5.0m	>3.0m	N/A
Moderate (M)	N/A	>10.0m	5.0 - 10.0m	N/A	N/A
Low (L)	N/A	N/A	>10.0m	N/A	N/A

Notes: (1) N/A = not applicable.
(2) Precise permeability values cannot be given at present.
(3) Release point of contaminants is assumed to be 1-2 m below ground surface.

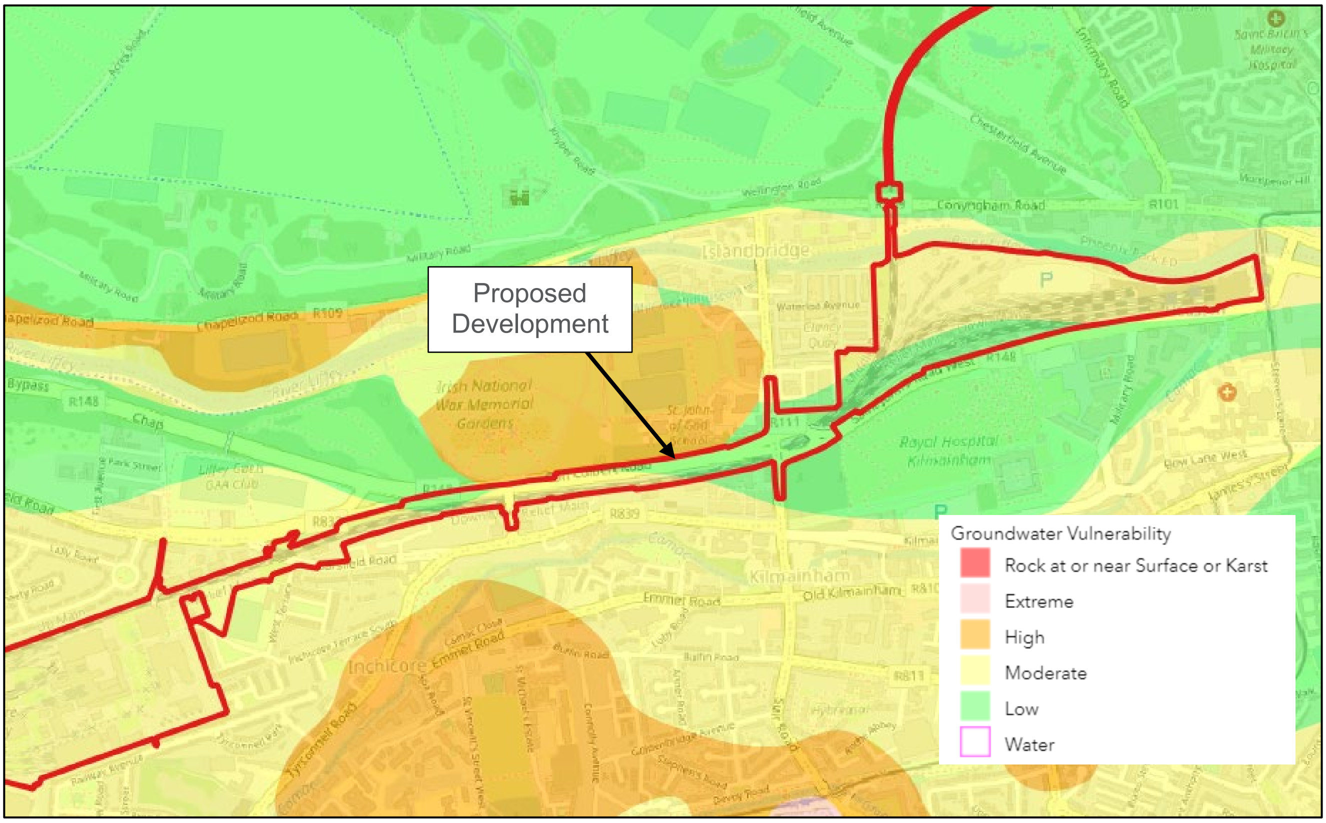


Figure 5-6 GSI Aquifer Vulnerability Mapping (Source Data and maps - GSI https://www.gsi.ie)

5.1.8. Existing Flood Defence Schemes in the Study Area

5.1.8.1. Liffey Flood Defence Scheme

Much of Dublin is relatively well-defended from flooding by the quay walls. The stretch of river bordering the Heuston Station site is defended by a combination of embankments and retaining walls. This currently gives a high standard of protection to the area. However, when designing new developments, the Guidelines require that no defences are assumed to be present when establishing flood zones due to a residual risk that the defences could fail. There is also no guarantee that the defences will be maintained indefinitely.

Appendix 11 - Flood Defence Infrastructure of the Plan of the Dublin City Development Plan 2016-2022 notes the following in relation to future flood defence works in the vicinity of the site:

> *"Liffey: The Liffey is the subject of recently started works. A good portion of the Liffey fluvial area in the Dublin City Council area is well defended by the steep Liffey valley. Most of the city is relatively well defended by the quay walls. There are however a number of low points such as the campshires, Victoria Quay, Wolfe Tone Quay and Matt Talbot Bridge."*

5.1.8.2. Camac Flood Protection Project

The Camac Flood Protection Project was initiated as part of the CFRAM process following major fluvial flooding in 1986 and 2011. It is currently at pre-feasibility stage following no apparent viable overall scheme emanating from the CFRAM process.

5.1.9. Salient Hydrological Features and Existing Flood Regime of the Area

The salient hydrological features, the impacts of which were assessed for flood risk are the Camac, a tributary of Liffey, and the River Liffey. Reports and maps from the OPW Flood Hazard Mapping website (www.floodmaps.ie) have been examined as part of this FRA as presented in Figure 5-7. There are records of two previous flood events, northwest and northeast of the site:

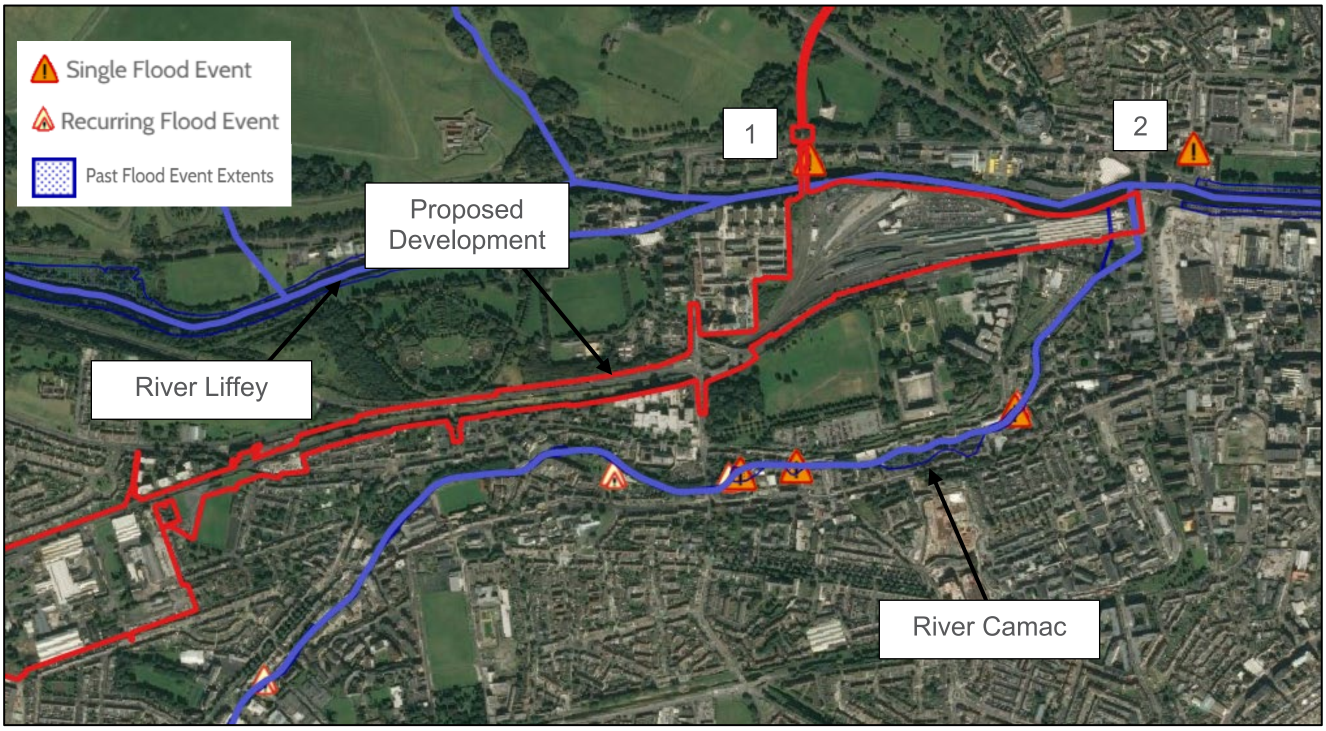


Figure 5-7 Historic flood extent from floodmaps.ie

1) **Flooding at Bridgewater Quay Apartments, Islandbridge, October 2011** – Surface water runoff from the Phoenix Park flowed into the Bridgewater Quay apartment complex and onto South Circular Road Bridge footpath. The River Liffey did not burst its banks in this area; it flooded a low-lying pedestrian walkway.
2) **Flooding at Ashling Hotel, Parkgate Street, October 2011** – Significant rainwater resulted in overland flows down Conyngham Road. Some flows may have come from the Phoenix Park and possibly the nearby Viceregal Stream. The water then pooled in front of the Ashling Hotel and eventually flooded the ground floor entrance.

5.1.10. Results of the previous flood studies

5.1.10.1. Tidal Flood Risk - The Eastern CFRAM Study (HA09), 2017

Coastal flood risk associated with the River Liffey has been assessed. The extents of the development are not located within the predicted flood risk area. Figure 5-8 and Figure 5-9 present the relevant flood maps and corresponding predicted water levels.

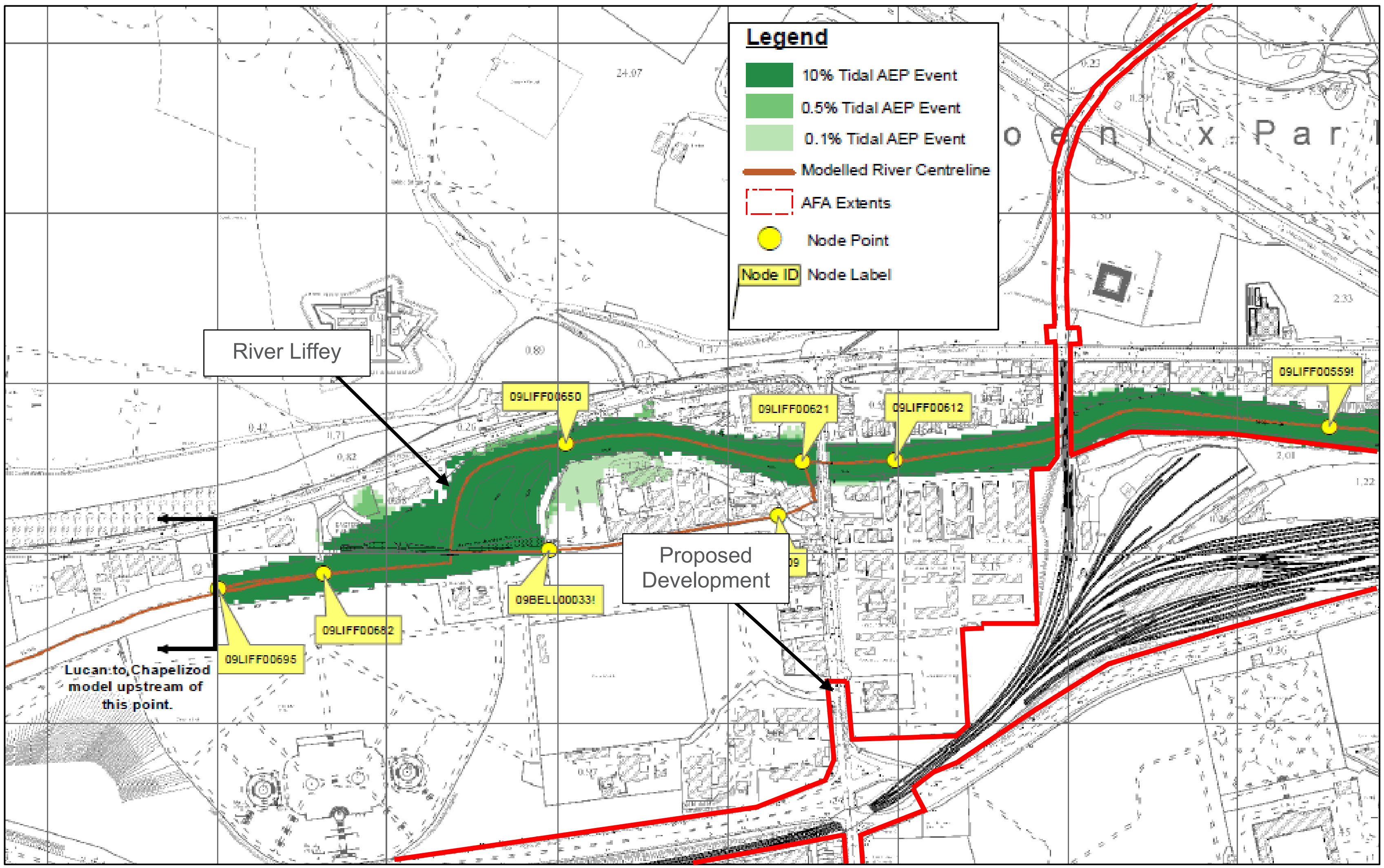


Figure 5-8 Eastern CFRAM Study - Liffey tidal flood extent map (1)[9]

[9] Continues to Figure 5-9 to the east

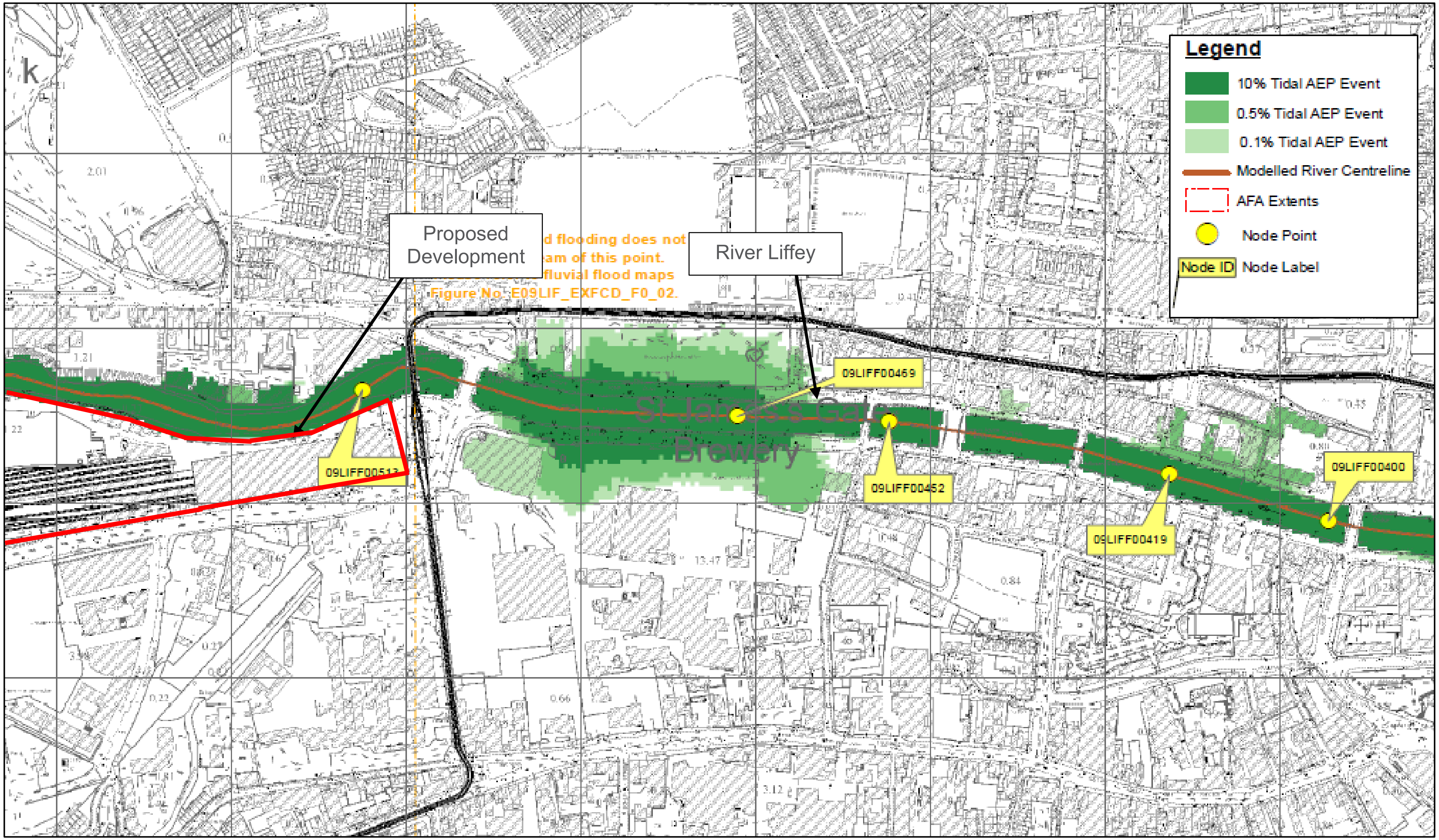


Figure 5-9 Eastern CFRAM Study - Liffey tidal flood extent map (2)

Table 5.2 : Node details - Liffey tidal flood extent map

Node Point	Tidal Flood Levels – Current Scenario		
	10%AEP	**0.5% AEP**	**0.1% AEP**
09LIFF00695	3.51	3.54	3.64
09LIFF00682	3.50	3.52	3.63
09BELL00033!	3.52	3.55	3.66
09LIFF00650	3.06	3.42	3.61
09BELL00009	3.36	3.48	3.63
09LIFF00621	3.01	3.38	3.58
09LIFF00612	2.99	3.36	3.56
09LIFF00559!	2.92	3.31	3.51
09LIFF00513	2.86	3.27	3.48
09LIFF00469	2.82	3.24	3.46
09LIFF00452	2.71	2.92	3.23
09LIFF00419	2.77	3.19	3.41
09LIFF00400	2.75	3.18	3.40

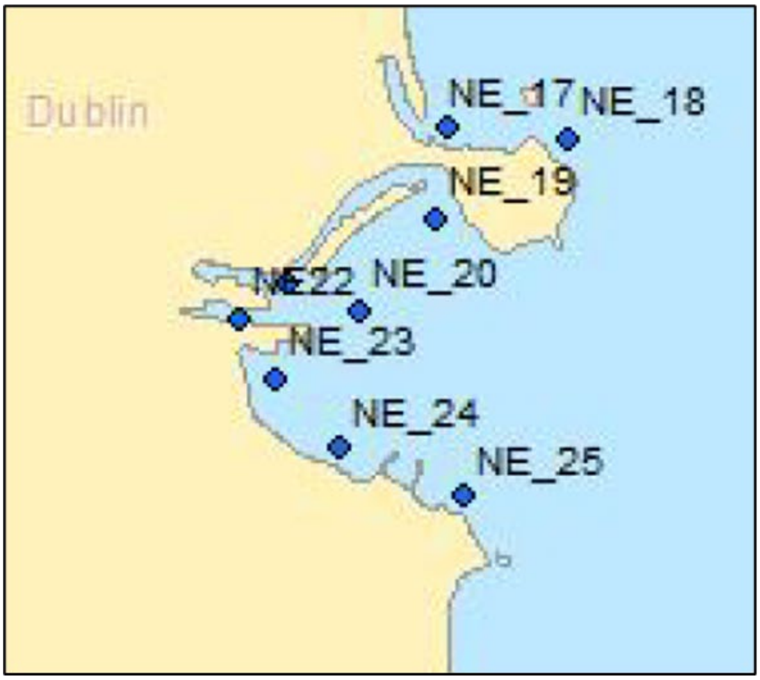
The most relevant nodes to the site are highlighted in grey in Table 5.2 above. It can be seen that the predicted water levels for the 1 in 10 year, 1 in 200 year, and 1 in 1,000 year tidal events vary from 2.86mOD to 3.56mOD. These levels are predictive levels for the current scenario and do not include any uplift for climate change.

5.1.10.2. Irish Coastal Protection Strategy Study Phase 3 - North East Coast, 2018

The ICPSS is a national study that was commissioned in 2003 with the objective of providing information to support decision making about how best to manage risks associated with coastal flooding and coastal erosion. The Study was completed in 2013 and provides strategic current scenario and future scenario (up to 2100) coastal flood hazard maps and strategic coastal erosion maps for the national coastline.

This study used numerical modelling of combined storm surges and tide levels to derive extreme water levels along this stretch of coastline. The application of extreme value analysis and joint probability analysis to both historic recorded tide gauge data and data generated by the numerical model allowed an estimation of the extreme water levels of defined exceedance probability to be established along the relevant sections of coastline.

Based on the various simulations of storms, time series of the water surface elevations were extracted at 29 points. In Figure 5-10, the points presented are the ones corresponding to the North East coast. It is observed that the proposed development site is in the vicinity of Point NE_22 (Figure 5-11). ICPSS predicted flood level has been further updated under the ICWWS (OPW, 2018). The ICPPS mapping was updated further in 2021 under the National Coastal Flood Hazard Mapping Project.



Design Event (AEP)	Point NE_22
50%	2.70
20%	2.79
10%	2.86
5%	2.93
2%	3.01
1%	3.08
0.5%	3.15
0.1%	3.30

Figure 5-10 ICPSS - Overview of Surge Model Runs, North East Coast – ICWWS - Water Levels for NE_22 – Meters to OD Malin (OSGM-15)

Figure 5-11 Location of the Proposed Development and NE_22

5.1.10.2.1. Current Scenario Coastal Flood Extent Map

The National Coastal Flood Hazard Mapping 2021 current scenario flood map for the 0.5% AEP Indicative flood extent and 0.1% AEP (extreme flood extent) in the vicinity of the study area is presented in Figure 5-12. The extract from the tidal flood extent map indicates that all the proposed development site is located outside of the 0.5% AEP coastal flood extent (or 1 in 200 Return Period in any given year). Consequently, all the existing site is situated in Flood Zone C, where the probability of tidal flooding is the lowest. Figure 5-12 illustrates the tidal flood extents (mOD Malin) for the 10%, 0.5% and 0.1 % AEP flood events associated with the current scenario at Node Point NE_22.

5.1.10.2.2. Mid-Range Future Scenario MRFS Coastal Flood Extent Map

Similarly, the National Coastal Flood Hazard Mapping 2021 MRFS flood map for the 0.5% AEP (Indicative flood extent) and 0.1 % AEP (extreme flood extent) in the vicinity of the study area is presented in Figure 5-13. The extract from the tidal flood extent map indicates that the proposed development site is not located within the 0.5% Annual Exceedance Probability (AEP) flood extent (or 1 in 200 Return Period In any given year). Consequently, the entire site is situated In Flood Zone C, where the probability of coastal flooding is low. Figure 5-13 illustrates the tidal flood water extents (mOD Malin) for the 10%, 0.5% and 0.1% AEP flood events associated with the MRFS at Node Point NE_22.

5.1.10.2.3. Current Scenario Coastal Flood Depth Map

Figure 5-14 presents an extract of the National Coastal Flood Hazard Mapping 2021 depth map for the 0.5% AEP (200-year return period) for the current scenario. Depth maps illustrate the estimated flood depths for areas inundated by a flood event of a given probability of occurrence which provides useful information for emergency services and property owners. The map depicts a range of depth bands ranging from 0 - 0.25m to a depth band greater than 2.00m resulting from coastal flooding. The approximate (due to low resolution mapping) depth bands from tidal flooding is predicted to range from 0.25 - 0.50m to 0.50 - 1.00m for the proposed development site.

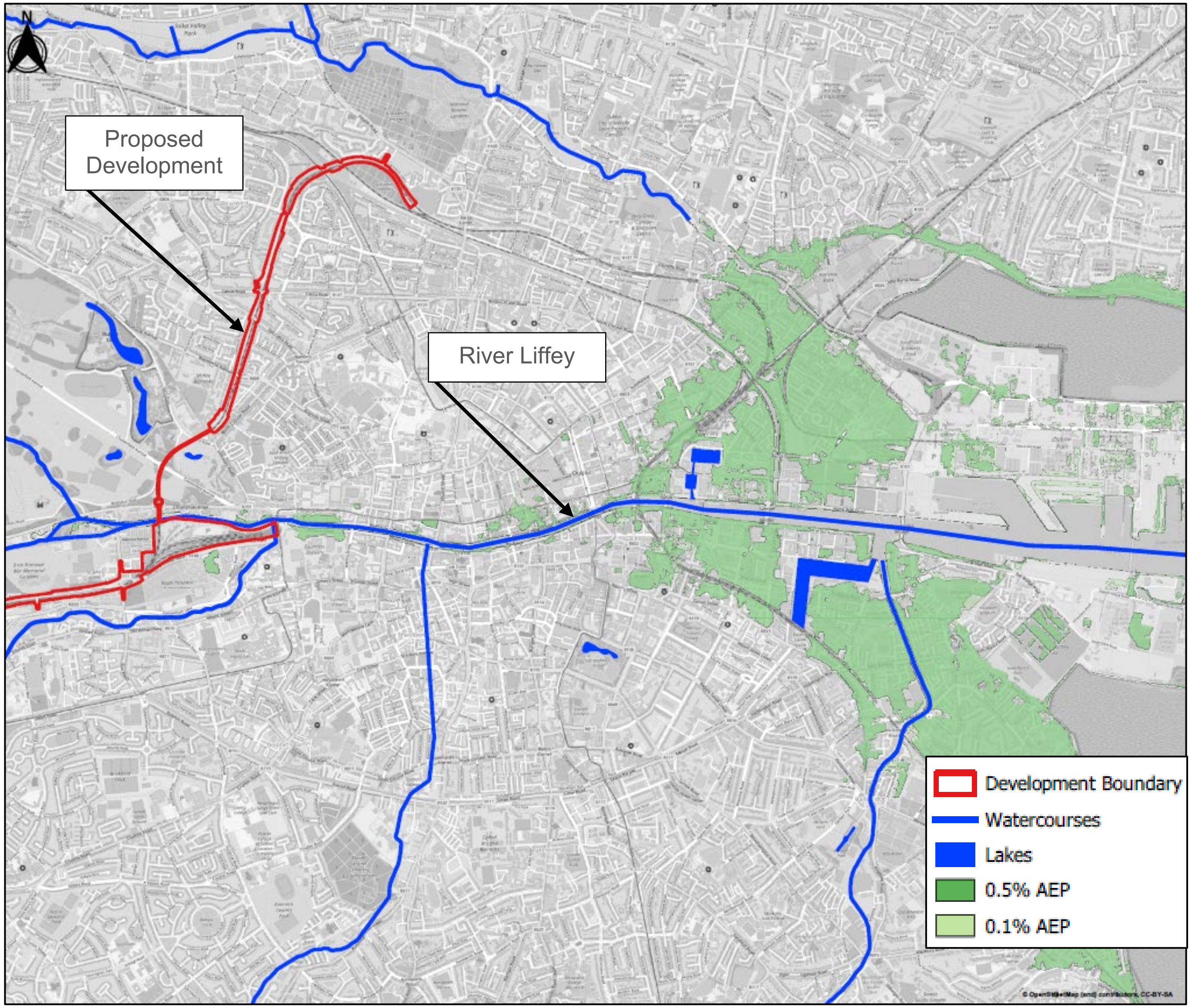


Figure 5-12 Extract of National Coastal Flood Hazard Mapping 2021 Current Scenario Coastal Flood Extent Map (Source: OPW)

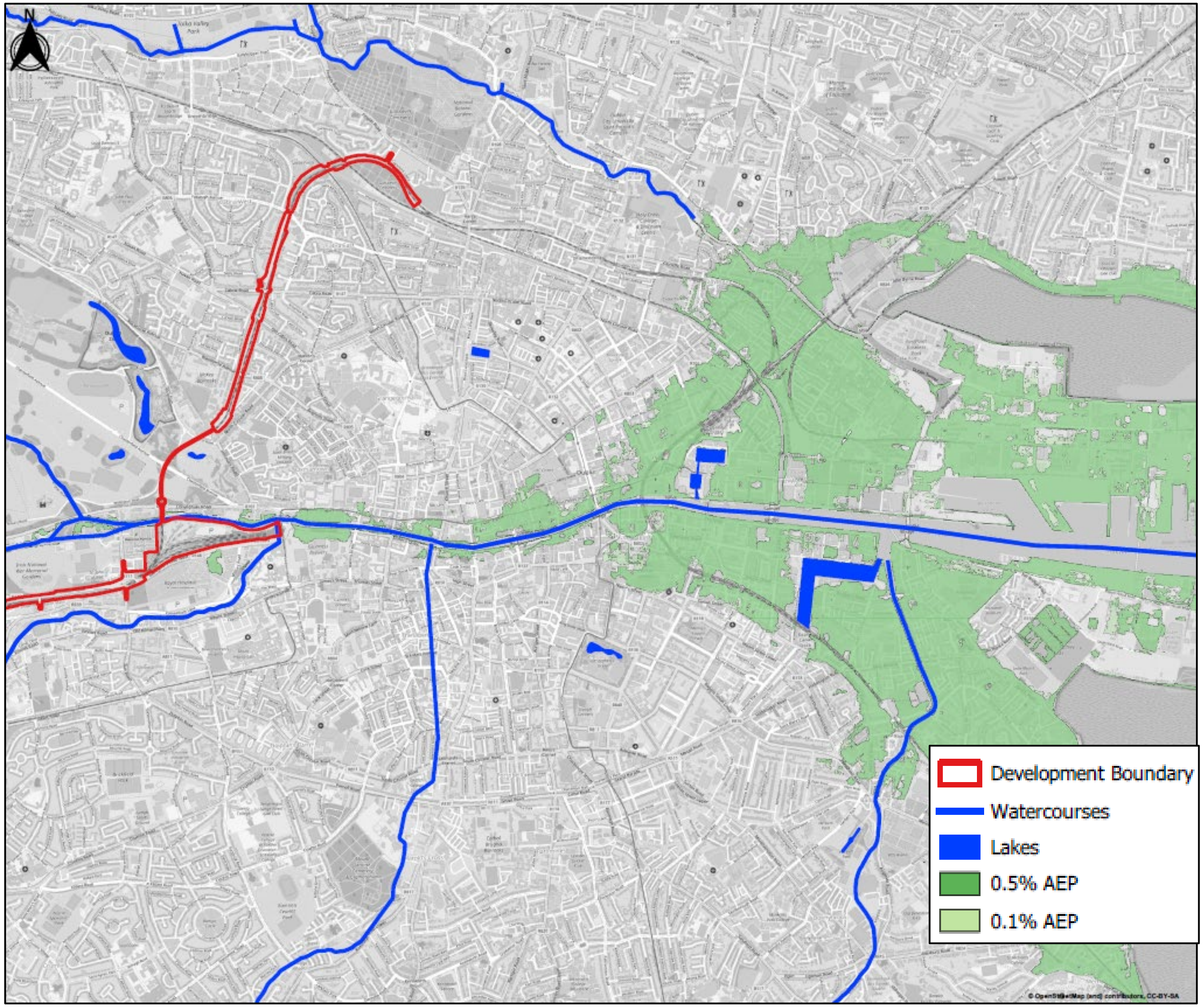


Figure 5-13 Extract of National Coastal Flood Hazard Mapping 2021 MRFS Coastal Flood Extent Map (Source: OPW)

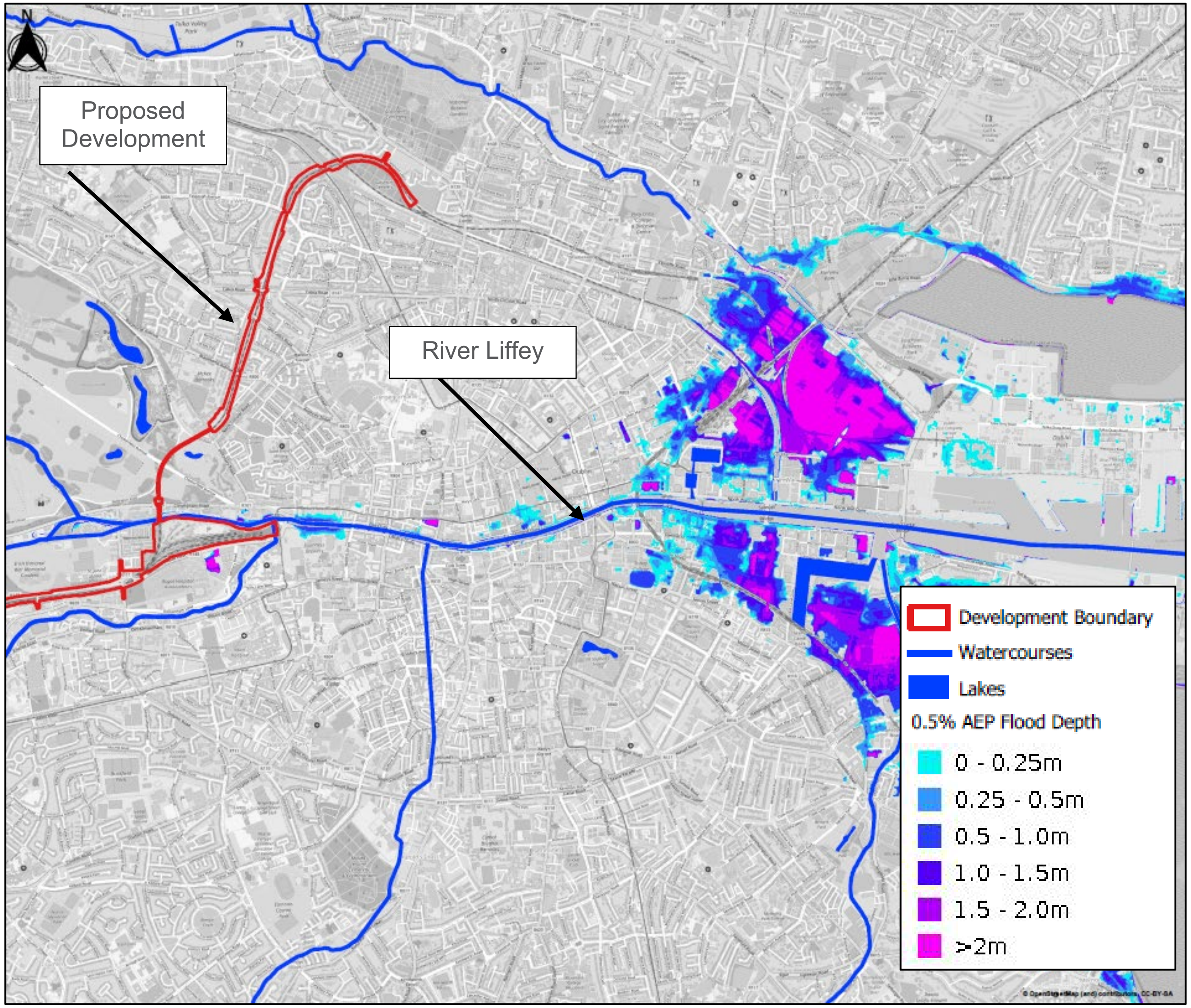


Figure 5-14 Extract of National Coastal Flood Hazard Mapping 2021 Depth map at 0.5% AEP (1 in 200 chance in any given year) (Source: OPW)

5.1.10.3. Fluvial Flood Risk - Eastern CFRAM Study (HA09), 2017

The Eastern CFRAM fluvial flood extent maps are presented in the following Figure 5-15 to Figure 5-17. The predicted flood extents for three separate return period events are presented on the map: 1 in 10, 100, and 1000 year for the Rivers Liffey and Camac, one of the main tributaries of Liffey which is culverted along the extents of the study area and crosses beneath the Heuston Station. It can be seen on the map that the proposed works lies outside the extent of all three fluvial events of the Liffey but is located withing the 0.1% AEP Fluvial Event for River Camac.

Table 5.3: Node details - Liffey fluvial flood extent map

Node Point	Flood Levels – Current Scenario		
	10%AEP	1%AEP	0.1%AEP
09LIFF00695	3.63	3.79	4.30
09LIFF00682	3.59	3.72	4.22
09BELL00033!	3.62	3.79	4.31
09LIFF00650	3.17	3.62	4.18
09BELL00009	3.42	3.69	4.25
09LIFF00621	3.09	3.50	4.03
09LIFF00612	3.05	3.45	3.95
09LIFF00559!	2.92	3.25	3.69
09LIFF00513	2.82	3.10	3.50
09LIFF00508	2.82	3.11	3.51
09LIFF00469	2.75	2.99	3.36
09LIFF00452	2.71	2.92	3.23
09LIFF00419	2.64	2.80	3.04
09LIFF00400	2.61	2.74	2.94

The most relevant nodes to the site are highlighted in grey in Table 5.3 above. It can be seen that the predicted water levels for the 1 in 10 year, 1 in 100 year, and 1 in 1,000 year fluvial events vary from 2.82mOD to 3.95mOD.

Table 5.4: Node details - Camac fluvial flood extent map

Node Point	Flood Levels – Current Scenario		
	10%AEP	1%AEP	0.1%AEP
09CAMM00125	9.61	10.18	10.93
09CAMM00084	6.88	7.68	8.49
09CAMM00027L	3.29	4.37	6.09

The relevant node to the site is highlighted in grey in Table 5.4 above for the various events and predicted levels to vary between 3.29mOD to 6.09mOD. This flood extent map shows some eastern part of the site area at the location of Heuston Station to be liable to fluvial flooding, however, not the at the proposed development location.

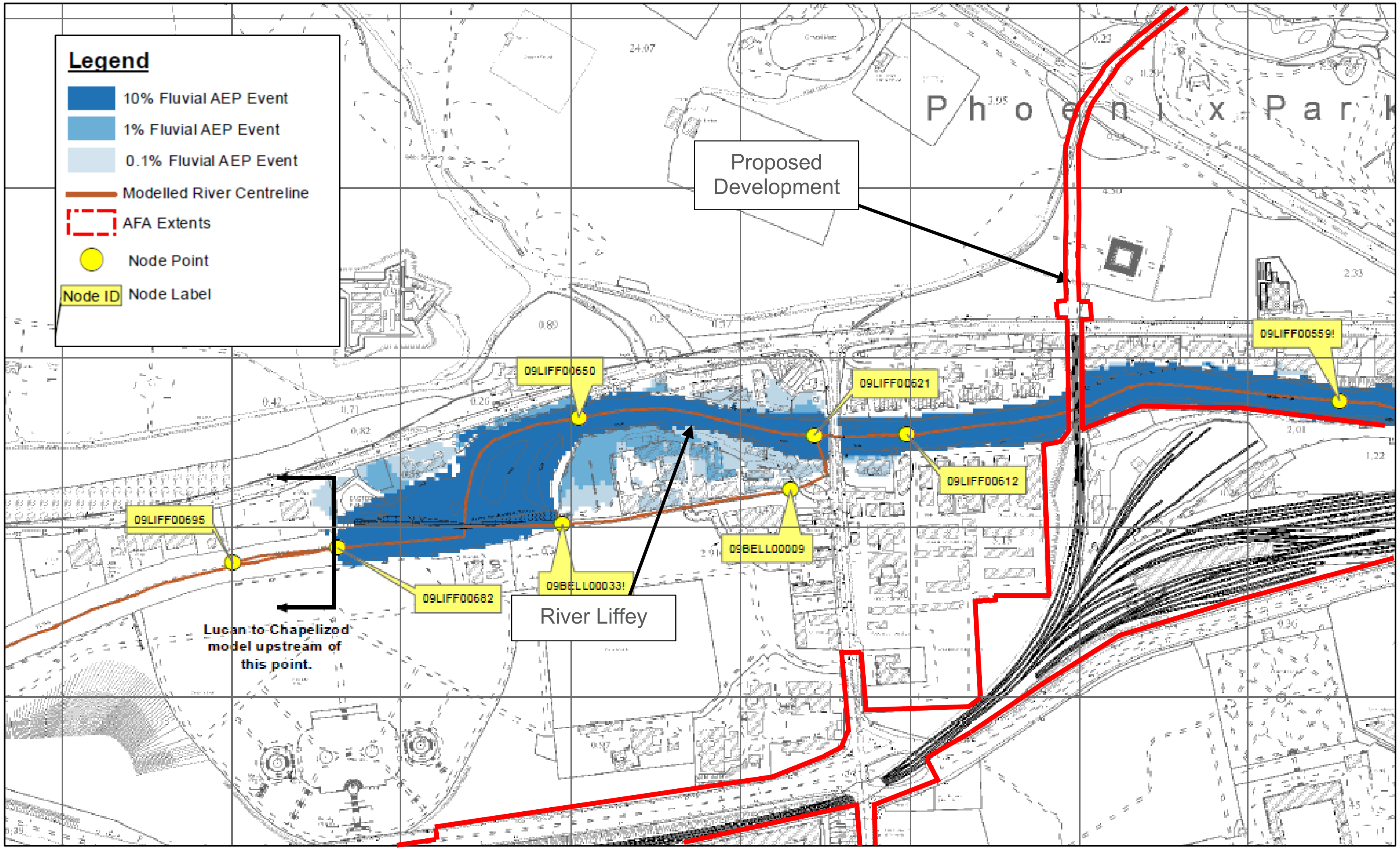


Figure 5-15 Eastern CFRAM Study - Liffey fluvial flood extent map (1) [10]

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[10] Continues to Figure 5-16 to the East

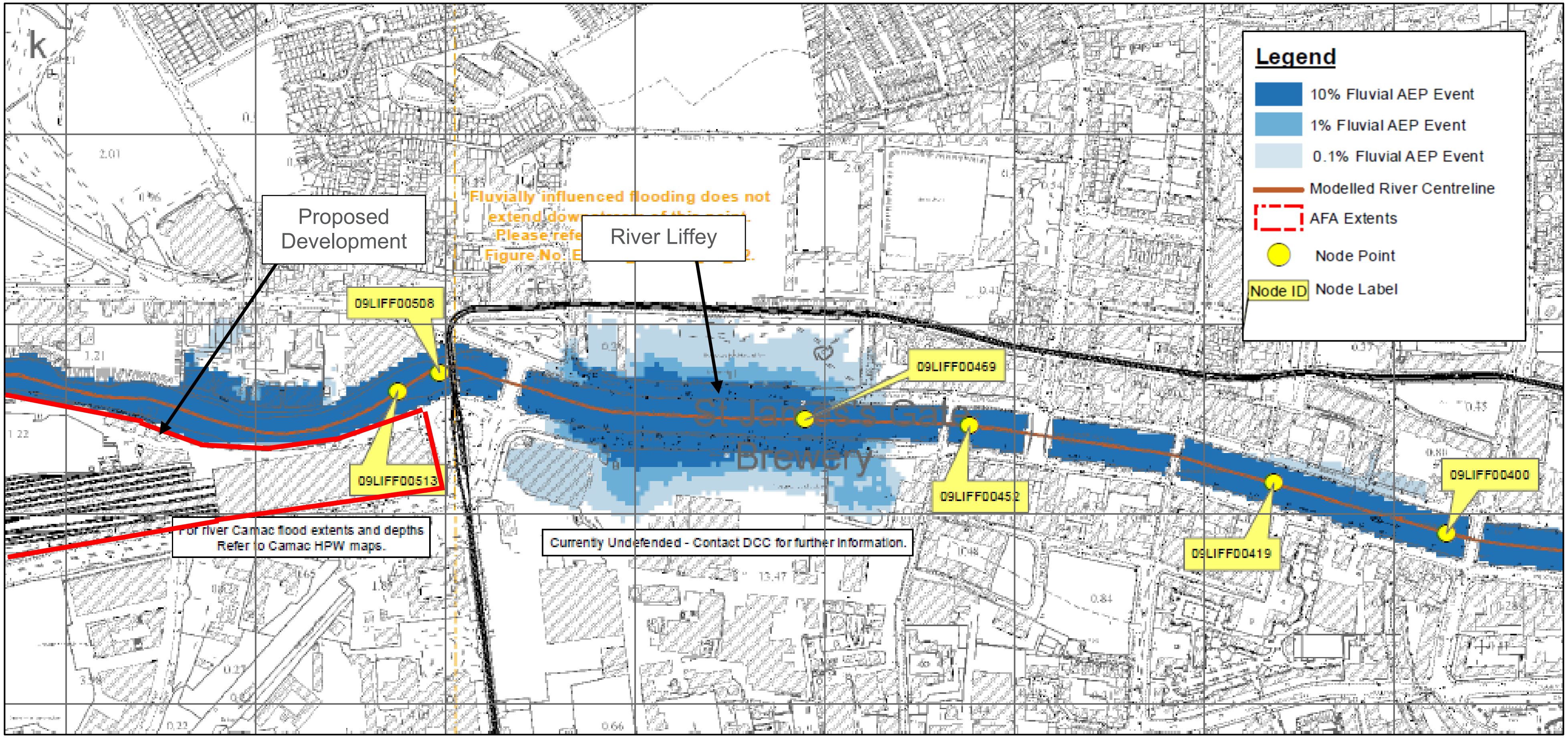


Figure 5-16 Eastern CFRAM Study - Liffey fluvial flood extent map (2)

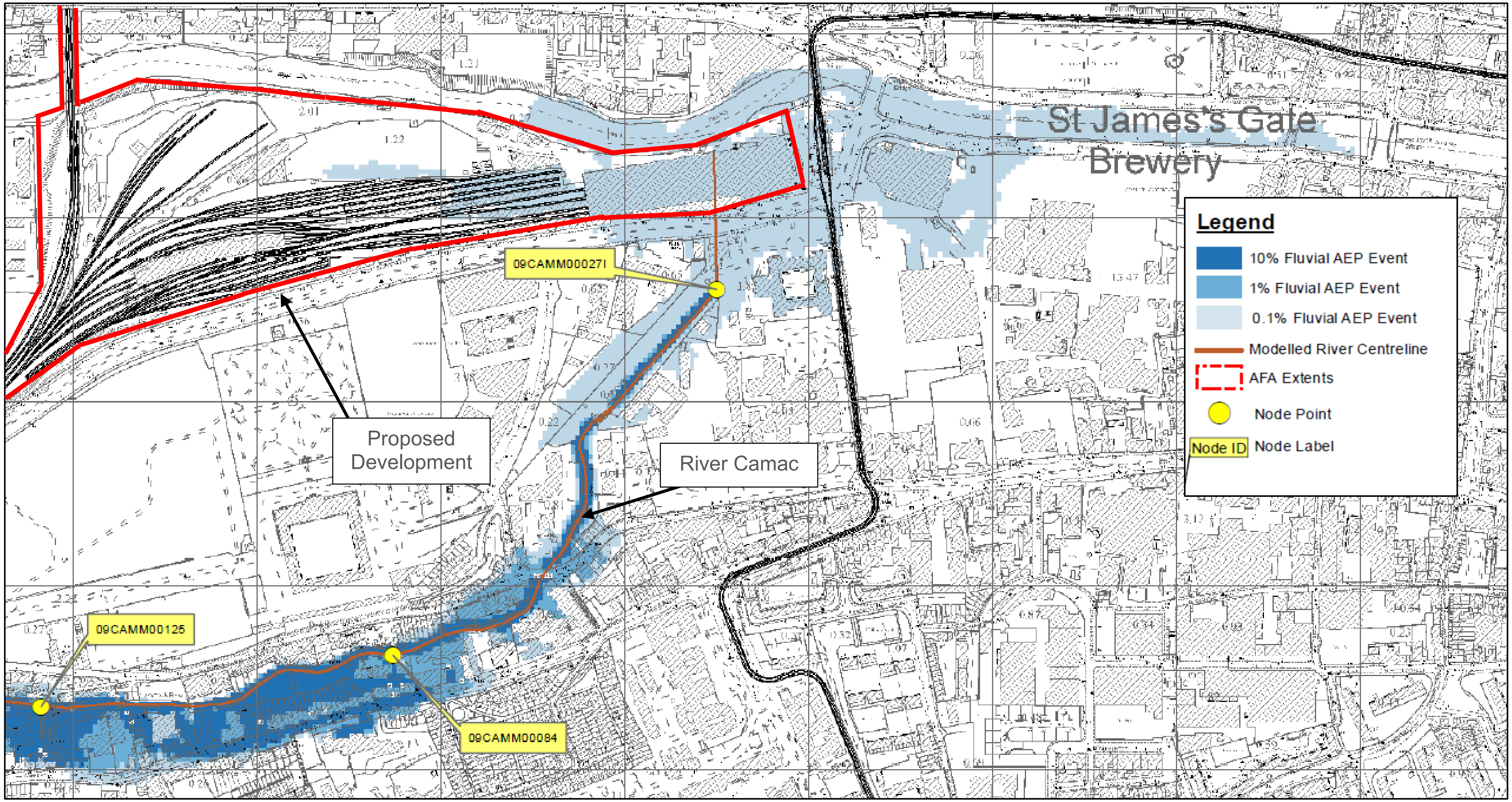


Figure 5-17 Eastern CFRAM Study - Camac fluvial flood extent map

5.1.10.4. Pluvial Flood Risk - Interreg IVB Flood Resilient City Project

Figure 5-18 presents a map of the modelled area from the FRC project, as detailed in Section 4.1.7. The layers show the modelled extent of land that might be directly flooded by rainfall under existing (Do-minimum) conditions. The proposed development is susceptible to pluvial flooding under all probabilities.

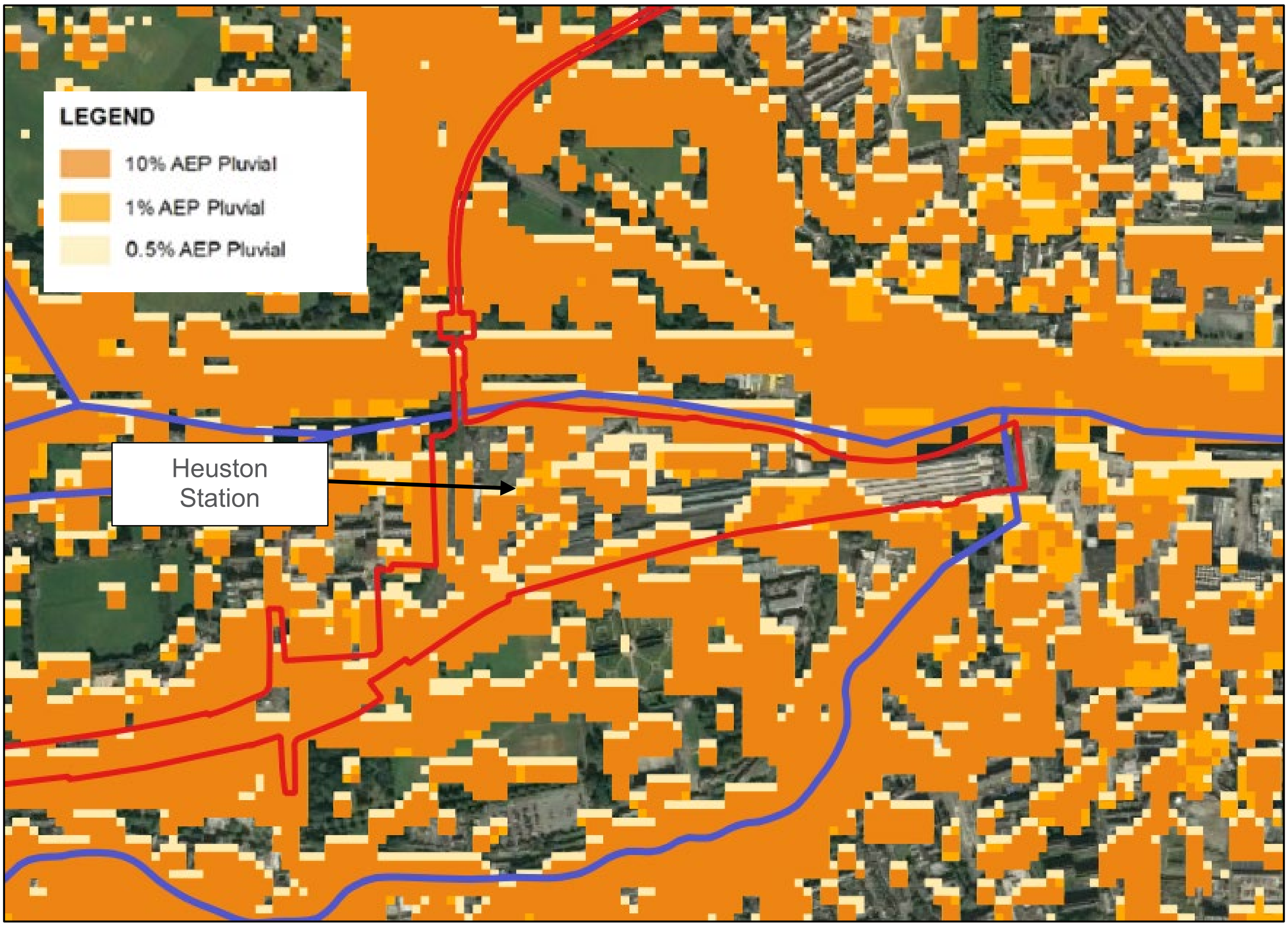


Figure 5-18 Rainfall Flood Extents – Dublin City Area (Source: https://www.floodinfo.ie/map/floodmaps/)

5.1.11. Conclusion of Stage 1 – Flood Risk Identification

Records of historical flooding, the flood extent mapping generated for the study area, and other records outlined in the preceding sections indicated that the proposed Development is potentially at risk from fluvial and pluvial flooding and to a lesser extent from coastal flooding. Therefore, the FRA was progressed to STAGE 2 – INITIAL FLOOD RISK ASSESSMENT.

5.2. Stage 2 – Initial Flood Risk Assessment

5.2.1. Sources of Flood Risk

5.2.2. Flood Risks and Flood Zone Mapping Summary

The purpose of the Stage 2 - Initial FRA was to appraise the availability and adequacy of the identified flood risk information, to qualitatively appraise the flood risk posed to the site and potential impacts on flood risk elsewhere and recommend possible mitigation measures to reduce the risk to acceptable level. In consideration of the above assessment, the primary flood risk to the proposed Development was attributed to:

- Coastal - Medium Risk;
- Fluvial – High Risk; and
- Pluvial– High Risk.

Coastal flood risk at the proposed location is considered to be medium. This has been concluded following a review of the ECFRAM Study, and the ICPSS.

5.2.3. Flood Risks and Flood Zone Mapping Summary

As mentioned above, the most significant source of fluvial flooding based on the ECFRAM Studies at the area is from River Camac in the vicinity of Heuston Station, which locates the site in **Flood Zone B,** given that the site boundaries are within the 1 in 1,000 year flood event extent.

The study area is also susceptible to pluvial flooding based on the FloodResilienCity Project mapping. It can be seen that the proposed site will potentially lie within **Flood Zone A and Flood Zone B.**

5.2.4. Conclusion of Stage 2 – Initial Flood Risk Assessment

The proposed Development was identified to have a fluvial and pluvial flood risk and hence a further assessment of the implications to the proposed site and surrounding areas is necessary. A review of the available flood extent mapping and reports indicates that the eastern part of the proposed Development is at risk from fluvial flooding for the 0.1% AEP event at a predicted level of 6.09 mAOD, without any allowance for climate change.

The buildings and infrastructure for the proposed Development shall be protected for the design event of 0.1% AEP inclusive of climate change. The finished floor levels for the new Heuston West Station and the Island bridge substation buildings for this scenario shall provide the minimum standard of protection which shall include a freeboard of 500 mm.

The flood levels and protection levels proposed have not been investigated using hydraulic modelling therefore the FRA was progressed to STAGE 3 – DETAILED FLOOD RISK ASSESSMENT to improve the accuracy of these levels and to assess the residual impact of the proposed mitigation measures on the predicted 0.1% AEP event flood extents in the surrounding area. Furthermore, the proposed development area in the environs of Liffey and Camac was modelled in a 1D/2D space, with the profiles of the outfalls to be assessed for various scenarios.

Joint scenarios for fluvial combined with tidal was developed, given the potential for surface water discharge to be tidally locked at high water level events, causing exacerbated surface water ponding upstream. Standard drainage design following the criteria set out by DCC should limit the risk of pluvial flooding to being low in normal tidal conditions but an assessment of the surface water discharge at high tide levels is recommended to be undertaken to assess any risk of flooding to the development site.

5.3. Stage 3 – Detailed Flood Risk Assessment

5.3.1. Overview

The objective of the detailed assessment is to identify locally predicted flood levels for the proposed Development and also to assess the potential impact of the proposed mitigation measures. The proposed measures may displace flood waters and adversely impact the site itself or the surrounding area.

5.3.2. Hydrology

5.3.2.1. Existing Study

As noted in Section 5.1.10 previous hydrological analysis for the study area was undertaken as part of the Eastern CFRAM Study. The CFRAM Study identified flood extents and flood levels have been used to calibrate the hydraulic model of this FRA.

5.3.2.2. Catchment Review

The FSU demarcated catchment for the River Liffey was utilised for the FRA as it is the most comprehensively defined Liffey catchment for flood studies within Ireland. A review of the Liffey catchment for the purposes of this FRA, would be excessive and unnecessary for the site specific scale of this FRA. The River Camac catchment was reviewed and updated using GIS based tools as previously detailed in Section 2.6.1. The updates were checked against aerial imagery and historical OSI mapping. The Liffey and Camac catchments are shown in Figure 5-19.

5.3.2.3. Peak Flows Estimation

The design flows estimation employed FSU and UK IH techniques to predict flood discharges at various locations across the modelled extents. These methodologies are previously detailed in Section 2.6.2.2.

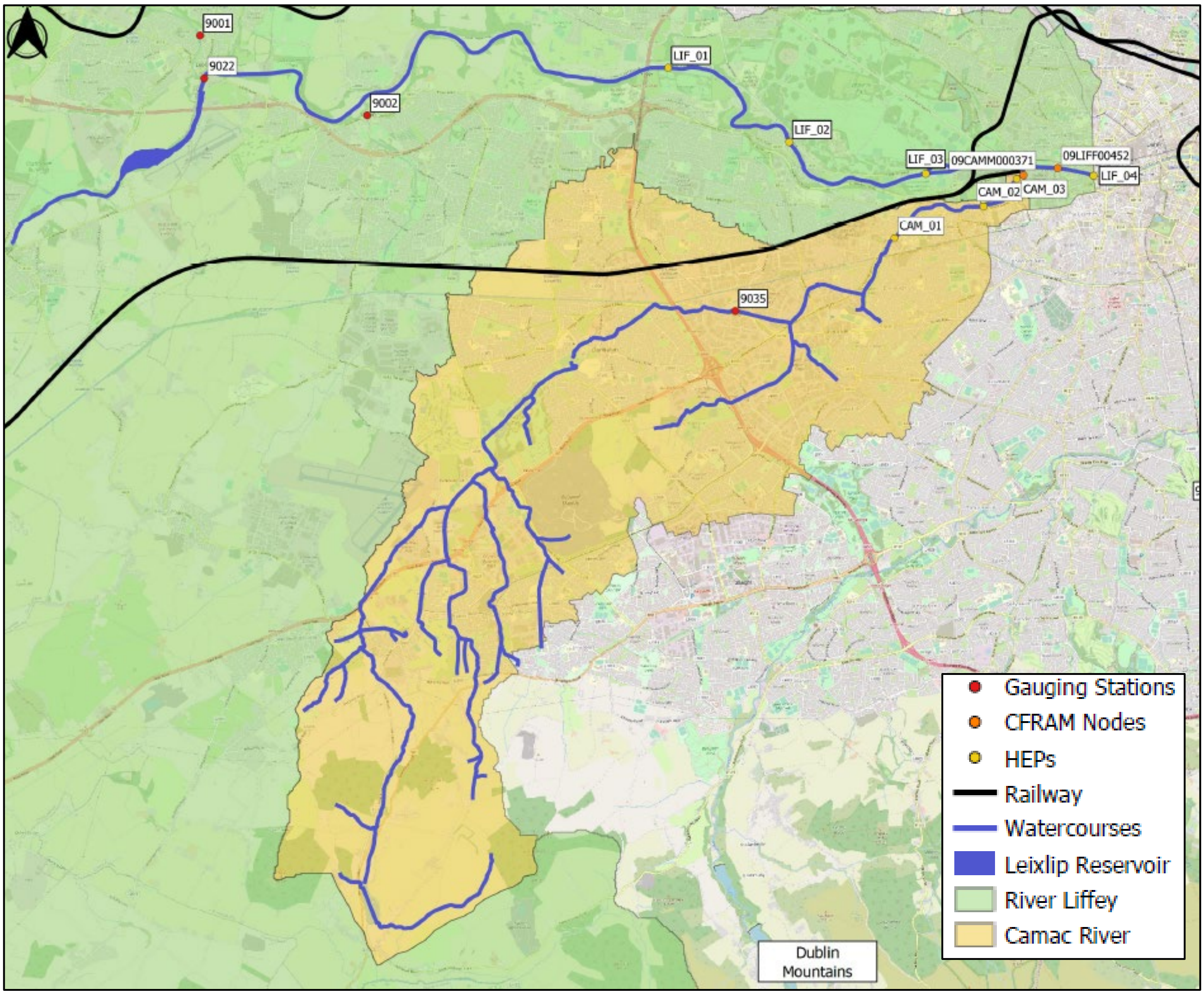


Figure 5-19 River Camac and River Liffey Catchments and HEPS

5.3.2.3.1. Pivotal Site Adjustment

Analysis was undertaken to identify the adjustment factor for both watercourses. For the Camac River the Killeen Road gauging station (9035) is located upstream of the model extents. For the River Liffey there is no suitable gauging station along its length. The station at the Lucan Reservoir (9022) is upstream of its confluence with the Ryewater which adds a large flow to the Liffey. Adjustment Factors for HEPs along the Liffey and Camac were estimated using the mean value of adjustment factors of five hydrological similar gauged catchments using the method previously described in Section 2.6.2.2. An adjustment factor for Killeen Road (9035) was estimated, however the adjustment factor would lead to the design flows for the Camac being substantially reduced and thus was discounted.

5.3.2.3.2. Urban Adjustment

UAFs were applied using the same methodology as shown in Section 2.6.2.2.

5.3.2.3.3. Growth Factor/Curve Development

Growth curves and growth factors were defined as per the methodology described in Section 2.6.2.3.

5.3.2.3.4. Design Hydrographs

Growth curves and growth factors were defined as per the methodology described in Section 2.6.2.4. HEPs in this study were adjusted using the observed flood hydrographs at the stations listed in Table 5.5.

Table 5.5: Design Hydrograph Method Pivotal Sites Adjustment

Watercourse	Gauging Station
Liffey	Killardry (16007)
Camac	Whitebridge (22009)

5.3.2.4. Physical Catchment Descriptors

Table 5.6 shows the PCD values associated with all HEPs identified in the study area, as shown in Figure 5-19.

Table 5.6: PCD values for HEPs

Watercourse	HEP	AREA (km^2)	SAAR (mm)	URBEXT	SOIL	BFISOIL	DRAIND (km/km^2)	S1085 (m/km)	ARTDRAIN2
Camac	CAM_01	58.048	776	0.587	0.344	0.598	0.959	12.342	0.000
Camac	CAM_02	60.297	775	0.603	0.342	0.593	0.952	11.808	0.000
Camac	CAM_03	60.681	775	0.610	0.342	0.581	0.959	11.384	0.000
Liffey	LIF_01	1128.120	810	0.075	0.364	0.569	0.920	2.148	0.036
Liffey	LIF_02	1135.296	808	0.077	0.364	0.569	0.917	2.019	0.035
Liffey	LIF_03	1140.454	806	0.079	0.363	0.568	0.916	1.908	0.035
Liffey	LIF_04	1149.835	804	0.084	0.363	0.568	0.912	1.822	0.035

5.3.2.5. Design Peak Flows

5.3.2.5.1. Index Flood Flows

<u>Qmed Estimates</u>

The Index-floods, Qmed, for all HEPs have been estimated in accordance with the methodology discussed in Section 2.6.2.2.1. Table 5.7 below presents the estimated Qmed & Qbar values.

Table 5.7: HEPs – PCD based Qmed & Qbar estimates

HEP	FSU PCD Qmed-rural (m^3/s)			IH124 Qbar (m^3/s)	FSU PCD -Qmed-urban (m^3/s)			IH124 Qbar Urban (m^3/s)
	7-Var	5-var	3 Var		7-Var	5-var	3 Var	
CAM_01	8.29	12.42	7.60	9.50	16.43	24.62	15.07	32.98
CAM_02	8.55	12.79	7.93	9.70	17.19	25.73	15.96	34.71
CAM_03	8.72	12.99	8.23	9.74	17.67	26.30	16.67	35.28
LIF_01	103.31	132.26	99.87	158.66	114.97	147.19	111.14	192.91
LIF_02	102.32	130.57	100.14	158.73	114.28	145.83	111.84	194.30
LIF_03	101.42	129.03	100.42	158.72	113.46	144.34	112.34	194.91
LIF_04	100.98	128.26	100.94	159.05	113.73	144.45	113.69	197.76

Table 5.8 presents the estimated adjustment factors for the HEPs based on the mean values pf adjustment factors from five hydrological similar gauged catchments.

Table 5.8: Mean Adjustment Factor from Hydrological Similar Gauged Catchments

HEP	Best Performing Hydrological Equation	Recommended Adjustment Factor
CAM_01	QMED (m3/s) 7 Variable	1.199
CAM_02	QMED (m3/s) 7 Variable	1.199
CAM_03	QMED (m3/s) 7 Variable	1.199
LIF_01	QMED (m3/s) 7 Variable	0.995
LIF_02	QMED (m3/s) 7 Variable	0.995
LIF_03	QMED (m3/s) 7 Variable	0.995
LIF_04	QMED (m3/s) 7 Variable	0.995

Design Index Floods

Table 5.9 presents the adjusted Qmed values for all the HEPs selected on the proposed model watercourse.

Table 5.9: Estimated Design Index-floods

HEP	Qmed (m^3/s)
CAM_01	19.705
CAM_02	20.612
CAM_03	21.185
LIF_01	114.422
LIF_02	113.734
LIF_03	112.919
LIF_04	113.185

5.3.2.5.2. Growth Factors / Curves Estimation

Using the selection guidelines for growth curves as detailed in 2.6.2.3, it is recommended to use a pooled analysis growth curve. A GEV distribution was chosen as it produced the most appropriate curve. The selected growth factors are shown in Table 5.10.

Table 5.10: Design Growth Factors

HEP	Growth Factors	
	1% AEP	0.10% AEP
CAM_01	2.296	2.942
CAM_02	2.344	2.942
CAM_03	2.344	2.942
LIF_01	2.016	2.825
LIF_02	2.010	2.810
LIF_03	2.010	2.810
LIF_04	2.037	2.862

5.3.2.6. Estimated Peak Flows

Table 5.11 presents the estimated design peak flows for all HEPs selected on the proposed model watercourse for a 1% and 0.1% AEPs. This has been estimated as the product of Qmed (Index-flood) and the value of the growth factor associated with any of the AEPs.

Table 5.11: Estimated Design Peak Flows

HEP	Peak Flows (m^3/s)	
	1% AEP	0.10% AEP
CAM_01	45.244	57.973
CAM_02	48.315	60.640
CAM_03	49.657	62.325
LIF_01	230.709	323.203
LIF_02	228.562	319.556
LIF_03	226.925	317.267
LIF_04	230.529	323.945

5.3.2.6.1. CFRAM & FRA Design Flow Comparisons

Table 5.12 shows a comparison between the CFRAM and FRA derived design flows. The FRA design flows for the Camac for the 1% AEP are slightly lower than the CFRAM design flows but for the 0.1% AEP they are much lower. The FRA design flows for the Liffey for the 1% AEP are higher than the CFRAM design flows, however the 0.1% AEP design flows they are slightly lower. The CFRAM nodes can be seen on Figure 5-19. The decrease in flows is due to the difference in growth factors used. The CFRAM study used generalised regional growth factors based on the catchment size for the entirety of the River Liffey Hydrometric Area. This approach was a conservative approach. In the current study a site specific approach was adopted.

Table 5.12: CFRAM & FRS Design Flow Comparisons

CFRAM Node	CFRAM 1% AEP (m^3/s)	CFRAM 0.1%AEP (m^3/s)	FRA 1% AEP (m^3/s)	FRA 0.1% AEP (m^3/s)
09CAMM000371	50.7	88.7	49.66	62.325
09LIFF00452	208.54	276.87	220.1	269.008

5.3.2.7. Design Flood Hydrographs

5.3.2.7.1. Characteristic Flood Hydrographs

The characteristic flood hydrograph for the modelled watercourses were generated using the methodology as described in Section 2.6.2.4.1. Figure 5-20 illustrates the estimated characteristic flood hydrograph for the Camac River having been adjusted by hydrologically similar station.

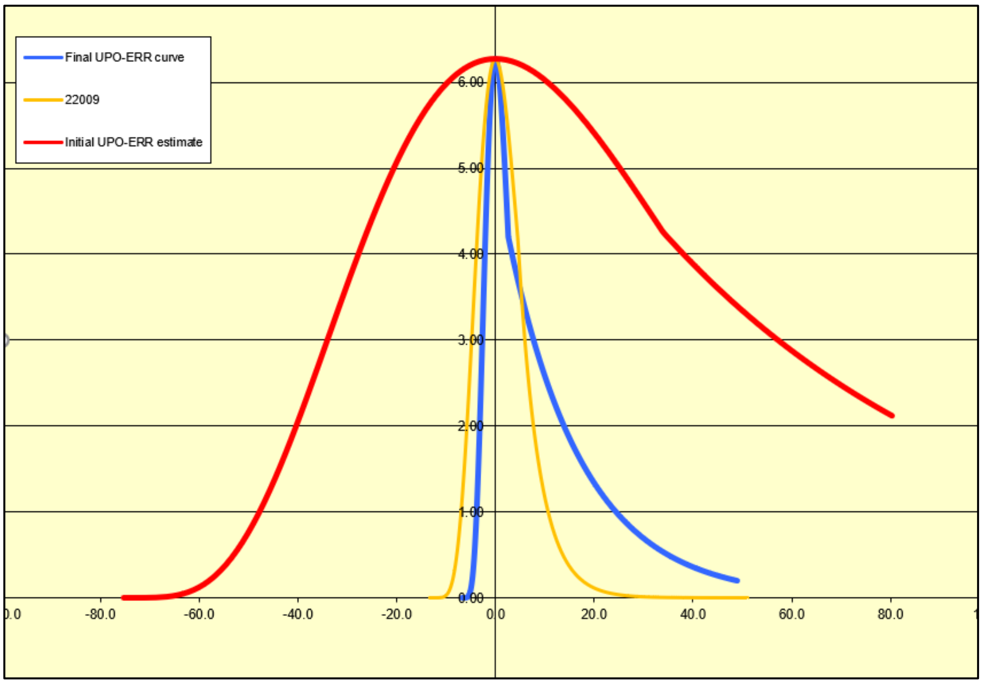


Figure 5-20 Characteristic flood hydrograph for the Camac River

5.3.2.7.2. Design Flood Hydrographs

The design flood hydrograph associated with any AEP has been estimated by scaling up the characteristic hydrograph ordinates by the relevant peak flow. Figure 5-21 illustrates the estimated 1% AEP flood hydrographs for the modelled watercourse.

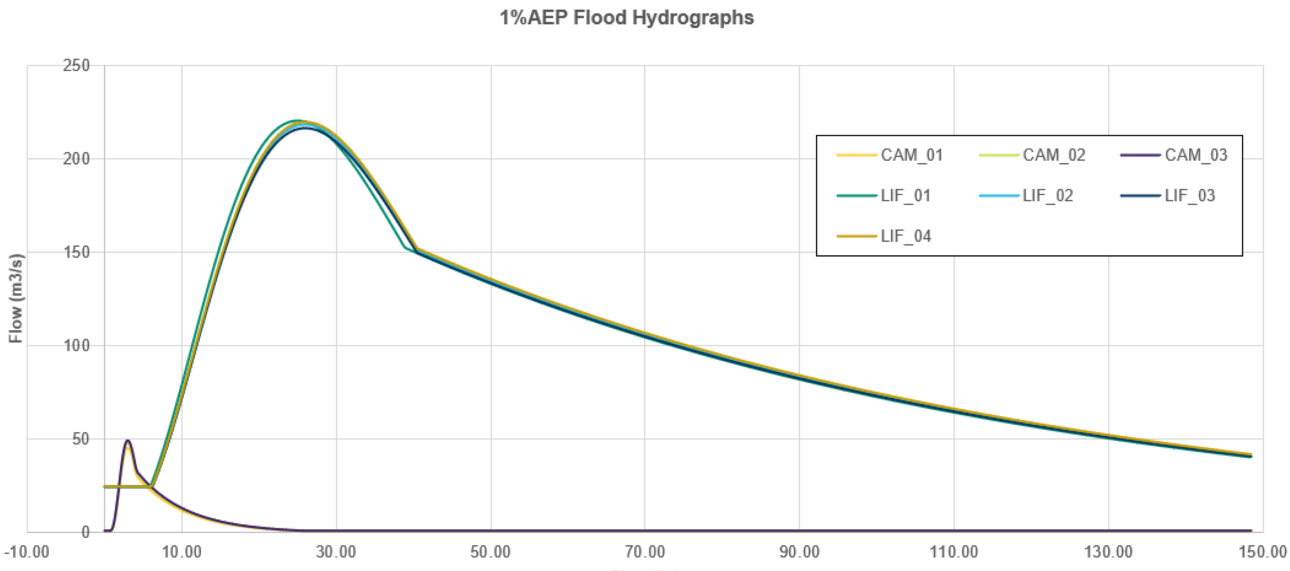


Figure 5-21 Design Flood Hydrographs for 1% AEP

5.3.2.8. Tidal Boundaries

Tidal boundaries have been set on the River Camac and Liffey hydraulics model in line with Table 2.3.

5.3.2.9. Future Conditions

Future Condition peak flows were defined taking into consideration all parameters discussed in Section 2.6.5.

5.3.3. Hydraulic Modelling

5.3.3.1. Existing Scenario

5.3.3.1.1. Flood Zone Mapping

Figure 5-22 shows that the proposed Development is not impacted by the 1% and 0.1% AEP fluvial flood events and does not lie within Flood Zones A and B. Table 5.13 shows the flood levels across the model extents. The flood zone map is shown in Appendix A.

5.3.3.1.2. CFRAM Comparison

Comparing Figure 5-15, Figure 5-16 and Figure 5-17 with Figure 5-22 it can be seen that overall there is good correlation between the flood extents along the Liffey, however there is a significant difference between the 0.1% AEP extents for the River Camac. The flood levels shown in Table 5.13 reflect this with the Liffey between very similar however there is large differences along the Camac. However, this was expected from the modelling along the Camac because as was noted in Section 5.3.2.6.1, the flows are lower than the CFRAM flows.

Table 5.13: CFRAM and FRA flood level comparisons

River	Monitoring Points	CFRAM Existing 1% AEP (m)	FRA Existing 1% AEP (m)	Difference (m)	CFRAM Existing 0.1% AEP (m)	FRA Existing 0.1% AEP (m)	Difference (m)
Camac	09CAMM00 0271	4.37	4.041	-0.329	6.09	5.025	-1.065
Camac	09CAMM00 084	7.68	7.444	-0.236	8.49	7.937	-0.553
Camac	09CAMM00 125	10.18	10.036	-0.144	10.93	10.454	-0.476
Camac	Mon 06	-	3.237	-	-	3.551	-
Liffey	Mon 07	-	0.000	-	-	0.000	-
Liffey	09LIFF006 21	3.5	3.528	0.028	4.03	3.97	-0.06
Liffey	09LIFF004 52	2.92	3.11	0.19	3.23	3.474	0.244
Liffey	09LIFF055 9!	3.25	3.293	0.043	3.69	3.686	-0.004

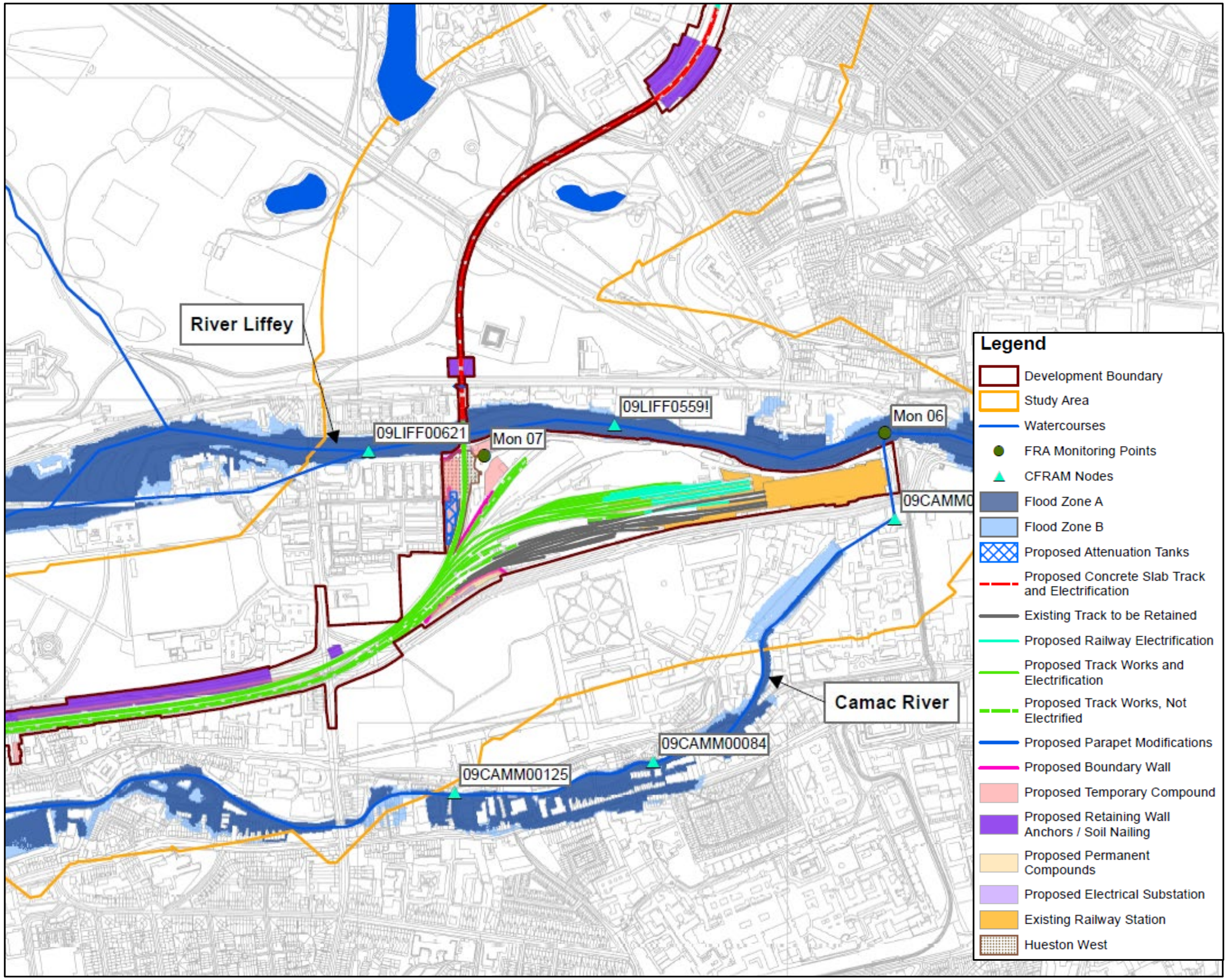


Figure 5-22 Heuston FRA Flood Zones

5.3.3.2. Climate Change Scenario

Model runs inclusive of climate change parameters, were generated to appraise the any potential flood risk to the development site. Results for the worst case HEFS scenario are shown in Figure 5-23, during the 0.1% HEFS AEP event, flooding primarily occurs at the Heuston Station Car Park but there is also some flooding impacting the railway track. There is no flooding predicted at the future Heuston West Station. There is also predicted flooding to the Heuston Station Terminal Building from the River Camac, however any mitigation measures for that scenario are outside the scope of this FRA. The HEFS flood extent map is shown in Appendix A.

5.3.3.3. Hydraulic Modelling - Proposed Scenario

Potential mitigation measures to alleviate flooding for the 0.1% HEFS AEP event along the railway track were investigated including a flood wall and flood barrier placed along its perimeter are proposed as mitigation measures. Figure 5-24 shows the flooding extents in the area. The predicted flooding has been removed from the railway track and is contained within the car park which is a flood compatible area and in areas under CIÉ ownership. Flooding extents are not increased in other areas due to the proposed measures. The minimum height of the flood wall, including an allowance for freeboard, is 0.9m with an approximate length of 266m. The minimum height of the flood barrier, including an allowance for freeboard, is 1.3m with an approximate length of 61m.

5.3.4. Conclusion of Stage 3 – Detailed Flood Risk Assessment

1D/2D combined hydraulic models were built to assess the existing and proposed flood risk to the railway and proposed Heuston West station in Zone C at Heuston Station. The primary rivers in the region are the River Liffey and River Camac. The design flood flows were estimated using the FSU and IH recommended flood estimation methodologies. The models were calibrated against the results from the relevant Eastern CFRAM Study flood extent mapping. The calibration analysis found that the flows and flood extents for the River Camac where less than the CFRAM study. The primary reason for the difference was the value of the growth factors used. The CFRAM study used generalised regional growth factors based on the catchment size for the entirety of the River Liffey Hydrometric Area. This approach was conservative and used in order to expediate hydrological calculations due the volume of them being undertaken for the CFRAMS.

The analysis of the existing scenario found that the railway and Heuston Station are not at risk of flooding from both the 1% AEP and 0.1% AEP flooding events.

The railway and car park is not at risk at during the 1% AEP HEFS climate change scenario event. However, the railway track and car park are at risk during the HEFS 0.1% AEP climate change scenario from the River Liffey and River Camac. There is no flooding from the Liffey predicted at the future Heuston West Station. There is predicted flooding to the Heuston Station Terminal Building from the River Camac, however any mitigation measures for that scenario are outside the scope of this FRA.

Potential mitigation measures to alleviate flooding were proposed and modelled. These proposed mitigation measures have been presented in Section 5.3.3.3. Hydraulic modelling of a flood relief wall and flood barrier to reduce flood risk during the 0.1% AEP HEFS flooding scenario was undertaken. The predicted flooding has been removed from the railway track and is contained within the car park which is a flood compatible area and also in areas under CIÉ ownership.

The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. TTA have presented the analysis of the modelling to Iarnród Éireann. Having considered the hydraulic analysis of the existing scenario for the HEFS 0.1% AEP event, Iarnród Éireann has determined that hard mitigation measures are not warranted at this time. Risk reduction associated with the HEFS 0.1% AEP could be achieved in the future by implementation of the proposed mitigation measures by Iarnród Éireann if warranted.

Noise barriers are proposed within Zone C to mitigate operational noise impact (Refer to Chapter 14 Noise & Vibration for further details). No impacts on the existing flooding regimes of the River Liffey and River Camac in the vicinity of the Heuston Station, due to the installation of proposed noise barriers, are expected, since the proposed noise barriers are not located within the design flood extents.

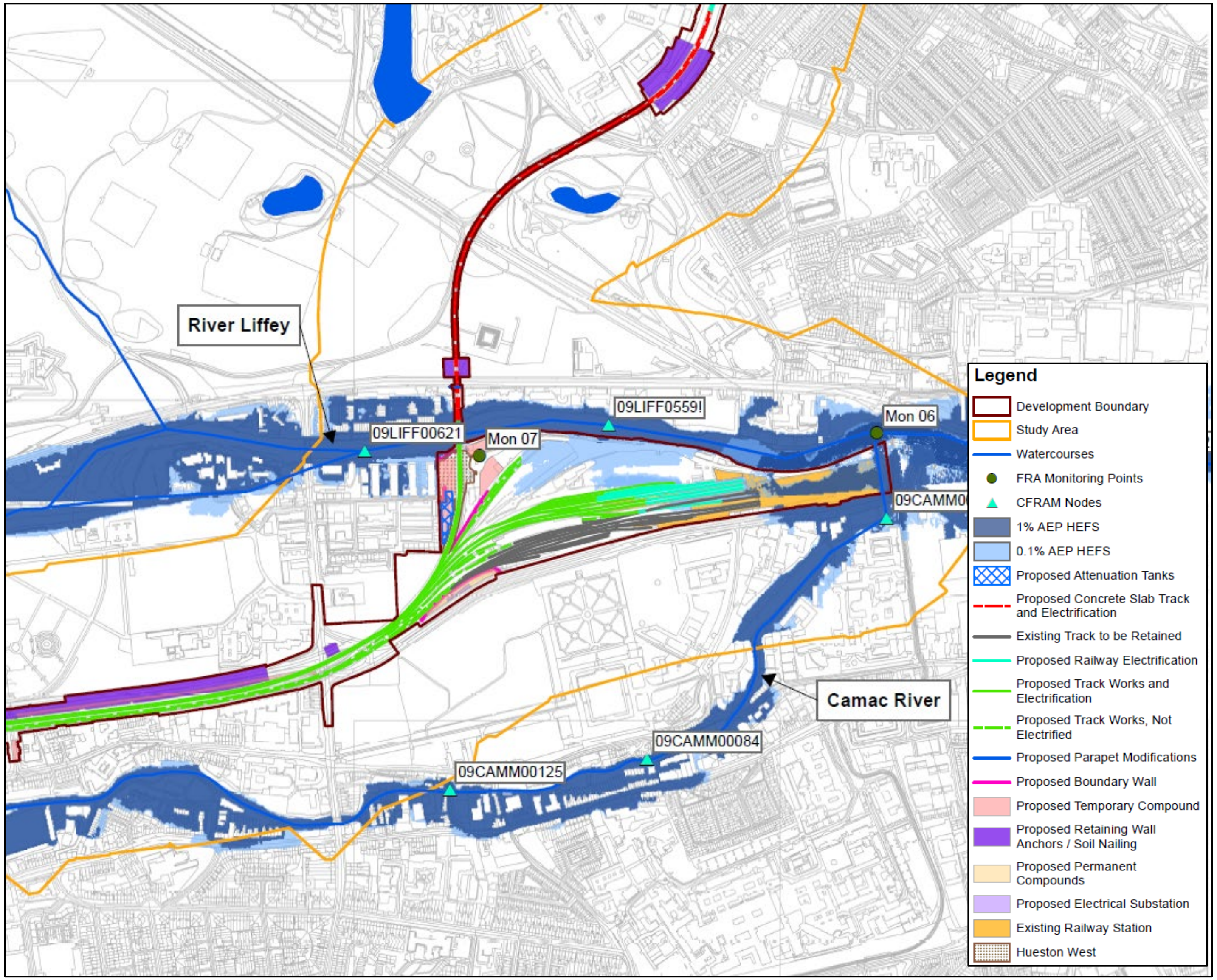


Figure 5-23 HEFS 0.1% AEP Flood Extents for Existing Scenario Heuston FRA

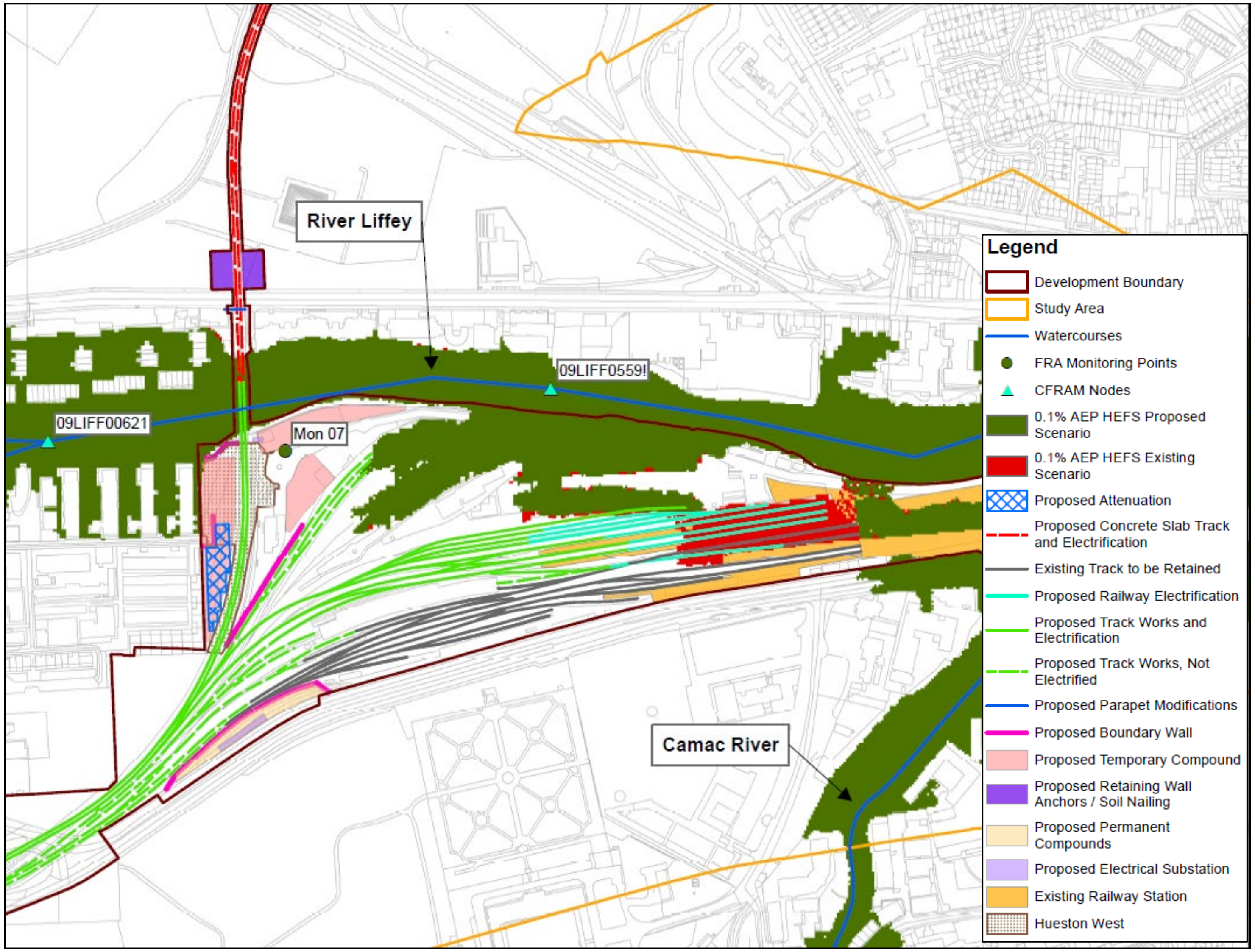


Figure 5-24 HEFS 0.1% AEP Flood Extents for Proposed Scenario Heuston FRA

6. Zone D - Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line) FRA

6.1. Stage 1 – Flood Risk Identification

6.1.1. Overview

This area commences on the south bank of the River Liffey (adjacent to the northern boundary of the Heuston Yard) and extends north east terminating at Glasnevin Junction.. The route extends northwards over the River Liffey via the Liffey Bridge (UB01) and under Conyngham Road Bridge (OBO2) after which, it enters the existing PPT. The route emerges on the north side of the PPT, thereafter extending north east under a series of bridges along the PPT Branch Line where the DART+ South West Project extent ties in to the existing track at Glasnevin Junction and interfaces with the DART+ West Project. The route then continues to the Dublin Docklands area (Spencer Dock and Grand Canal Dock). After the line exits the PPT, the track passes under 8 no. overbridges as shown in Figure 6-1 and Figure 6-2:

- McKee Barracks Bridge (OBO3);
- Blackhorse Avenue Bridge (OBO4):
- Old Cabra Road Bridge (OBO5);
- Cabra Road Bridge (OBO6);
- Faussagh Avenue Bridge (OBO7);
- Royal Canal and LUAS Twin Arches (OBO8);
- Maynooth Line Twin Arch (OBO9); and
- Glasnevin Cemetery Road Bridge (OBO10).

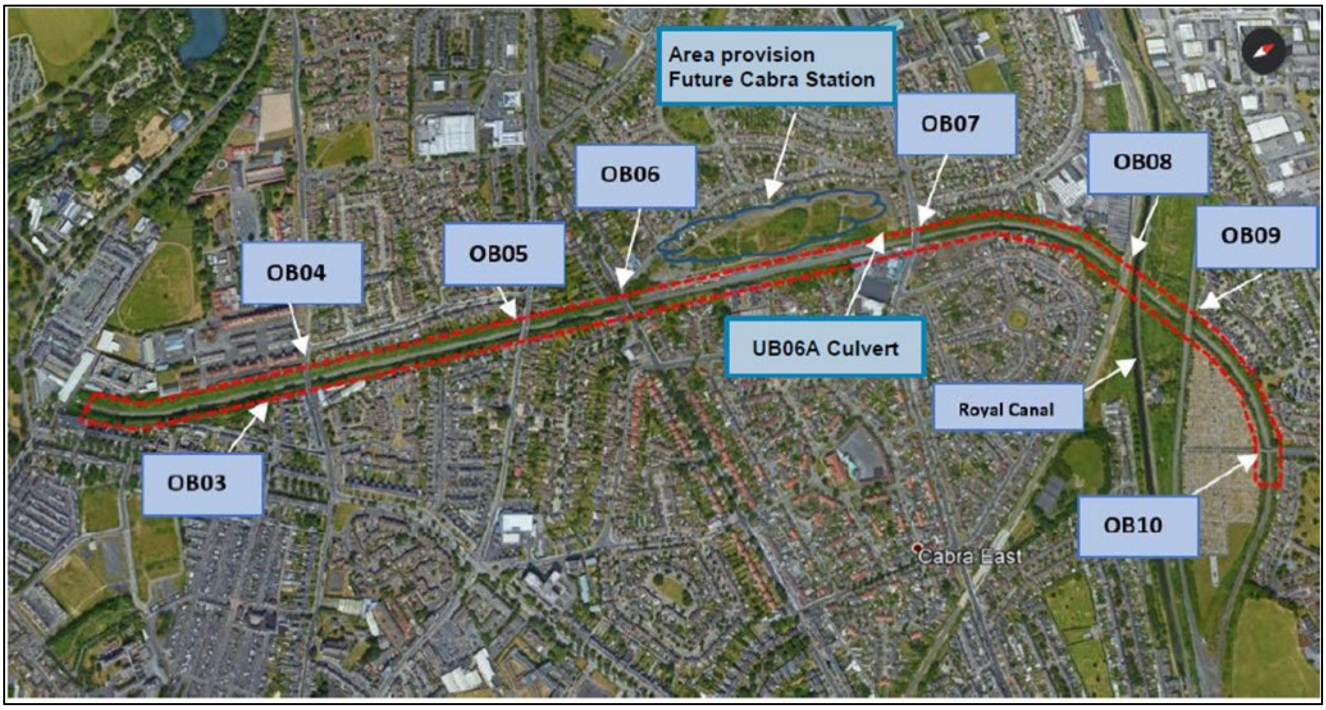


Figure 6-1 East of St. John's Road Bridge to Glasnevin Junction – General View

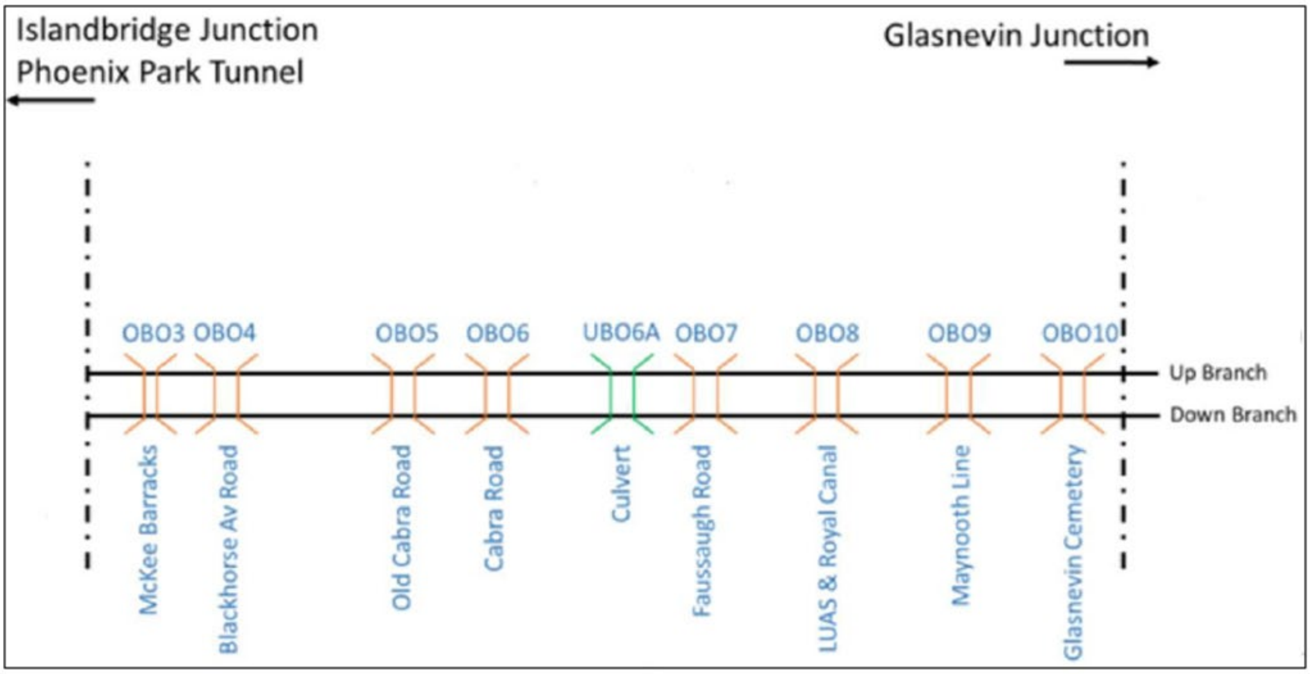


Figure 6-2 Existing Track Layout

6.1.2. Site Topography

The topography of the area is typically flat, with the land north and south of the River Liffey sloping gently towards the river. The railway is almost entirely located within steep cuttings covered by vegetation. A short section west of the railway between Cabra Road Bridge and Faussagh Road Bridge is locally at grade.

6.1.3. Existing Site Drainage

At the PPT, available information identifies a rectangular drain that runs along the track axis (Figure 6-3 and Figure 6-4) and recent pictures show a 300mm perforated pipe with filtration geotextile, granular material surrounds and topped with the track ballast to drain and convey runoff waters (Figure 6-3). The performance of this system (especially regarding its outfall) is not fully known, being assumed from site visits that some elements exist which convey the water to the discharge point at the Liffey River. However, there is evidence of flooding in the tunnel with water leaking through the walls particularly during heavy rain events. In addition, an upgrade to slab track is being proposed in the tunnel, which will require a dedicated drainage system. Therefore, an integrated drainage solution is to be designed to ensure a safe and reliable operation of the infrastructure.

The existing drainage systems for the rest of the section of railway track comprises of filter-drains running along the tracks, draining water to a pumping station located at a low point between structures OBO8 and OBO9 (Figure 6-5). Accumulated water is then pumped to an infiltration basin located 50m west of the pumping station.

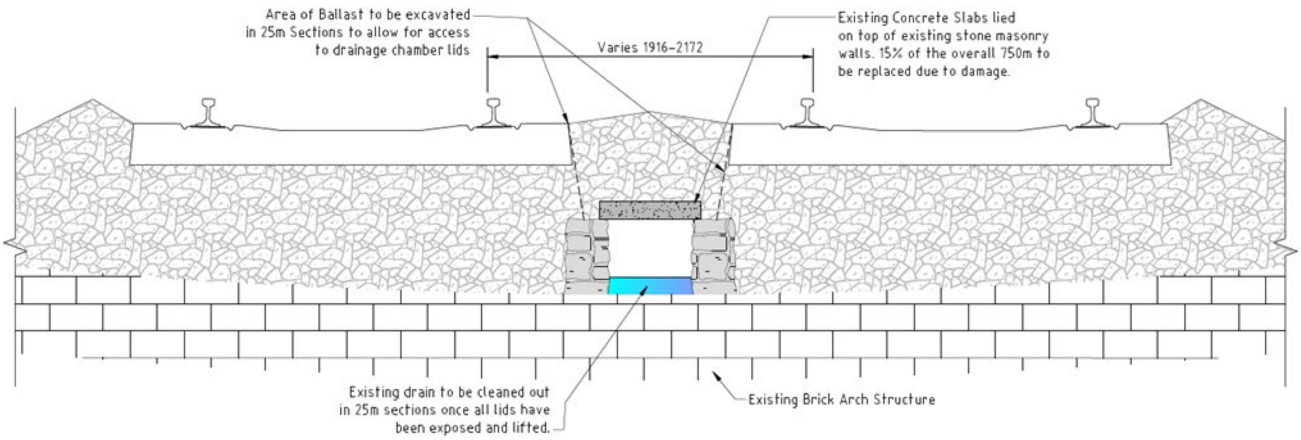


Figure 6-3 Typical section on Phoenix Park Tunnel showing existing drainage. Source: Phoenix Park Tunnel, drawing SDS-15-152-P03-022

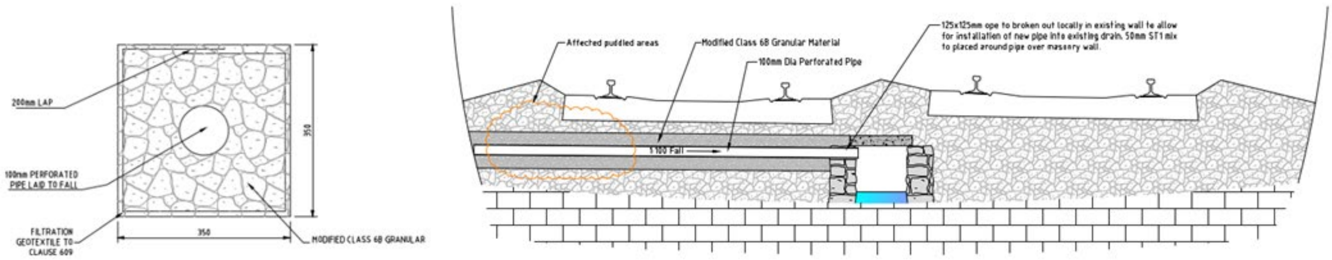


Figure 6-4 Typical section on Phoenix Park Tunnel showing existing drainage. Source: Phoenix Park Tunnel, drawing SDS-15-152-P03-023

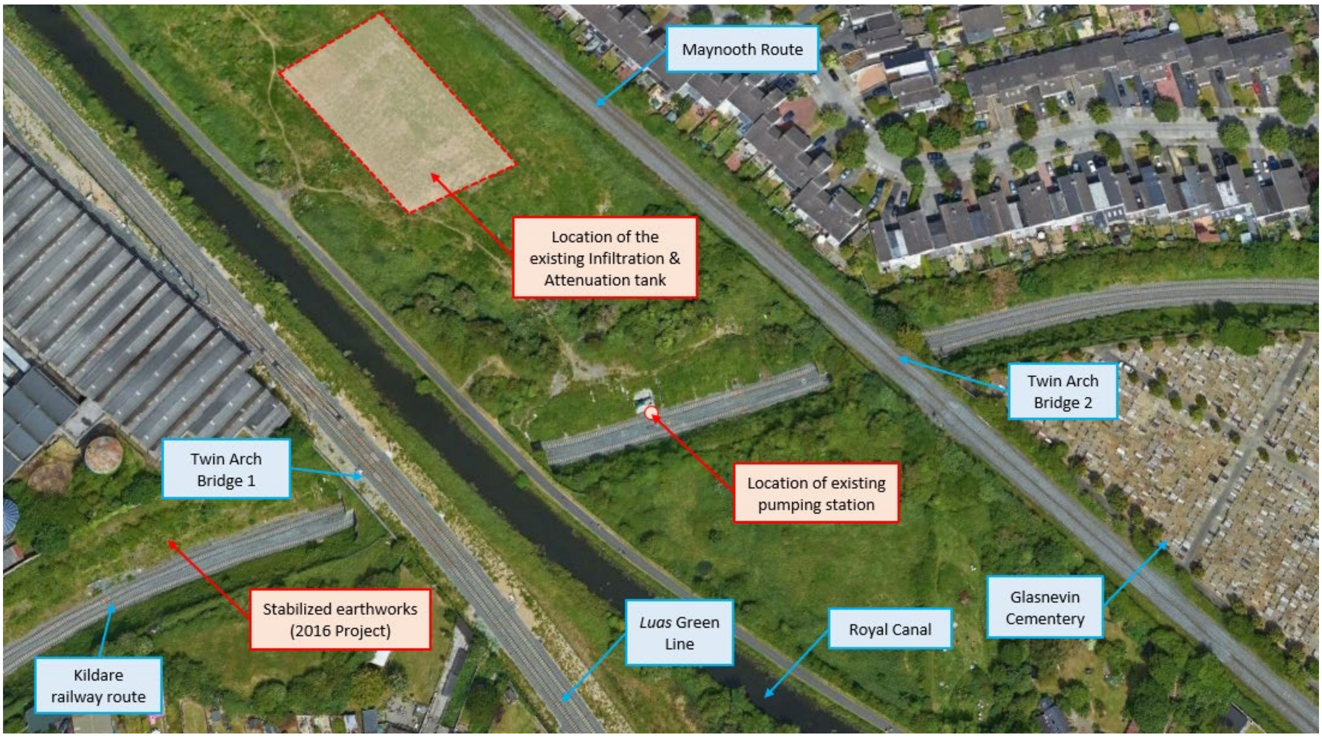


Figure 6-5 Location of the Twin Arch Bridges (OBO8 & OBO9) and existing drainage systems in the vicinity of Royal Canal.

6.1.4. The Proposed Development

The elements which form the design for this section of the Project are outlined in Table 6.1 below.

Table 6.1: Proposed Development

Section	Proposed Development
Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line)	• Permanent Way to be re-aligned to ensure that structural and passing clearances are achieved; • Track lowering at certain locations along the Phoenix Park Tunnel Branch Line between the Phoenix Park Tunnel and Glasnevin Junction to achieve the height requirements for electrification; • Construction Compounds at Cabra, Faussagh Avenue and Glasnevin Cemetery; • Diversion of the existing sewer pipe bridge located south of Blackhorse Ave Bridge • Works to parapets on the following existing bridges to meet safety requirements: ○ Conyngham Road Bridge (OBO2) ○ McKee Barracks Bridge (OBO3) ○ Blackhorse Avenue Road Bridge (OBO4) ○ Old Cabra Road Bridge (OBO5) ○ Cabra Road Bridge (OBO6);

Section	Proposed Development
	○ Faussagh Avenue Bridge (OBO7); ○ Deck replacement at Glasnevin Cemetery Road Bridge (OBO10)

6.1.5. Land Use

The line runs through a relatively dense urban environment with a mix of residential and commercial properties bordering the rail corridor.

6.1.6. Existing Geology and Hydrogeology of the Area

Geological mapping indicates the superficial deposits comprise till underlain by bedrock (limestone and shale). To the south, close to the PPT, ground investigations show the ground conditions to comprise gravel stone fill (likely ballast associated with the railway) underlain by stiff to very stiff black gravelly clay. Bedrock consisting of a medium strong to strong limestone was encountered at 7.20m bgl (17.90m AOD). Groundwater strikes are shown to be recorded between existing ground level and 4.70m bgl.

Towards Cabra, made ground described as sandy gravelly clay with glass, red brick and organic fragments has been recorded up to 3.10m thick. The made ground is underlain by firm to stiff gravelly clay with unproven thickness. The recorded groundwater levels towards Cabra range from 2.85m bgl to 3.45m bgl. Further north, to the east of the railway at Quarry Road, ground investigation shows the ground conditions comprise made ground or fill underlain by stiff to very stiff black gravelly clay. The till is overlain by pockets of sand or firm brown gravelly clay in places. Groundwater at Quarry Road was recorded between 2.10m bgl to 6.20m bgl.

6.1.7. Salient Hydrological Features and Existing Flood Regime of the Area

The salient hydrological feature for the study area between Heuston Station and Glasnevin Junction is the Royal Canal. There are no recorded Past Flood Events available in the OPW's database, however, it was highlighted by Iarnród Éireann the existence of a low point between the Royal Canal and LUAS Twin Arch (OBO8) and the Maynooth Line Twin Arch Bridge (OBO9). This has caused some flooding issues in the past (2014-2017). The system of the existing drainage between the Royal Canal and LUAS Twin Arch (OBO8) and the Maynooth Line Twin Arch Bridge (OBO9) consists of an existing pumping station and an infiltration tank between the tracks became fully operational in 2017 (see Figure 6-5), initially there were over pumping issues which were resolved around November/December of that year.

6.1.8. Interreg IVB FloodResilienCity Project

Figure 6-6 presents a map of the modelled area FRC project, as detailed in Section 4.1.7. The layers show the modelled extent of land that might be directly flooded by rainfall under existing (Do-minimum) conditions. The proposed development is susceptible to pluvial flooding under all probabilities.

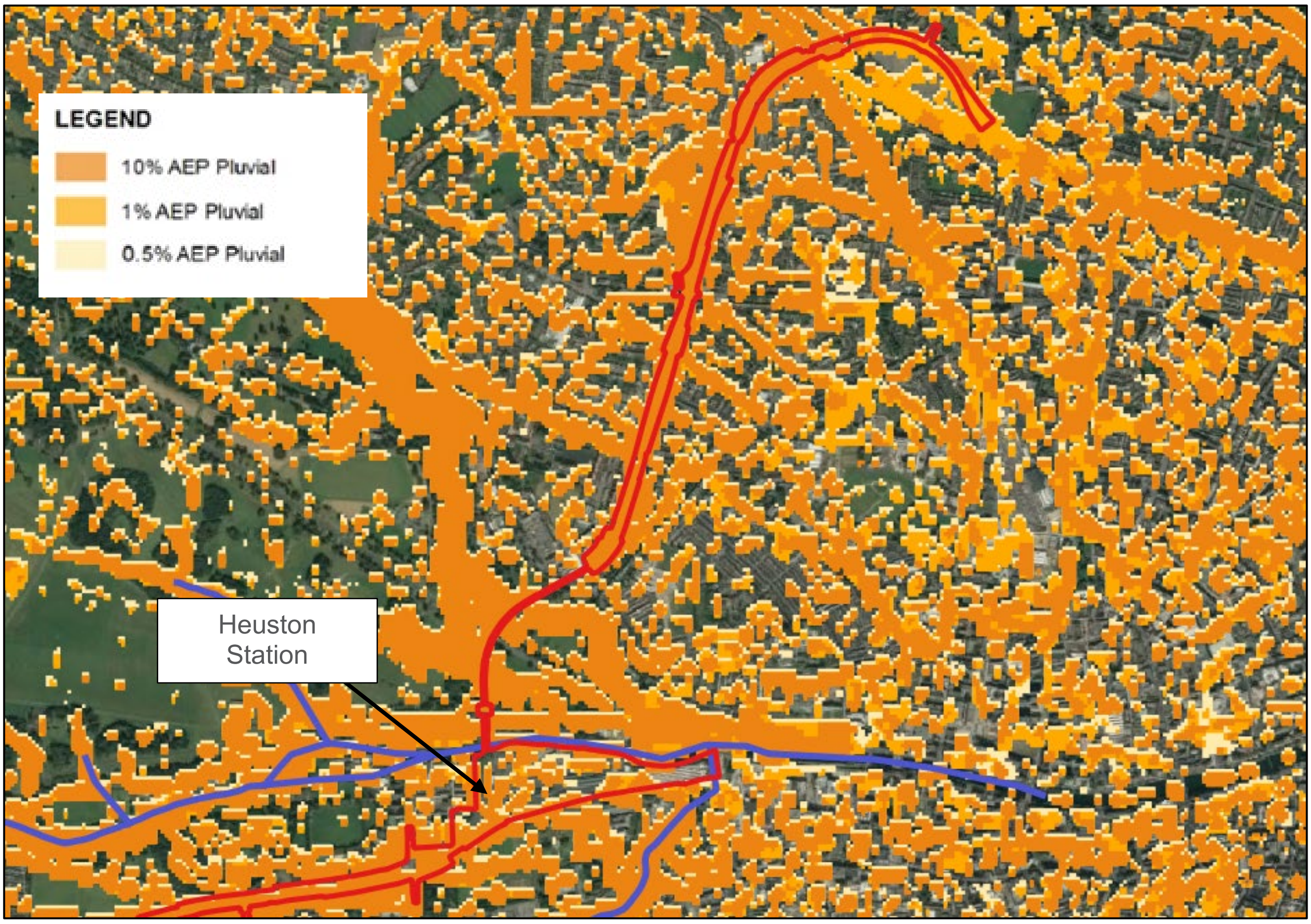


Figure 6-6 Rainfall Flood Extents – Dublin City Area (Source: https://www.floodinfo.ie/map/floodmaps/

6.1.9. Conclusion of Stage 1 – Flood Risk Identification

Records of historical flooding, the flood extent mapping generated for the study area, and other records outlined in the preceding sections indicated that the proposed Development is potentially at risk from pluvial flooding and to a lesser extent from groundwater. Therefore, the FRA was progressed to STAGE 2 – INITIAL FLOOD RISK ASSESSMENT.

6.2. Stage 2 – Initial Flood Risk Assessment

6.2.1. Sources of Flood Risk

The purpose of the Stage 2 - Initial FRA was to appraise the availability and adequacy of the identified flood risk information, to qualitatively appraise the flood risk posed to the site and potential impacts on flood risk elsewhere and recommend possible mitigation measures to reduce the risk to acceptable level. In consideration of the above assessment, the primary flood risk to the proposed Development was attributed to:

- Pluvial– High Risk.
- Groundwater – Medium Risk

6.2.2. Flood Risks and Flood Zone Mapping Summary

As mentioned above, the most significant source of flooding based on the Studies is pluvial, which locates the site in **Flood Zone A.**

6.2.3. Conclusion of Stage 2 – Initial Flood Risk Assessment

The flood levels and protection levels proposed have not been investigated using hydraulic modelling therefore the FRA shall be progressed to STAGE 3 – DETAILED FLOOD RISK ASSESSMENT to improve the accuracy of these levels and to assess the residual impact of the proposed mitigation measures on the predicted 0.1% AEP event flood extents in the surrounding area. For this purpose, a 1D model is recommended to be prepared in the vicinity of the crossing at Royal Canal. Information has been sought from Waterways Ireland with regards to the design levels for the three locks adjacent to the railway route (Locks 5, 6 and 7) and the water level gauge data for Lock 6 and 7 (confirmation from Waterways Ireland of when these were installed is awaiting).

Standard drainage design following the criteria set out by DCC should limit the risk of pluvial flooding to being low. An assessment of the surface water discharge should be undertaken to assess any risk of flooding to the development site or to any properties located adjacent to the development site. Storm water infrastructure (including attenuation tanks, pipes and SuDS features) shall be adequately designed to the requirements of DCC to prevent pluvial flooding on the site.

6.3. Stage 3 – Detailed Flood Risk Assessment

The main threats to the proposed Development would be the fluvial/pluvial flooding from Royal Canal in the vicinity of the Twin Arch Bridges (OBO8 and OBO9). The Royal Canal links the River Liffey in Dublin to the River Shannon in Longford. It is 145 kilometres in length and has an 8 kilometre branch line into Longford Town. The canal winds its way through the North Dublin suburbs, the green pastures of Kildare, Meath and Westmeath, through the town of Mullingar and on through Co. Longford and down into Richmond Harbour in the village of Clondra. Rising out of Dublin through a series of 26 locks it reaches the summit level (a height of about 94 m above sea level) near Mullingar and then descends a further 20 locks to its destination in Richmond Harbour. Lough Owel in Co. Westmeath is the main water supply for the canal.

A total of 46 locks (including the sea lock at the river Liffey in Dublin) were needed and four major aqueducts were built to carry the canal over the rivers Ryewater, Boyne and Inny. In all 86 bridges were constructed.

Approximately 55% of the Royal canal is embanked with 3 peat embankments at Cloonbreany, Begnagh and Ballymaclavy and a 3km embankment running around the town of Mullingar, Co. Westmeath. The Royal Canal was closed to navigation from 1960 and was only fully reopened in 2010 following a lengthy period of reconstruction. Figure 6-7 illustrates the locations of lock gates in the vicinity of Twin Arch bridge crossing over Royal Canal.

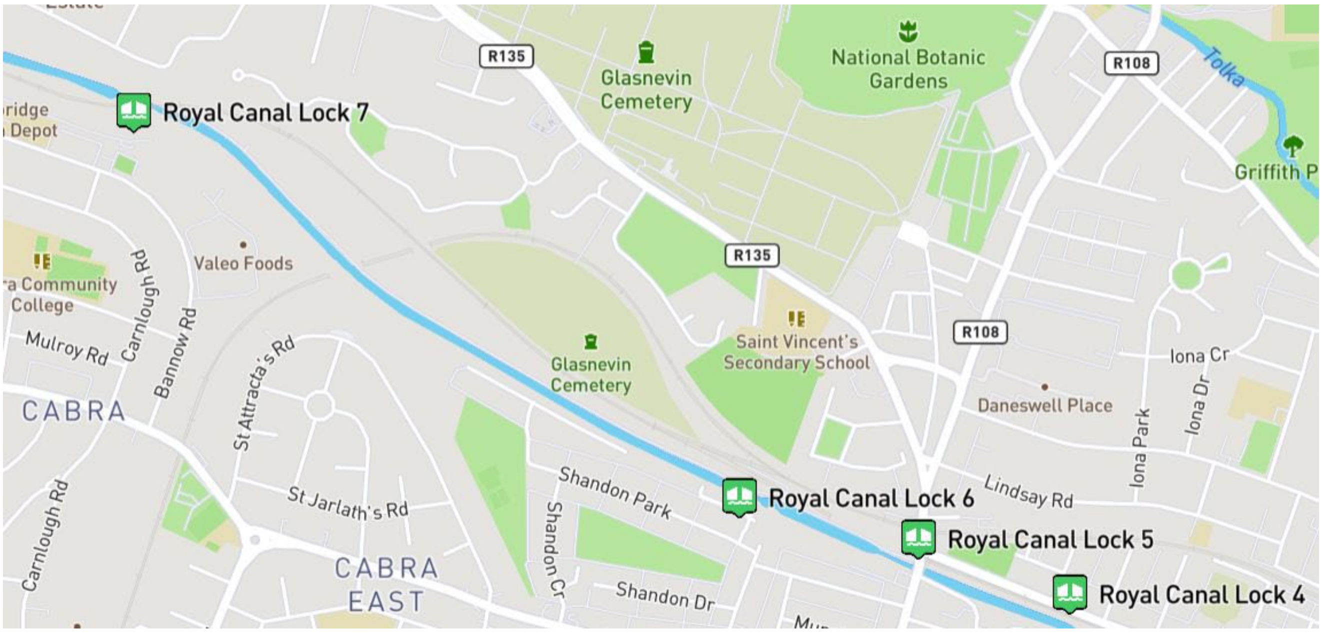


Figure 6-7 Location of Royal Canal Gate Locks

The Royal Canal overtops its banks in the vicinity of the Twin Arch Bridge crossing (OBO8) on a number of occasions in the past. The Broombridge Railway Station (which is located 1km northwest of the OBO8) was flooded on 24th October 2011(see Image 6-1). The canal overflowed which may have been due to a blockage at Glasnevin. The drainage on the road was blocked or was unable to cope with the volume of water and it flowed into the station. The drains from the local housing estates are in the direction of the railway, which may have impacted on the flood. The canal also overflowed on to the it's towpath/bank, approximately 100m west of the Royal Canal and LUAS Twin Arch (Structure OBO8) on 9th February 2020 (see Image 6-2). The causes of flooding on both occasions were the heavy rain falling over the canal surface. Excess flood waters spilled over the banks. The observed daily total rainfall at Phoenix Park on 24th October 2011 and 9th September were 71.30mm and 36.7mm respectively. Based on the Met Éireann's Depth Duration Frequency (DDF) table at Phoenix Park, these rainfall depths have approximate return periods of 1 in 20 year and 1 in 2 year respectively.

Table 6.2 below presents the Royal Canal Dimension details including the allowable maximum water levels, historic flood events and potential flood volumes in the vicinity of the Royal Canal and LUAS Twin Arch (Structure OBO8). It can be seen from this table that water levels in the canal are controlled by the locks. There are significant level differences between upstream and downstream of a lock. During the 9th of December 2020 flood event canal water level in the vicinity of the Twin Arch Bridge (Structure OBO8) rose to a level of 32.48mOD which is the Canal embankment towpath level. The lowest canal embankment level in the vicinity is in the order of 32.90mOD. During an extreme rainfall event (i.e. during 1% & 0.1% AEP events) coupled with any blockages at the downstream lock gates flood water would overtop this embankment and cause flooding on to the surrounding lands and railway track between the bridge structures OBO8 and OBO9.

This could be avoided through constant monitoring of water through lock gate operations. As such, it is recommended that an early warning system is implemented through installation by Iarnród Éireann of water level monitoring equipment at an agreed location on the Royal Canal with permission from Waterways Ireland. The installation of a real-time monitoring system with telemetry can alert Iarnród Éireann if a certain threshold is breached and take the necessary appropriate actions.

Image 6-1 Flooding at Broombridge Station on 24 October 2011.

Image 6-2 Flooding on the Canal north towpath at Batchelor Food Manufacturing Factory on 9th Feb. 2020

Table 6.2: Royal Canal dimension details and the past flood records

Level Name/ Lock No.	Water Level (mOD)	Length (km)	Estimated embanked	Embankment Condition	Water Depth (m) (will	Ave Canal Width (m)	Water Volume (m3)	Spread Radius (m)	Historic Flooding	Structures
SDK (Spencer Dock)	1.99	1.15	0		2.5	20	57500	271	Spencer Dock area flooded in 2002 due to the high tide level in the River Liffey which was 0.4m higher than the level in the Royal Canal. DCC noted this caused widespread flooding. New sea lock flood protection since constructed.	Sea Lock / Spencer Dock
1	4.09	1.10	0		2.59	12	34188	209		Newcomen Bridge
2	10.19	0.30	0		1.94	12	6995	94		Binns Bridge
3	15.76	0.25	0		2.20	12	6591	92		
4	21.33	0.35	0		2.26	12	9496	110		
5	26.96	0.30	0		2.19	12	7884	100		Cross Guns
6	32.42	1.20	350	Fair	2.15	12	30960	199	Canal overflowed onto the northern bank/towpath at the Batchelors Food manufacturing Factory on 9th February 2020.	
7	35.08	1.20	500	Fair	2.04	12	29405	193	Broombridge Railway Station was flooded on 24th October 2011.The canal overflowed which may have been due to a blockage at Glasnevin.	Liffey Junction
8	37.62	0.60	500	Fair	2.11	12	15170	139		Reilly's Bridge

The proposed track drainage systems in Zone D (River Liffey Bridge to Glasnevin Junction) comprises of the following:

1. Phoenix Park Tunnel : The existing collection system (perforated pipe) will be replaced by an in situ concrete channel drain 400mm wide by 500mm deep placed between tracks, to collect any surface water runoff on the track and convey flows from the upstream drainage network up to the existing outfall at The River Liffey (Figure 6-8 and Figure 6-9). The current catchment area at the tunnel and its portals will not be modified by the proposed track works and therefore, the generated runoff volumes will not increase.

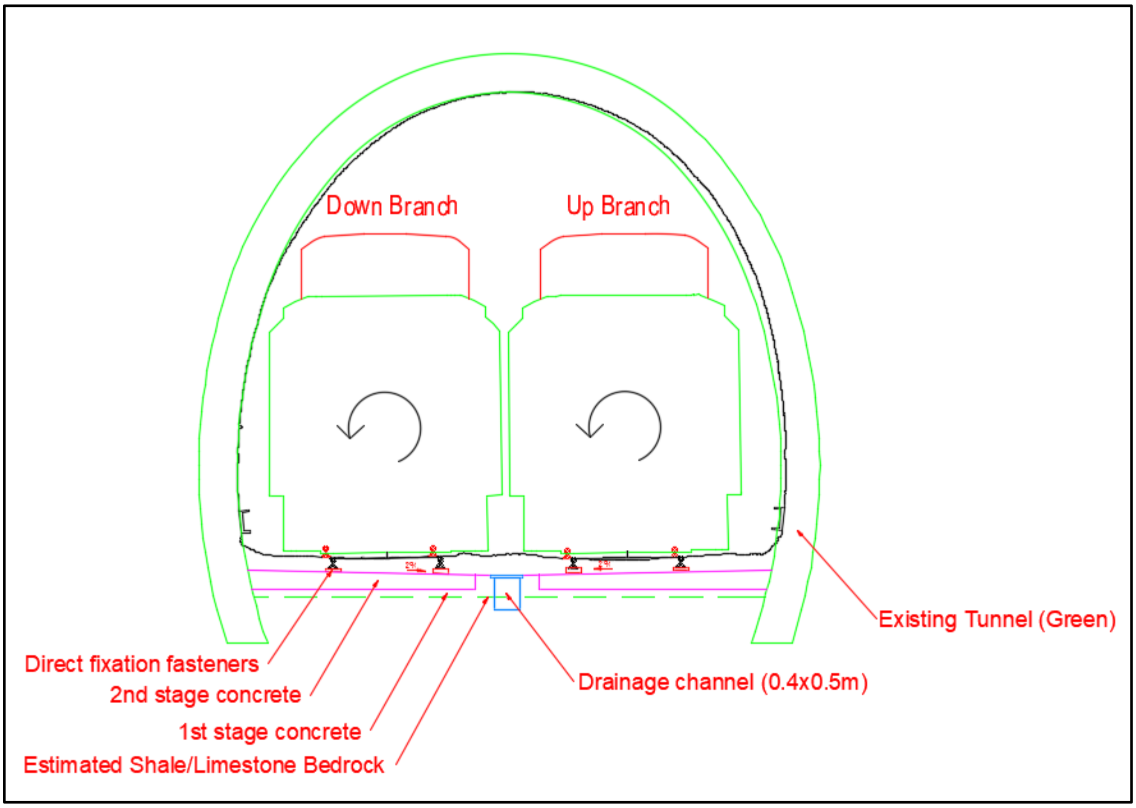


Figure 6-8 Proposed cross drainage system at Phoenix Park Tunnel

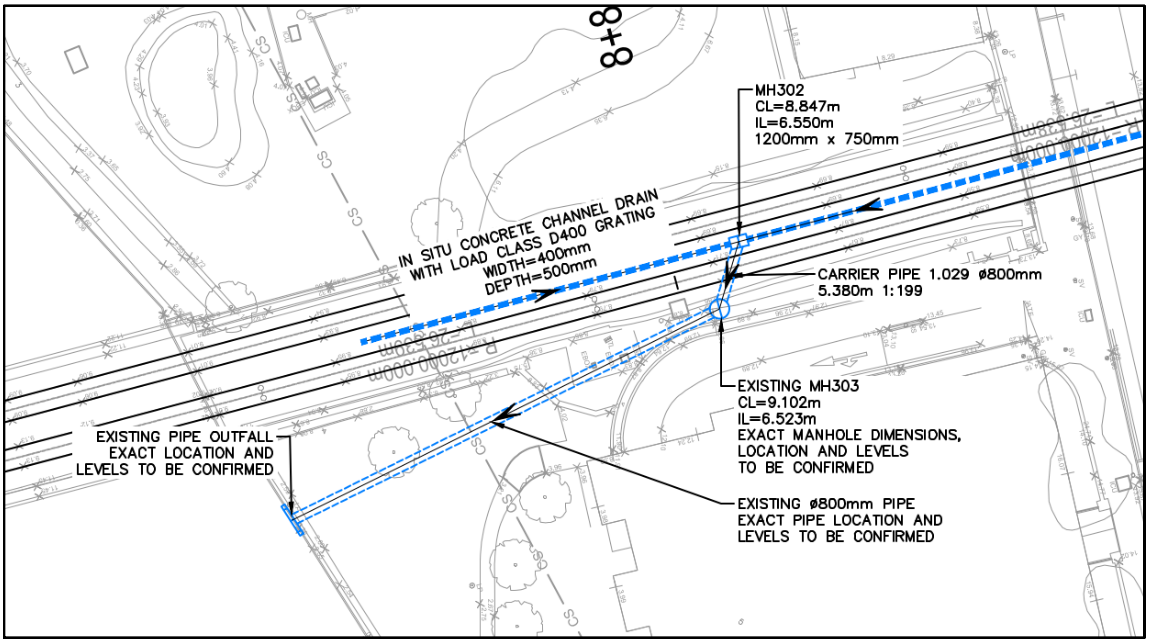


Figure 6-9 Proposed drainage works at Liffey River outfall

2. North Portal of Phoenix Park Tunnel to Glasnevin: The drainage catchment between PPT and Royal Canal and Luas Twin Arch (OBO8) and Maynooth Line Twin Arch (OBO9) will remain as existing, and therefore, runoff flows will not be increased as result of the proposed works. Although track lowering is proposed at a number of locations along this rout, no changes to the drainage system are proposed, apart from re-adjusting the current pipe and chamber levels to the new track profile. However, due to the proposed track level changes, lowering the existing pumping station would be required with an increase of the existing wet well chamber dimensions. This increase in size will allow holding the additional volumes collected by the drainage system in order to maintain the new water levels required by the EMU's. The proposed wet well will deal with the extra volume collected by the system whilst maintaining current pumping flows. Accumulated storm water will be pumped to the existing infiltration basin similar to the existing arrangement. Figure 6-10 illustrates the proposed drainage layout plan between structures OBO8 and OB0O9.

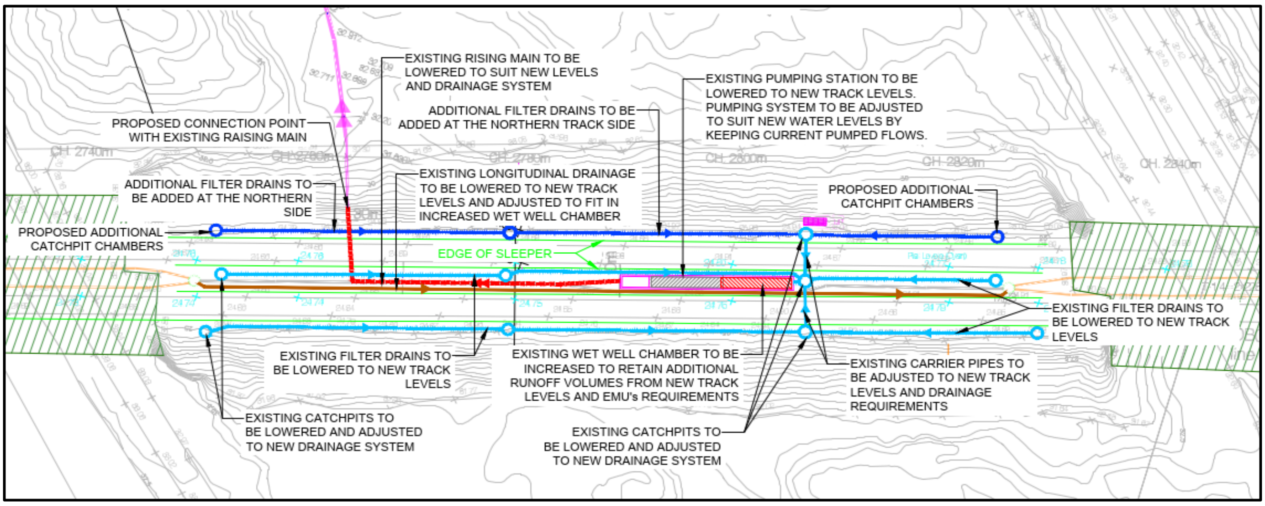


Figure 6-10 Proposed Drainage Upgrade Between OB08 and OB09

The above-mentioned drainage systems will eliminate any existing flooding along the track and will cater for the runoff volume likely to be generated from 1% AEP rainfall event (inclusive of 30% increase in rainfall due to future climate change).

7. Justification Test

7.1. Justification Test Requirement

The requirement for a Justification Test for the proposed Development was reviewed in accordance with FRM Guidelines. The matrix shown below in Table 7-1 details the criteria used to determine whether a Justification Test for the study area was required.

Table 7-1: Justification Test Matrix

Vulnerability Level	Flood Zone A	Flood Zone B	Flood Zone C
Highly Vulnerable Development	Justification Test	Justification Test	Appropriate
Less Vulnerable Development	Justification Test	Appropriate	Appropriate
Water-Compatible Development	Appropriate	Appropriate	Appropriate

As previously described in Section 3.7, the railway track is located in Flood Zones A and B at Hazelhatch (Figure 3-18) but also in the climate change HEFS 0.1% AEP scenario at Adamstown (Figure 3-44) and since the railway is considered highly vulnerable development, a Development Management Justification Test is required to be completed to support the planning application.

7.2. Development Management Justification Test

The criteria listed in Figure 7-1 is extracted from Section 5.15 of the FRM Guidelines and forms the basis for the Development Management Justification Test. The Justification Test criteria comprises Items 1 and 2 which are addressed in the relevant sub-sections below.

Box 5.1 Justification Test for development management (to be submitted by the applicant)

When considering proposals for development, which may be vulnerable to flooding, and that would generally be inappropriate as set out in Table 3.2, the following criteria must be satisfied:

1. The subject lands have been zoned or otherwise designated for the particular use or form of development in an operative development plan, which has been adopted or varied taking account of these Guidelines.

2. The proposal has been subject to an appropriate flood risk assessment that demonstrates:

   (i) The development proposed will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk;

   (ii) The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible;

   (iii) The development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access; and

   (iv) The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.

The acceptability or otherwise of levels of residual risk should be made with consideration of the type and foreseen use of the development and the local development context.

Figure 7-1 Justification Test Criteria

7.2.1. Criteria 1

Responses to the sub item for criteria 1 are listed in Table 7.2. The key planning and wider policy context for the whole development is outlined below.

Table 7.2: Item 1 Responses

Sub Item	The development has been zoned or otherwise designated for the particular use or form of development in an operative development plan, which has been adopted or varied taking account of these Guidelines
1	**EU Level Policy**
	The Trans-European Transport Network (TEN-T)
	EU White Paper on Transport: Roadmap to a single European Transport Area - Towards a competitive and resource efficient transport system
	European Green Deal
	National Policy
	Project Ireland 2040
	The National Planning Framework
	The National Development Plan 2021-2030
	Smarter Travel – A Sustainable Transport Future
	Planning Land Use and Transport Outlook 2040
	Climate Action and Low Carbon Development (Amendment) Act 2021
	The White Paper: Ireland's Transition to a Low Carbon Energy Future 2015-2030
	National Investment Framework for Transport in Ireland (NIFTI) (2021)
	Regional Policy
	Eastern and Midland Regional Spatial & Economic Strategy 2019-2031
	Metropolitan Area Spatial Plan
	Transport Strategy for the Greater Dublin Area 2016-2035 and DRAFT Transport Strategy for the Greater Dublin Area 2022-2042
	Greater Dublin Area Cycle Network Plan
	Integrated Implementation Plan 2019-2024
	Local Policy
	Dublin City Development Plan 2022-2028
	Park West – Cherry Orchard Local Area Plan 2019
	The City Edge Project
	The Draft Dublin City Development Plan 2022-2028
	South Dublin County Development Plan 2022-2028
	Adamstown Strategic Development Zone
	Clonburris Strategic Development Zone 2019
	Kildare County Development Plan 2017-2023
	Celbridge Local Area Plan
	The Draft Kildare County Development Plan 2023 - 2029

	The proposed DART+ South West Project represent railway infrastructure within an operational railway line and primarily within or directly adjacent to the existing rail corridor. The above is the relevant policy which underpins the proposed DART+ South West Project at European Union (EU), national, regional, and local level. The above have been taken into consideration in the development of the Project. The DART+ South West Project supports the objectives and goals of the above policies. **Options Selection Process for DART+ South West** The DART+ South West Project involves an existing operational rail line running in a pre-defined corridor and as such, the Project can be characterised as one which provides for enhancement of existing railway infrastructure. A clearly defined appraisal methodology has been used in the selection of the Preferred Option for the proposed Project. Consistent with other NTA projects, the appraisal methodology applied is based on 'Guidelines on a Common Appraisal Framework for Transport Projects and Programmes' (CAF) published by the Department of Transport, Tourism, and Sport (DTTAS), March 2016 (updated 2020), TII's Project Management Guidelines (TII PMG 2019) and NTA Project Approval Guidelines 2020. The process comprises of a two-stage approach, as appropriate: • Stage 1 – Preliminary Appraisal (sifting) of a long list of options; and • Stage 2 – Multi-Criteria Analysis (MCA) of a shorter list of feasible options. The Options Selection Reports present the outcome of the optioneering process. The Prelimary Option Selection Report (POSR) presented the Emerging Preferred Option as it was at that point in time. The Emerging Preferred Option presented in the POSR at PC1 was subsequently analysed and re-evaluated based on public consultation feedback from PC1 and this informed the Preferred Option which was presented during the second round of public consultations. To support PC2, a second report was published – the DART+ South West Options Selection Report (OSR). The Preferred Option presented in that report superseded the earlier Emerging Preferred Option which had been presented in the POSR. The MCA process provides a coherent mechanism for choosing between options on a comparative basis. Each option is characterised under six principal categories as defined within the CAF and compared on a qualitative basis. The principles of the process apply to all options assessment for the project. The mechanism allows for an objective approach to be taken to selection of the most suitable option to be advanced for the project. A summary of the MCA process is presented in the OSR, as has the application of the comparative assessment methodology when appraised against the Project Objectives.

7.2.2. Criteria 2

The proposed Development has been subject to an appropriate detailed FRA for each Zone. The FRAs demonstrate flood risk will not increase elsewhere and minimises flood risk to the railway track and associated infrastructure and the surrounding area. The FRAs also demonstrated that the proposed flood mitigation measures ensure that the residual risks to the surrounding area are managed to an acceptable level. Responses to the sub items for criteria 2 for each development zone are listed in Table 7.3.

Table 7.3: Item 2 Responses

Sub-Items	Development Zones	Response
(i) The development proposed will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk.	Zone A - Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station.	The proposed Development at Adamstown and Hazelhatch will not increase flood risk in the surrounding area. The existing railway track at Hazelhatch is liable to flooding from the 1% AEP and 0.1%AEP flood events. However, the proposed upgrading of infrastructure at Hazelhatch to facilitate the electrification will not increase flood risk to the surrounding as the proposed ground levels will be maintained at the current levels to ensure that displacement of floodwaters does not occur and cause a residual risk to the surrounding areas. The proposed noise barriers in the Hazelhatch area are located within the 1% AEP and 0.1% AEP flood extents. A hydraulic model simulation showed that these proposed noise barriers would cause a slight increase in flood level, particularly in the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. In order to mitigate this impact to the flood level, an 83m long and 2m wide conveyance channel was proposed along the railway track along the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. This channel will help in conveying the increased flood volume from the adjacent flooded land areas into the Shinkeen river and maintain the status quo flooding regime. At Adamstown the track and associated infrastructure is located outside Flood Zones A and B. The analysis of the existing scenario found that the railway at Adamstown is not at risk of flooding from both the 1% AEP and 0.1% AEP flooding events. The railway is not at risk at during the 1% AEP HEFS climate change scenario, however the railway is at risk at Adamstown during the 0.1% AEP HEFS climate change scenario. The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. Iarnród Éireann has determined that hard mitigation measures are not warranted at this time. Risk reduction associated with the HEFS 0.1% AEP could be achieved in the future by implementation of the proposed mitigation measures by Iarnród Éireann if warranted. No impacts on the existing flooding regimes of the Lucan and Griffin Rivers in the Adamstown areas, due to the installation of the proposed noise barriers, are expected, since the proposed noise barriers are not located within the design flood extents.
	Zone B - Park West & Cherry Orchard Station to Heuston Station	The proposed Development within Zone B was identified to be liable to flooding from pluvial event. No fluvial flooding was predicted. The proposed drainage system has been designed to cater for 1%AEP -HEFS pluvial event. No increase in flood level in the adjacent watercourses are anticipated, since a SUDS type drainage system (filter drain/attenuation ponds) has been proposed which will limit the outflows to the pre-development stage runoff rates.

Sub-Items	Development Zones	Response
		No impacts on the existing flooding regimes of the in this section of the railway track, due to the installation of the proposed noise barriers, are expected, since the proposed noise barriers are not located within the design flood extents.
	Zone C – Heuston Yard and Station	The proposed new Heuston West Station was not identified as liable to flooding from the 0.1%AEP – HEFS flood event. The proposed development at the Heuston station will not increase flood risk in the surrounding area. The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. Any predicted flooding from the 0.1% AEP-HEFS event will be contained within the Heuston Station Car Park which is a flood compatible land use and in an area currently under CIÉ ownership. The risk will be managed by following the current operational procedures outlined in Section 2.9. No impacts on the existing flooding regimes of the in this area of the railway track, due to the installation of the proposed noise barriers, are expected, since the proposed noise barriers are not located within the design flood extents.
	Zone D – River Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line)	No increase in flood level is anticipated since the existing drainage catchment area will not increase. Furthermore, the proposed drainage system will be improved by lowering the pumping station (between OBO8 and OBO9) which will allow increased wet well storage capacity and provide attenuation. The proposed drainage system has been designed to cater for 1%AEP - HEFS pluvial event.
(ii) The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible	Zone A - Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station.	Proposed ground levels at Hazelhatch will be maintained at the current levels to ensure that displacement of floodwaters does not occur and cause a residual risk to the surrounding areas. The analysis of the existing scenario found that the railway at Adamstown is not at risk of flooding from both the 1% AEP and 0.1% AEP flooding events. The railway is not at risk at during the 1% AEP HEFS climate change scenario, however the railway is at risk at Adamstown during the 0.1% AEP HEFS climate change scenario. The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. Iarnród Éireann has determined that hard mitigation measures are not warranted at this time. The risk will be managed by following the current operational procedures outlined in Section 2.9. Hence no further impact in terms of flood risk to people, property and environment is expected. A hydraulic model simulation showed that the proposed noise barriers in the Hazelhatch area would cause a slight increase in flood level, particularly in the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. In order to mitigate this impact to the flood level, an 83m long and 2m wide conveyance channel was proposed along the railway track along the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. This channel will help in

Sub-Items	Development Zones	Response
		conveying the increased flood volume from the adjacent flooded land areas into the Shinkeen river and maintain the status quo flooding regime.
	Zone B - Park West & Cherry Orchard Station to Heuston Station	The proposed drainage system has been designed to cater for 1%AEP -HEFS pluvial event. No increase in flood level in the adjacent watercourses are anticipated, since a SUDS type drainage system (filter drain/attenuation ponds) has been proposed which will limit the outflows to the pre-development stage runoff rates.
	Zone C – Heuston Yard and Station	The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. Any predicted flooding for the HEFS will be contained within the Heuston Station Car Park which is a flood compatible land use or in areas already owned by IE. The risk will be managed by following the current operational procedures outlined in Section 2.9. Hence no further impact in terms of flood risk to people, property and environment is expected.
	Zone D – River Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line)	No increase in flood level or any increased flooding risk to the adjacent lands and properties are anticipated since the existing drainage catchment area will not increase. Furthermore, the proposed drainage system will be improved by lowering the pumping station (between OBO8 and OBO9) which will allow increased wet well storage capacity and provide attenuation.
(iii) The development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access;	Zone A - Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station.	The main residual risks identified at the Hazelhatch is the potential increase of flood levels due to climate change. Hydraulic model runs were developed to assess the identified risks. The results from the modelling confirm that track and station are at risk from climate change scenarios. The upgrading of infrastructure at Hazelhatch to facilitate the electrification will not increase flood risk to the surrounding as the proposed ground levels will be maintained at the current levels to ensure that displacement of floodwaters does not occur and cause a residual risk to the surrounding areas. There are no hard flood mitigation measures proposed for the station under this study. A preliminary investigation on the flood risk management options at Hazelhatch area showed that any localised flood protection measures at the railway track would pose increased flooding risks to the lands & properties located immediate upstream & downstream of the railway track. Given the complex nature of flood mechanisms and presence of low-lying flood prone areas in the vicinity of the proposed development, a catchment wide flood mitigation option/approach should be adopted in coordination with the relevant local authority and OPW. This should be implemented under a separate FRS. All critical equipment at the proposed substation can be set at a level above the flood level while the substation site ground level can be maintained at existing levels. In order to mitigate the predicted impact on the flood level as a result of the installation of noise barriers in the vicinity of the Shinkeen river crossing, an 83m long and 2m wide conveyance channel has been proposed along the railway track. This channel will help in conveying the increased flood volume from the adjacent flooded land areas into the Shinkeen river and maintain

Sub-Items	Development Zones	Response
		the status quo flooding regime. No residual flood risks as a result of these noise barriers are therefor expected. The main residual risks identified at the Adamstown is the potential increase of flood levels due to climate change. Hydraulic model runs were developed to assess the identified risks. The results from the modelling confirm that the provided freeboard is sufficient to protect the track from the identified residual risks.
	Zone B - Park West & Cherry Orchard Station to Heuston Station	The proposed drainage systems are of SUDs type (Filter drains/ attenuation ponds) which will provide attenuation to any increased surface runoff before discharging into the surface water sewers/surface watercourses. Furthermore, the proposed drainage system was designed to cater for any increase surface runoff due to climate change.
	Zone C – Heuston Yard and Station	The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. Any predicted flooding for the HEFS will be contained within the Heuston Station Car Park which is a flood compatible land use or in areas already owned by IE until the water recedes. The risk will be managed by following the current operational procedures outlined in Section 2.9. Hence no further impact in terms of flood risk to people, property and environment is expected.
	Zone D – River Liffey Bridge to Glasnevin Junction (Phoenix Park Tunnel Branch Line)	The proposed drainage systems are of SUDs type (Filter drains/ attenuation ponds) which will provide attenuation to any increased surface runoff before discharging into the surface water sewers/surface watercourses. Increased Pumping Station wet well capacity will provide increased attenuation to runoff volume. Furthermore the proposed drainage system was designed to cater for any increase surface runoff due to climate change.
(iv) The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes	Zone A - Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station. Zone B - Park West & Cherry Orchard Station to Heuston Station Zone C – Heuston Yard and Station Zone D – River Liffey Bridge to Glasnevin	The proposed development are confined within the existing railway corridor. This has been zoned as primary transport corridor. Furthermore the SUDs type drainage system has been proposed which is compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.

Sub-Items	Development Zones	Response
	Junction (Phoenix Park Tunnel Branch Line)	

8. Conclusion And Recommendations

8.1. Overview

An FRA was carried out to support an EIAR and Railway Order by Córas Iompair Éireann and Iarnród Éireann for the proposed DART+ South West Project. The DART+ South West Project will deliver an electrified network, with increased passenger capacity and enhanced train service between Hazelhatch & Celbridge Station to Heuston Station (circa 16km) on the Cork Mainline, and Heuston Station, and Glasnevin Junction via the PPT Branch Line (circa 4km). The was carried out in accordance with the FRM Guidelines. The FRA was subdivided into several zones to assess the flood risk to each individual zone along the length of the proposed Development. The Zones included:

- Zone A - FRA from Hazelhatch & Celbridge Station to Park West & Cherry Orchard Station (Zone A was further subdivided into the Hazelhatch and Adamstown regions);
- Zone B - FRA from Park West & Cherry Orchard Station to Heuston Station (incorporating Inchicore Works;
- Zone C - FRA from Heuston Yard and Station (incorporating New Heuston West Station); and
- Zone D - FRA from Liffey Bridge to Glasnevin Junction.

A review of available flood risk information for each zone was undertaken and found the following:

- Zone A – Hazelhatch has a high fluvial risk and a medium pluvial risk FRA, while Adamstown has a high fluvial risk and a low pluvial risk;
- Zone B – High pluvial risk;
- Zone C - High fluvial risk, medium coastal risk and a high pluvial risk FRA; and
- Zone D - High pluvial risk and medium groundwater risk.

The design standard for flood mitigation measures and assessment for the FRA was identified as the 0.1% AEP HEFS flooding scenario as railway infrastructure is considered critical infrastructure under the FRM Guidelines flood risk vulnerability classifications.

Iarnród Éireann has an operating procedure which sets out recommended flood level limits for their rolling stock passing over flooded tracks. The maximum limit identified within the procedure for this study (to facilitate the EMU rolling stock) is 170mm deep from ground level.

To further assess these risks for each zone, detailed assessments were undertaken, and are detailed below in the subsequent sections.

8.2. Zone A

To improve the accuracy of the locally predicted flood levels at the proposed site and assess any adverse impacts to the surrounding areas, a detailed 1D/2D combined hydraulic model assessments were undertaken at Hazelhatch and Adamstown. The hydrological inputs for the models were derived using FSU and IH124 hydrological methodologies. The models were calibrated against the results from flood mapping for existing studies including the Hazelhatch Further Study and the Eastern CFRAM Study.

8.2.1. Hazelhatch

The proposed Development site is impacted by the 1% and 0.1% AEP fluvial flood events and lies within Flood Zones A and B. There is predicted flooding on the track at the Hazelhatch station and also at track adjacent to the Shinkeen Stream. There was good correlation between the flood extents and flood depths for the FRA and the Hazelhatch Further Study. The proposed Development is also at risk during climate change flooding scenarios at the same locations where flood depths are increased and extents are larger.

Hydraulic modelling of possible mitigation measures included at Hazelhatch would increase flood risk to the surrounding area and not reduce flooding below the Iarnród Éireann flood depth operational limits. Therefore it is recommended that no mitigation measures are included for the application for Railway Order and that Iarnród Éireann engage with the OPW who is currently progressing a FRS for the wider Hazelhatch area.

The upgrading of infrastructure at Hazelhatch to facilitate the electrification will not increase flood risk to the surrounding as the proposed ground levels will be maintained at the current levels to ensure that displacement of floodwaters does not occur and cause a residual risk to the surrounding areas. The predicted flooding for the HEFS 0.1% AEP event at the location of the proposed substation is 57.559 mOD All critical equipment can be set at a level above this flood level while the substation site ground level can be maintained at existing levels.

Noise barriers are proposed at a number of locations within Zone A to mitigate operational noise impact (Refer to Chapter 14 Noise & Vibration of Volume 2, EIAR for further details). The proposed noise barriers in the Hazelhatch area are located within the 1% AEP and 0.1% AEP flood extents. A hydraulic model simulation showed that these proposed noise barriers would cause a slight increase in flood level, particularly in the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. The causes of this flood level rise can mainly be attributed to the obstruction to flood water flow paths caused by the proposed noise barriers. In order to mitigate this impact to the flood level, an 83m long and 2m wide conveyance channel was proposed along the railway track along the north-eastern vicinity of the railway culvert crossing on the Shinkeen River. This channel will help in conveying the increased flood volume from the adjacent flooded land areas into the Shinkeen river and maintain the status quo flooding regime.

Iarnród Éireann shall develop operational procedures which would ensure that Hazelhatch is not utilised during an extreme flooding situation.

8.2.2. Adamstown

The railway track is not impacted by the 1% and 0.1% AEP fluvial flood events in current scenario and lies within Flood Zone C. There was good correlation between the flood extents and flood depths for the Lucan Stream FRA and the Eastern CFRAM Study. However, the extents and flood levels for the Griffeen are larger for this FRA upstream of the railway for both the 1% AEP and 0.1 % AEP events when compared than the CFRAM mapping. The flood levels correlate with the mapping showing increased water levels upstream of the railway and lesser downstream of the railway for the FRA when compared to the CFRAM. Upon review of the LiDAR surface and CFRAM topographical information it was found that there is a lower section of the right riverbank upstream of the railway which does not appear to have been accounted for in the CFRAM modelling. Thus flood waters could overtop this in the FRA and produced larger flooding extents on the right bank.

Modelling results for the worst case HEFS scenario indicate flooding occurs at the Hayden's Lane culvert. The culvert is unable to convey the 0.1% AEP HEFS flows and causes the water to overtop the river bank along the left bank just upstream of the culvert. This flood water encroaches on the railway line causing flooding of approximately 120 mm depth. There is no predicted flooding to the proposed substation to the west of the Lucan Stream.

Hydraulic modelling of mitigation measures included at Adamstown showed that they remove flooding from the railway track. However, depending on the solution employed, it increases (flood embankment) or reduces (culvert upgrade) flooding depths and extents upstream of the railway line. There is no increases for either mitigation measure downstream of the railway.

Having considered the hydraulic analysis of the existing scenario for the HEFS 0.1% AEP event, which identified the approximate depth of flood water on the track as 120mm for an approximate duration of 12 hours, the EMU (the rolling stock of primary concern) is within the recommended operating limits passing over flooded track as outlined within Iarnród Éireann's operating procedure.

The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. TTA have presented the analysis of the modelling to Iarnród Éireann and Iarnród Éireann has determined that hard mitigation measures are not warranted at this time. Risk reduction associated with the HEFS 0.1% AEP could be achieved in the future by implementation of the proposed mitigation measures by Iarnród Éireann if warranted.

Noise barriers are proposed at a number of locations within Zone A to mitigate operational noise impact (Refer to Chapter 14 Noise & Vibration of Volume 2, EIAR for further details). No impacts on the existing flooding regimes of the Lucan and Griffin Rivers in the Adamstown areas, due to the installation of the proposed noise barriers, are expected, since the proposed noise barriers are not located within the design flood extents.

8.3. Zone B

The proposed Development within Zone B was identified to be liable to flooding from pluvial event. No fluvial flooding was predicted. The proposed drainage system has been designed to cater for 1%AEP -HEFS pluvial event. No increase in flood level in the adjacent watercourses are anticipated, since a SUDS type drainage system (filter drain/attenuation tanks) has been proposed which will limit the outflows to the pre-development stage runoff rates.

8.4. Zone C

To improve the accuracy of the locally predicted flood levels at the proposed site and assess any adverse impacts to the surrounding areas, a detailed 1D/2D combined hydraulic model assessments were undertaken at for Heuston modelling the River Liffey and River Camac. The hydrological inputs for the models were derived using FSU and IH124 hydrological methodologies. The models were calibrated against the results from flood mapping for the existing Eastern CFRAM Study.

The proposed Development site is not impacted by the 1% and 0.1% AEP fluvial flood events and lies within Flood Zone C.

There was good correlation between the flood extents and flood depths for the River Liffey and the Eastern CFRAM Study. However, the extents and flood levels for the Camac are smaller for this FRA for both the 1% AEP and 0.1 % AEP events when compared than the CFRAM mapping. The decrease in extents is due to the difference in growth factors used which reduce the flows. The CFRAM study used generalised regional growth factors based on the catchment size for the entirety of the River Liffey Hydrometric Area. This approach was conservative and used in order to expediate hydrological calculations due the volume of them being undertaken for the CFRAMS.

The analysis of the existing scenario found that the railway and Heuston Station are not at risk of flooding from both the 1% AEP and 0.1% AEP flooding events.

The railway track and car park are at risk during the HEFS 0.1% AEP climate change scenario from the River Liffey and River Camac. There is no flooding predicted at the future Heuston West Station. There is predicted flooding to the Heuston Station Terminal Building from the River Camac, however any mitigation measures for that scenario are outside the scope of this FRA.

Potential mitigation measures to alleviate flooding were proposed and modelled. Hydraulic modelling of a flood relief wall and flood barrier to reduce flood risk during the 0.1% AEP HEFS flooding scenario was undertaken. The predicted flooding has been removed from the railway track and is contained within the car park which is a flood compatible area and also in areas under CIÉ ownership.

The risk and probability of the HEFS 0.1% AEP occurring is low and the railway is not at risk during the 1% AEP event. TTA have presented the analysis of the modelling to Iarnród Éireann. Having considered the hydraulic analysis of the existing scenario for the HEFS 0.1% AEP event, Iarnród Éireann has determined that hard mitigation measures are not warranted at this time. Risk reduction associated with the HEFS 0.1% AEP could be achieved in the future by implementation of the proposed mitigation measures by Iarnród Éireann if warranted.

Noise barriers are proposed within Zone C to mitigate operational noise impact (Refer to Chapter 14 Noise & Vibration for further details). No impacts on the existing flooding regimes of the River Liffey and River Camac in the vicinity of the Heuston Station, due to the installation of proposed noise barriers, are expected, since the proposed noise barriers are not located within the design flood extents.

8.5. Zone D

The proposed drainage systems are of SUDs type (Filter drains/ attenuation ponds) which will provide attenuation to any increased surface runoff before discharging into the surface water sewers/surface watercourses. Increased Pumping Station wet well capacity will provide increased attenuation to runoff volume. Furthermore the proposed drainage system was designed to cater for any increase surface runoff due to climate change. An examination of the past flood events and existing surrounding topography and Royal Canal design details showed that during an extreme rainfall event (i.e. during 1% & 0.1% AEP events) coupled with any blockages at the downstream lock gates flood water would overtop this embankment and cause flooding on to the surrounding lands and railway track between the bridge structures OBO8 and OBO9.

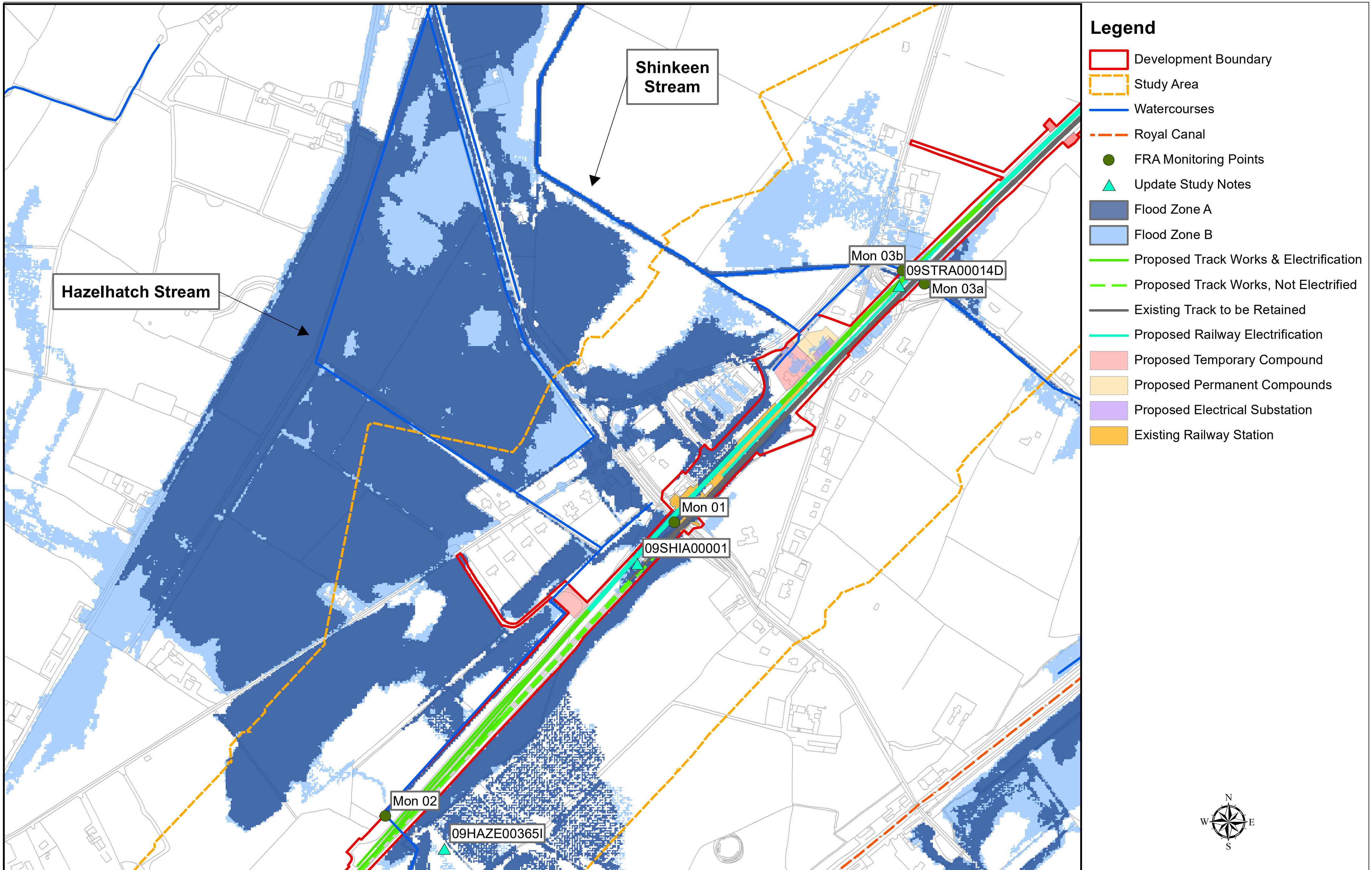
This could be avoided through constant monitoring of water through lock gate operations. As such, it is recommended that an early warning system is implemented through installation by Iarnród Éireann of water level monitoring equipment at an agreed location on the Royal Canal with permission from Waterways Ireland. The installation of a real-time monitoring system with telemetry can alert Iarnród Éireann if a certain threshold is breached and take the necessary appropriate actions.

8.6. Justification Test

Justification Tests were carried out for the proposed Development within each Zone. The tests concluded that all the relevant criteria set out in FRM Guidelines were satisfied and development at the proposed upgrades is appropriate.

Appendix A

Flood Mapping



Rev	Date	Drn	Chk'd	App'd	Description
v02	03/11/2022	MV	UM	CR	Water (Including Hydrology & Flood Risk)
v01	12/09/2022	MV	UM	CR	Water (Including Hydrology & Flood Risk)

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA, ATKINS (Member of the SNC-Lavalin Group), TUC RAIL

Supported by: RPS

Date	Scale	Drawn	Checked	Approved
03/11/2022	1:7,500 @ A4	MV	UM	CR

Project Code	Issuer	QMS Code
5195886	TTA	

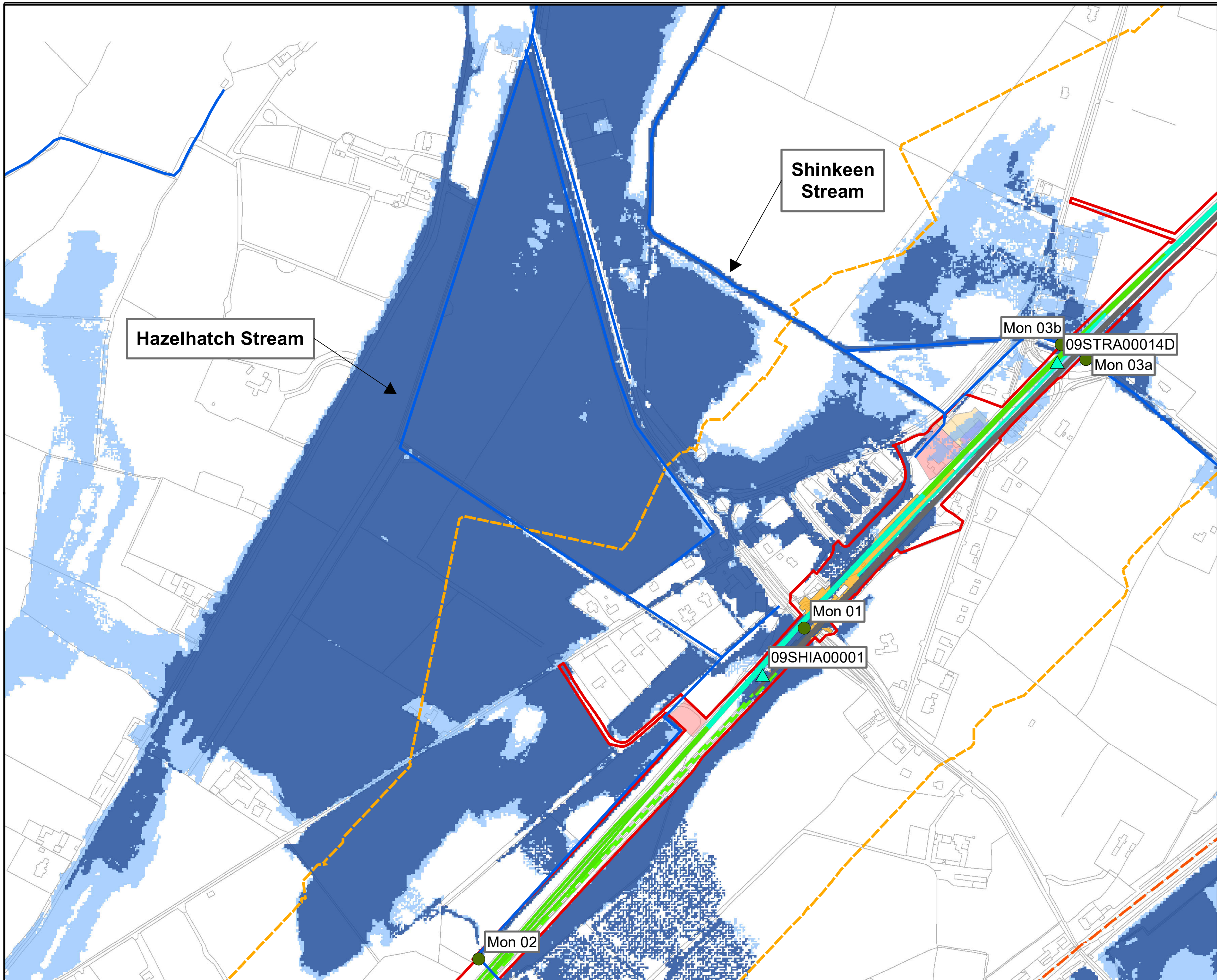
Project Title: DART + SOUTH WEST

Drawing Title:

Figure 3-18: Hazelhatch FRA Flood Zones

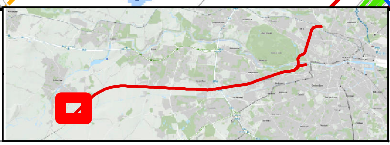
Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23792	v02	S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

- Development Boundary
- Study Area
- Watercourses
- Royal Canal
- FRA Monitoring Points
- Update Study Notes
- Proposed Track Works & Electrification
- Proposed Track Works, Not Electrified
- Existing Track to be Retained
- Proposed Railway Electrification
- 1% AEP HEFS
- 0.1% AEP HEFS
- Proposed Temporary Compound
- Proposed Permanent Compounds
- Proposed Electrical Substation
- Existing Railway Station



DART+ South West

Rev	Date	Drn	Chk'd	App'd	Description
v02	03/11/2022	MV	UM	CR	Water (Including Hydrology & Flood Risk)
v01	12/09/2022	MV	UM	CR	Water (Including Hydrology & Flood Risk)

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA, ATKINS (Member of the SNC-Lavalin Group), TUC RAIL

Supported by: rps

Date	Scale	Drawn	Checked	Approved
03/11/2022	1:7,500 @ A4	MV	UM	CR

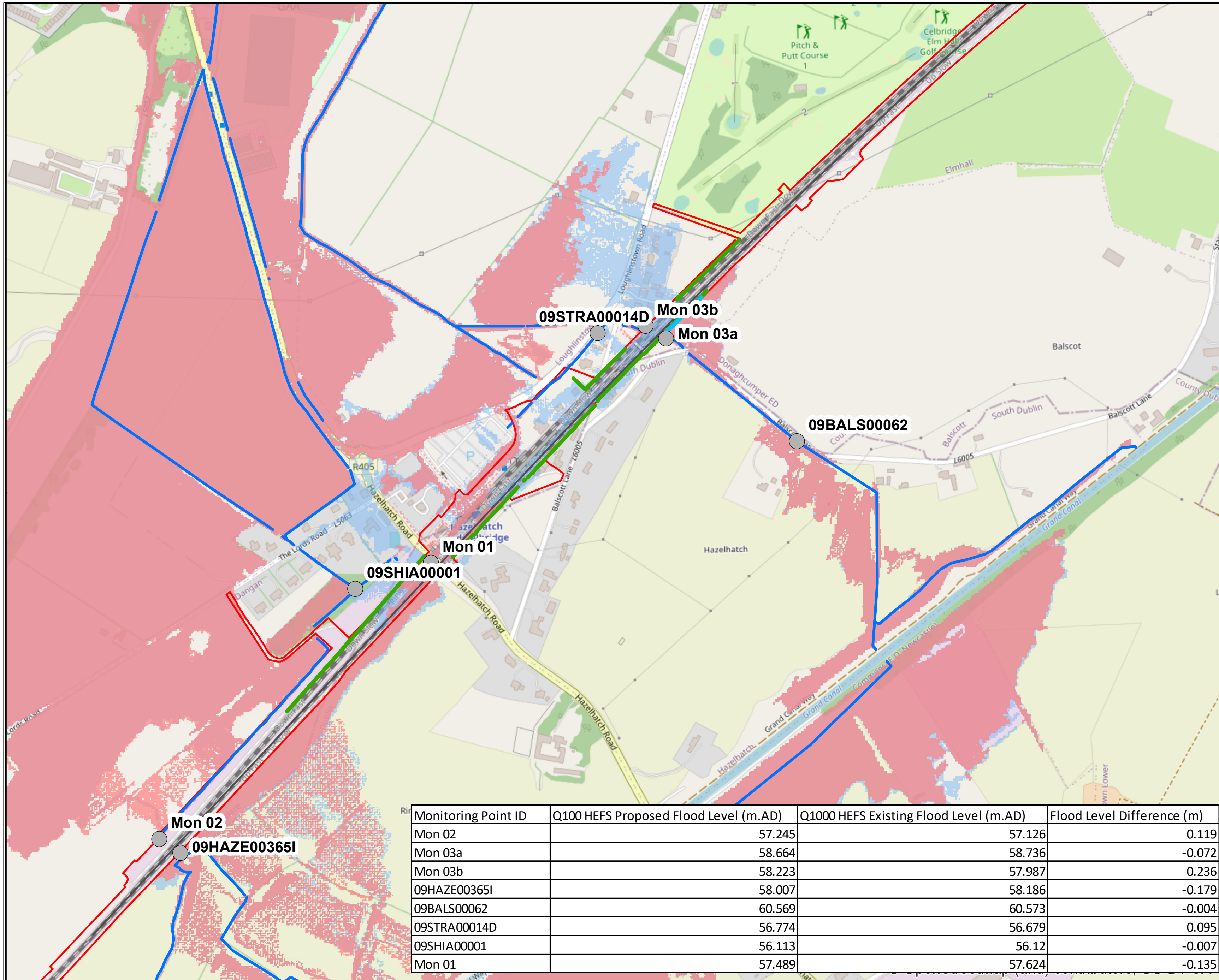
Project Code	Issuer	QMS Code
5195886	TTA	

Project Title: DART + SOUTH WEST

Drawing Title: **Figure 3-19: Hazelhatch FRA HEFS Flood Extents**

Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23793	v02	S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

- Redline Development Boundary
- Monitoring Points
- River Reach
- Proposed 2m Wide Channel
- Proposed Noise Barriers
- Q1000 HEFS Proposed
- Q1000 HEFS Existing

Note:
Proposed - includes for mitigation measures proposed in FRA Report & Proposed Noise Barriers

Monitoring Point ID	Q100 HEFS Proposed Flood Level (m.AD)	Q1000 HEFS Existing Flood Level (m.AD)	Flood Level Difference (m)
Mon 02	57.245	57.126	0.119
Mon 03a	58.664	58.736	-0.072
Mon 03b	58.223	57.987	0.236
09HAZE00365I	58.007	58.186	-0.179
09BALS00062	60.569	60.573	-0.004
09STRA00014D	56.774	56.679	0.095
09SHIA00001	56.113	56.12	-0.007
Mon 01	57.489	57.624	-0.135

Rev	Date	Drn	Chk'd	App'd	Description
v01	26/01/2023	IP	EH	CR	0.1% AEP HEFS Predicted Flood Extents

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA ATKINS TUC RAIL
Supported by: rps

Date	Scale	Drawn	Checked	Approved
26/01/2023	1:9,000 @ A4	NR	UM	CR

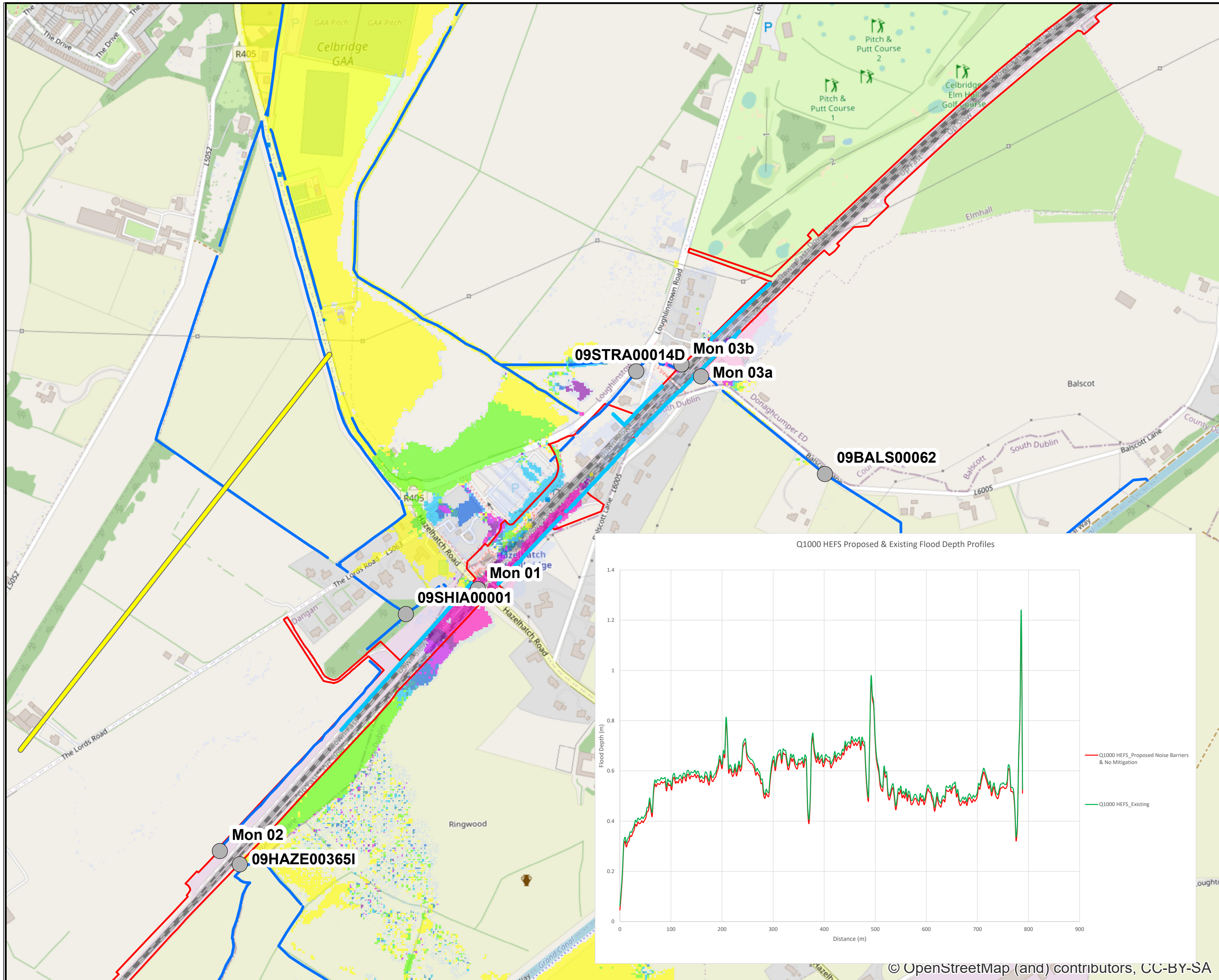
Project Code: 5195886
Issuer: TTA
QMS Code:

Project Title: DART + SOUTH WEST

Drawing Title: **0.1% AEP HEFS Predicted Flood Extents**

Drawing File Name: DP-04-23-DWG-EV-TTA-23898
Version: v01
Status: S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

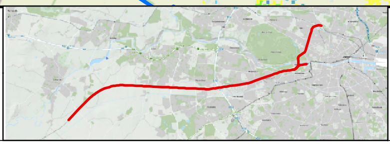
- Redline Development Boundary
- Flood Level Profile
- Proposed Noise Barriers
- River Reach
- Monitoring Points

Q1000 HEFS Noise Barriers & No Mitigation Flood Extents Increase

Q1000 HEFS Noise Barriers & No Mitigation Flood Depth Increase

- 0.001 - 0.010 m
- 0.010 - 0.020 m
- 0.020 - 0.030 m
- 0.030 - 0.040 m
- 0.040 - 0.050 m
- 0.05 - 0.075 m
- 0.075 - 0.100 m
- 0.100 - 0.200 m
- > 0.200 m

N E S W



DART+ South West

Rev	Date	Drn	Chk'd	App'd	Description
v01	26/01/2023	IP	EH	CR	0.1% AEP HEFS Predicted Flood Extents

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA, ATKINS

Supported by: rps

Date	Scale	Drawn	Checked	Approved
27/01/2023	1:9,483 @ A4	NR	UM	CR

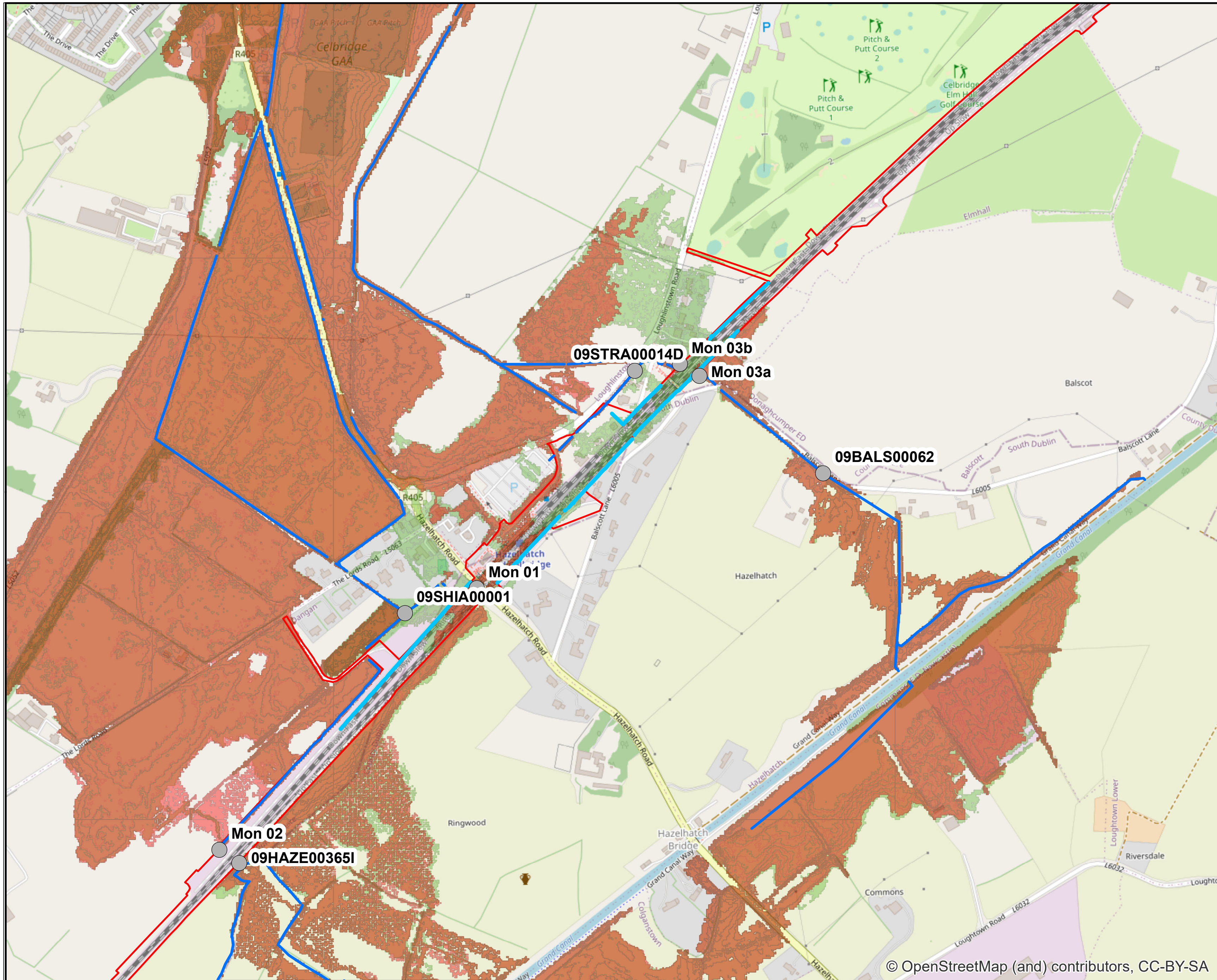
Project Code: 5195886 | Issuer: TTA | QMS Code:

Project Title: DART + SOUTH WEST

Drawing Title: **Figure 3-19b 0.1% AEP HEFS Predicted Flood Depth & Extents Increase (Noise Barriers & No Mitigation)**

Drawing File Name: DP-04-23-DWG-EV-TTA-23900 | Version: v01 | Status: S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

- Redline Development Boundary
- Proposed Noise Barriers
- River Reach
- Monitoring Points
- Q1000_HEFS_Pr. Mitigation & Noise Barriers & channel included
- Q100 HEFS Existing

DART+ South West

Rev	Date	Drn	Chk'd	App'd	Description
v01	26/01/2023	IP	EH	CR	0.1% AEP HEFS Predicted Flood Extents

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA ATKINS

Supported by: rps

Date	Scale	Drawn	Checked	Approved
26/01/2023	1:9,483 @ A4	NR	UM	CR

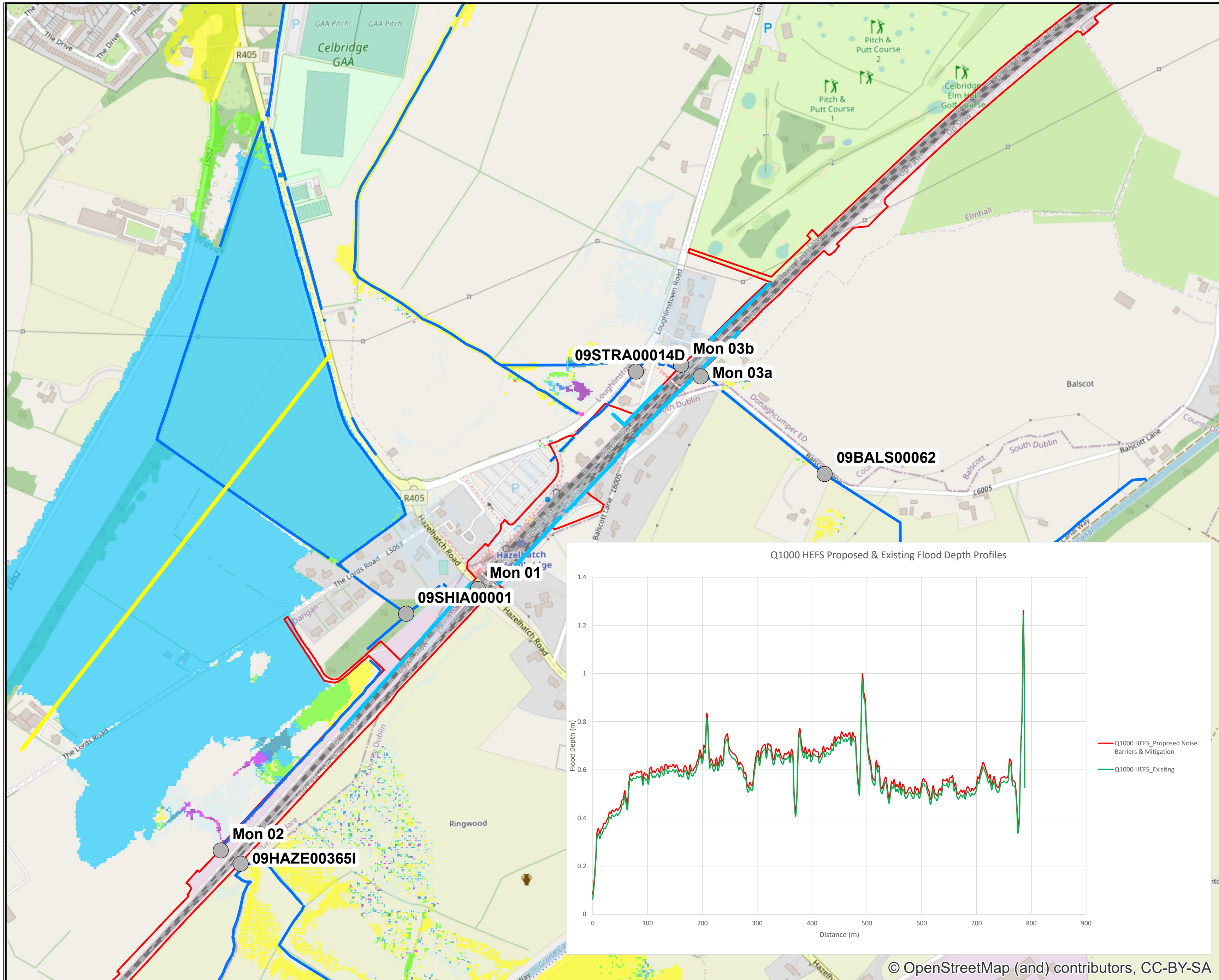
Project Code	Issuer	QMS Code
5195886	TTA	

Project Title: DART + SOUTH WEST

Drawing Title: **Figure 3-22 0.1% AEP HEFS Predicted Flood Extents (Noise Barriers & Mitigation Measures)**

Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23899	v01	S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

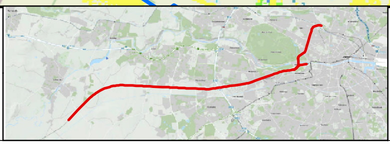
- Redline Development Boundary
- Flood Level Profile
- Proposed Noise Barriers
- River Reach
- Monitoring Points

Q1000 HEFS Noise Barriers & Mitigation Measures Flood Extents Increase

Q1000 HEFS Noise Barriers & Mitigation Flood Depth Increase

- 0.001 - 0.010 m
- 0.010 - 0.020 m
- 0.020 - 0.030 m
- 0.030 - 0.040 m
- 0.040 - 0.050 m
- 0.05 - 0.075 m
- 0.075 - 0.100 m
- 0.100 - 0.200 m
- > 0.200 m

N E S W



DART+ South West

Rev	Date	Drn	Chk'd	App'd	Description
v01	26/01/2023	IP	EH	CR	0.1% AEP HEFS Predicted Flood Extents

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA ATKINS Member of the SNC-Lavalin Group TUC RAIL

Supported by: rps

Date	Scale	Drawn	Checked	Approved
27/01/2023	1:9,500 @ A4	NR	UM	CR

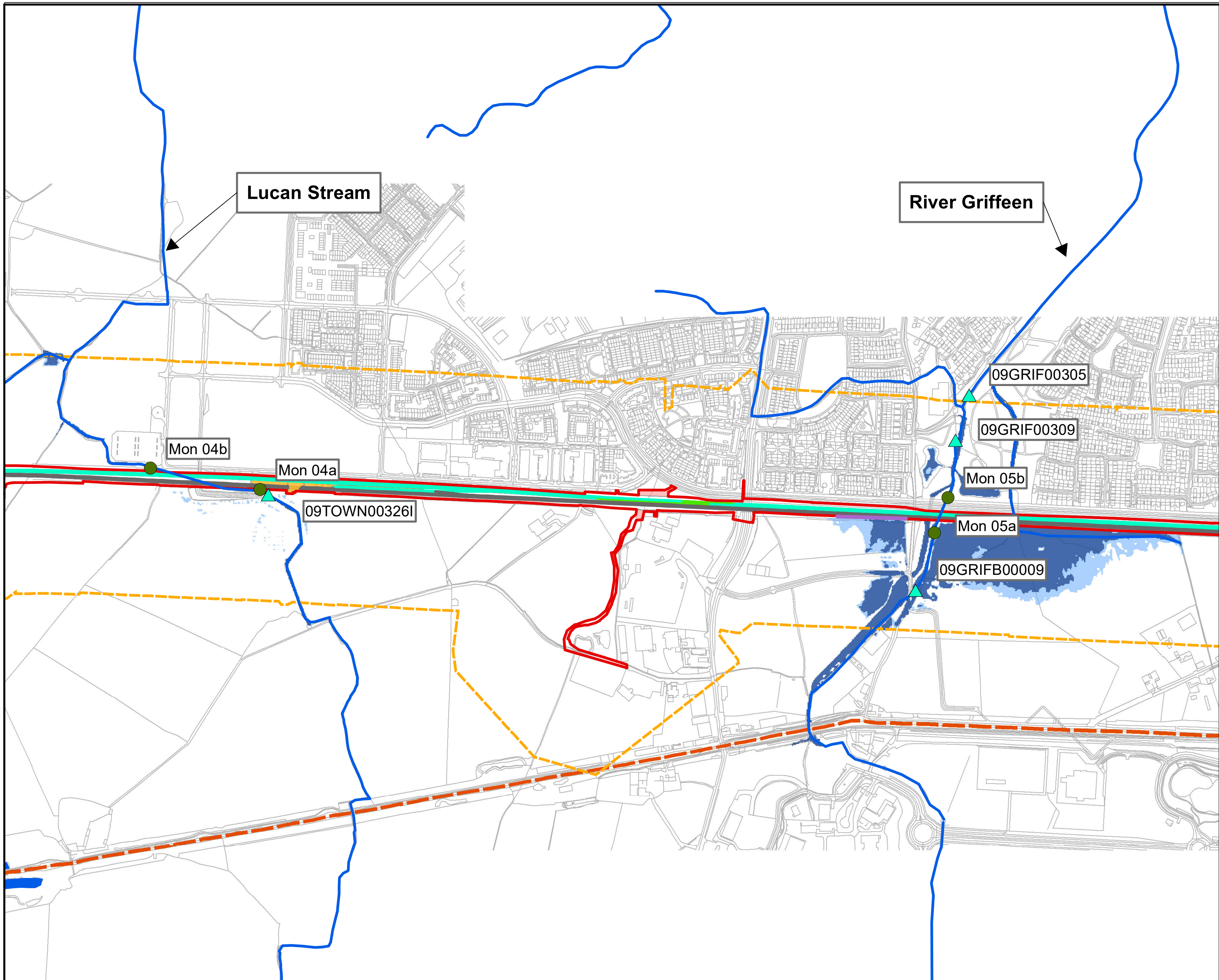
Project Code	Issuer	QMS Code
5195886	TTA	

Project Title: **DART + SOUTH WEST**

Drawing Title: **Figure 3-21 0.1% AEP HEFS Predicted Flood Depth & Extent Increase (Noise Barriers & Mitigation Measures)**

Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23902	v01	S3

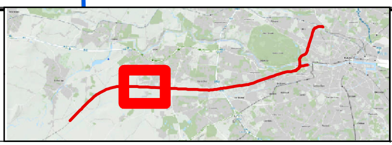
DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

- Development Boundary
- Study Area
- Watercourses
- Royal Canal
- FRA Monitoring Points
- CFRAM Nodes
- Flood Zone A
- Flood Zone B
- Existing Track to be Retained
- Proposed Railway Electrification
- Proposed Track Works and Electrification
- Proposed Track Works, Not Electrified
- Proposed Temporary Compound
- Proposed Permanent Compounds
- Proposed Electrical Substation
- Existing Railway Station

N W E S



Rev	Date	Drn	Chk'd	App'd	Description
v02	03/11/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)
v01	08/09/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA, ATKINS (Member of the SNC-Lavalin Group), TUC RAIL
Supported by: rps

Date	Scale	Drawn	Checked	Approved
03/11/2022	1:12,000 @ A4	NR	UM	CR

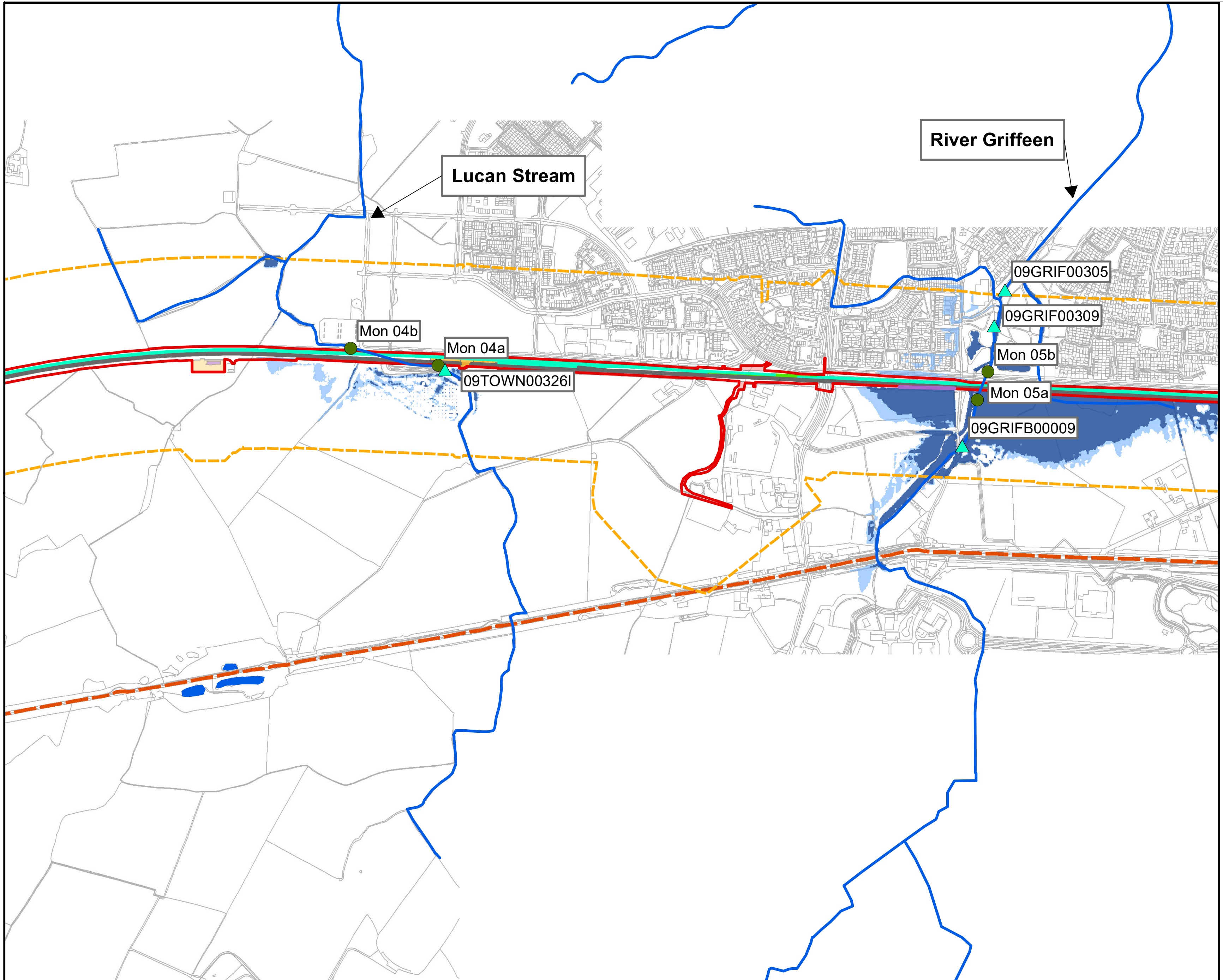
Project Code	Issuer	QMS Code
5195886	TTA	

Project Title: **DART + SOUTH WEST**

Drawing Title: **Figure 3-43 Flood Zones on Griffeen and Lucan**

Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23798	v02	S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

- Development Boundary
- Study Area
- Watercourses
- Royal Canal
- FRA Monitoring Points
- CFRAM Nodes
- 1% AEP HEFS
- 0.1% AEP HEFS
- Existing Track to be Retained
- Proposed Railway Electrification
- Proposed Track Works and Electrification
- Proposed Track Works, Not Electrified
- Proposed Temporary Compound
- Proposed Permanent Compounds
- Proposed Electrical Substation
- Existing Railway Station

DART+ South West

Rev	Date	Drn	Chk'd	App'd	Description
v02	03/11/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)
v01	08/09/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA, ATKINS Member of the SNC-Lavalin Group, TUC RAIL

Supported by: rps

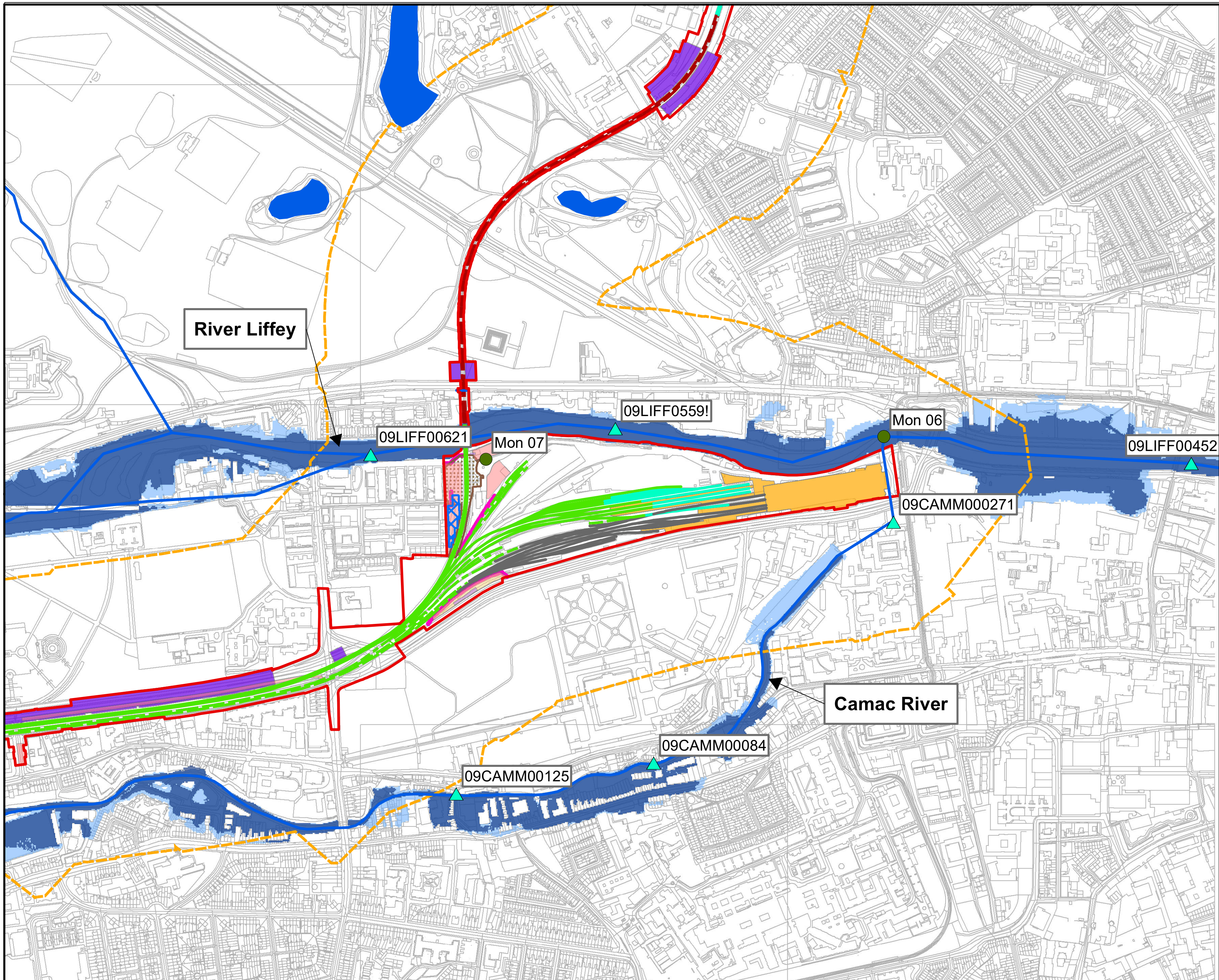
Date 03/11/2022	Scale 1:15,000 @ A4	Drawn NR	Checked UM	Approved CR
Project Code 5195886	Issuer TTA	QMS Code		

Project Title: DART + SOUTH WEST

Drawing Title: **Figure 3-47: HEFS flood extents for the Lucan and Griffeen Streams**

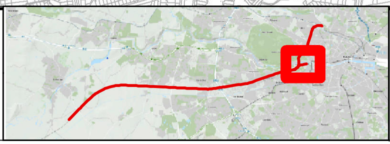
Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23799	v02	S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

- Development Boundary
- Study Area
- Watercourses
- FRA Monitoring Points
- CFRAM Nodes
- Flood Zone A
- Flood Zone B
- Proposed Attenuation
- Proposed Concrete Slab Track and Electrification
- Existing Track to be Retained
- Proposed Railway Electrification
- Proposed Track Works and Electrification
- Proposed Track Works, Not Electrified
- Proposed Parapet Modifications
- Proposed Boundary Wall
- Proposed Temporary Compound
- Proposed Retaining Wall Anchors / Soil Nailing
- Proposed Permanent Compounds
- Proposed Electrical Substation
- Existing Railway Station
- Hueston West



Rev	Date	Drn	Chk'd	App'd	Description
v02	03/11/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)
v01	08/09/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA ATKINS Member of the SNC-Lavalin Group, TUC RAIL

Supported by: rps

Date	Scale	Drawn	Checked	Approved
03/11/2022	1:10,000 @ A4	NR	UM	CR

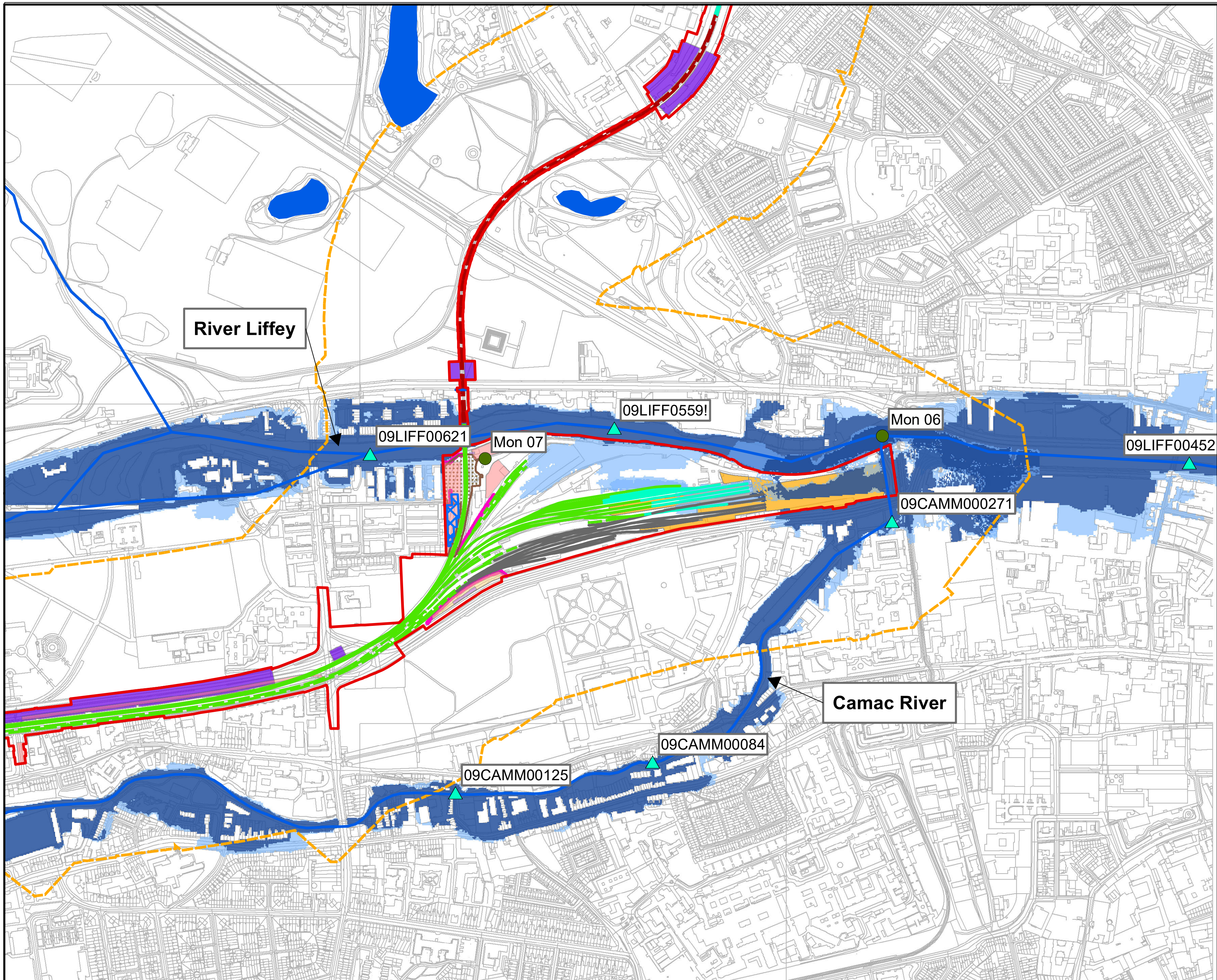
Project Code: 5195886 | Issuer: TTA | QMS Code:

Project Title: **DART + SOUTH WEST**

Drawing Title: **Figure 5-24: Heuston FRA Flood Zones**

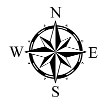
Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23804	v02	S3

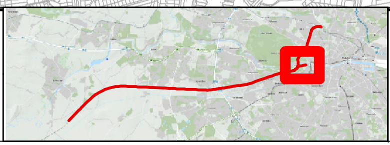
DO NOT SCALE USE FIGURED DIMENSIONS ONLY



Legend

- Development Boundary
- Study Area
- Watercourses
- FRA Monitoring Points
- CFRAM Nodes
- 1% AEP HEFS
- 0.1% AEP HEFS
- Proposed Attenuation Tanks
- Proposed Concrete Slab Track and Electrification
- Existing Track to be Retained
- Proposed Railway Electrification
- Proposed Track Works and Electrification
- Proposed Track Works, Not Electrified
- Proposed Parapet Modifications
- Proposed Boundary Wall
- Proposed Temporary Compound
- Proposed Retaining Wall Anchors / Soil Nailing
- Proposed Permanent Compounds
- Proposed Electrical Substation
- Existing Railway Station
- Hueston West





Rev	Date	Drn	Chk'd	App'd	Description
v02	03/11/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)
v01	08/09/2022	NR	UM	CR	Water (Including Hydrology & Flood Risk)

Client: Iarnród Éireann Irish Rail

Engineering Designer: TYPSA, ATKINS (Member of the SNC-Lavalin Group), TUC RAIL

Supported by: rps

Date	Scale	Drawn	Checked	Approved
03/11/2022	1:10,000 @ A4	NR	UM	CR

Project Code	Issuer	QMS Code
5195886	TTA	

Project Title: **DART + SOUTH WEST**

Drawing Title: **Figure 5-25: HEFS 0.1% AEP Flood Extents for Existing Scenario Heuston FRA**

Drawing File Name	Version	Status
DP-04-23-DWG-EV-TTA-23805	v02	S3

DO NOT SCALE USE FIGURED DIMENSIONS ONLY