Castlemartyr
Flood Risk Assessment

FRA Report

November 24

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Contract

This report describes work commissioned by Kieran Bray, on behalf of Marshall Yards Development Company Ltd. David Casey, Florentina Ionita and Ross Bryant of JBA Consulting carried out this work.

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Purpose

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Abbreviations

AEP .... Annual Exceedance Probability
CFRAM .... Catchment Flood Risk Assessment and Management
DoEHLG.......................... Department of the Environment, Heritage and Local Government
FARL .... FEH index of flood attenuation due to reservoirs and lakes
FB .... Freeboard
FFL................................. Finish Floor Level
FRA................................. Flood Risk Assessment
FSR .... Flood Studies Report
FSU .... Flood Studies Update
GL .... Ground Level
GSI................................. Geological Survey of Ireland
LHB .... Left Hand Bank
OPW .... Office of Public Works
PFRA .... Preliminary Flood Risk Assessment
RFI .... Request for Further Information
RHB .... Right Hand Bank
RR.................................. Rainfall-Runoff
SAAR .... Standard Average Annual Rainfall (mm)
SFRA .... Strategic Flood Risk Assessment
URBEXT .... FEH index of fractional urban extent
WL.................................. Water Level

1 Introduction

Under the Planning System and Flood Risk Management Guidelines for Planning Authorities (DoEHLG & OPW, 2009) the proposed development must undergo a Flood Risk Assessment prior to planning to ensure sustainability and effective management of flood risk.

1.1 Terms of Reference and Scope

JBA Consulting was appointed by Marshall Yards Development Company Ltd to prepare a Flood Risk Assessment (FRA) for a proposed residential development for a site located in Castlemartyr, Co Cork.

1.2 Flood Risk Assessment; Aims and Objectives

This study is being completed to inform the future development of the site as it relates to flood risk. It aims to identify, quantify and communicate to Planning Authority officials and other stakeholders the risk of flooding to land, property and people and the measures that would be recommended to manage the risk.

The objectives of this FRA are to:

- Identify potential sources of flood risk;
- Confirm the level of flood risk and identify key hydraulic features;
- Assess the impact that the proposed development has on flood risk;
- Either;
    - Clarify what further assessment may need to take place to adequately define the risk from the Dower River, or;
    - Develop appropriate flood risk mitigation and management measures which will allow for the long-term development of the site.

Recommendations for development have been provided in the context of the OPW / DECLG planning guidance, "The Planning System and Flood Risk Management". A review of the likely effects of climate change, and the long-term impacts this may have on any development has also been undertaken.

For general information on flooding, the definition of flood risk, flood zones and other terms see 'Understanding Flood Risk' in Appendix A.

1.3 Development Proposal

Permission for the following Large-scale Residential Development (LRD) comprising the construction of 150 no. residential units, 1 no. creche, 2 no. ESB substations and all associated development works including footpaths, car and bicycle parking, drainage, fencing, bicycle and bin stores, lighting and landscaping/amenity areas at Gortnahomna More (townland), Castlemartyr, Co. Cork. Access to the site will be via a new vehicle access point from the existing N25 Killeagh Road.

The proposed site layout is displayed in Figure 1-1.

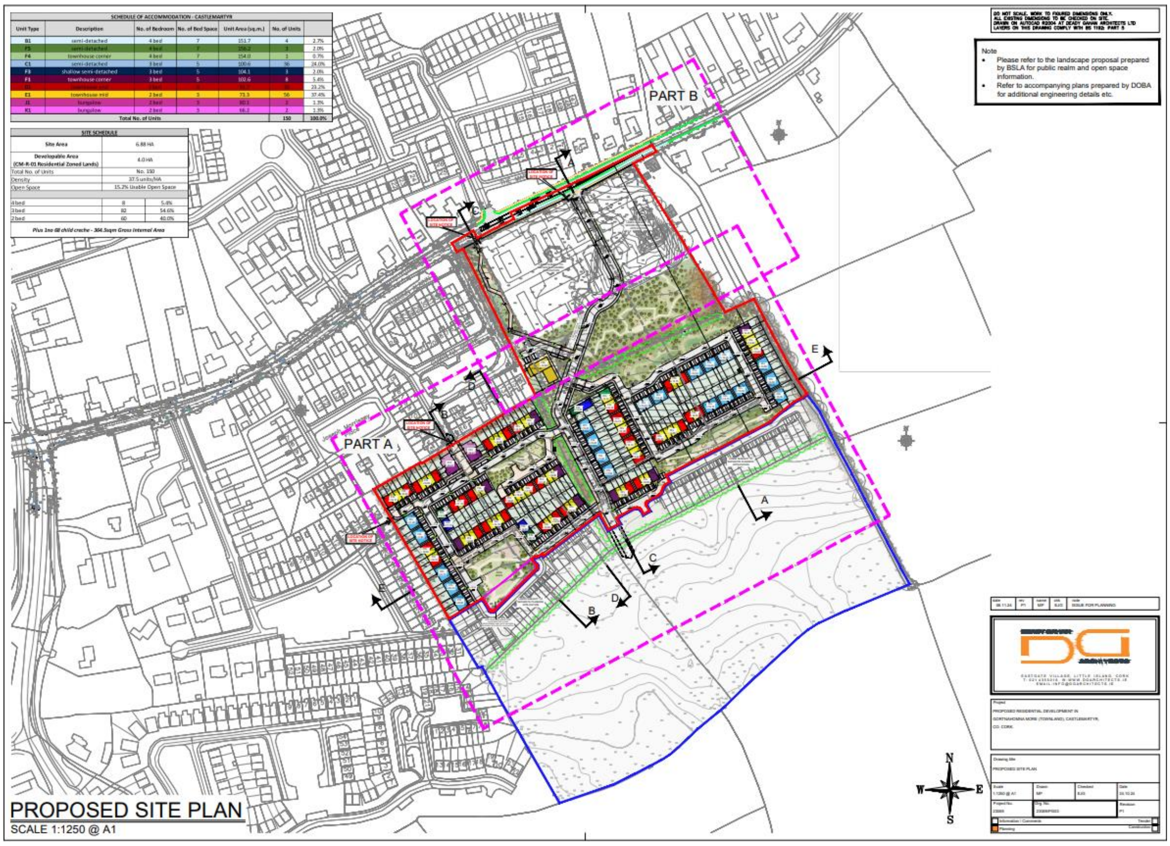


Figure 1-1: Proposed site layout

1.4 Report Structure

Section 2 of this report gives an overview of the study location and associated watercourses. Section 3 contains background information and initial assessment of flood risk. The detailed FRA, including hydrological and hydraulic assessment, is provided in Section 4 mitigation is discussed in Section 5, while conclusions are provided in Section 6.

2 Site Background

This section describes the proposed residential development in Castlemartyr, Co. Cork, including watercourses, geology and wider geographical areas.

2.1 Location

The development site is currently open space and is a green field area, see Figure 2-1. The site itself is made up of five fields. The northern section of the site is bounded by the N25. The northern field adjoins residential development (Cuirt na Greine) to the west and detached dwellings to the east. The western boundary of the two lower fields is defined by residential development consisting of Castlemartyr Crescent and Bridgetown Estate. Lands to the south and east are used for agricultural purposes.

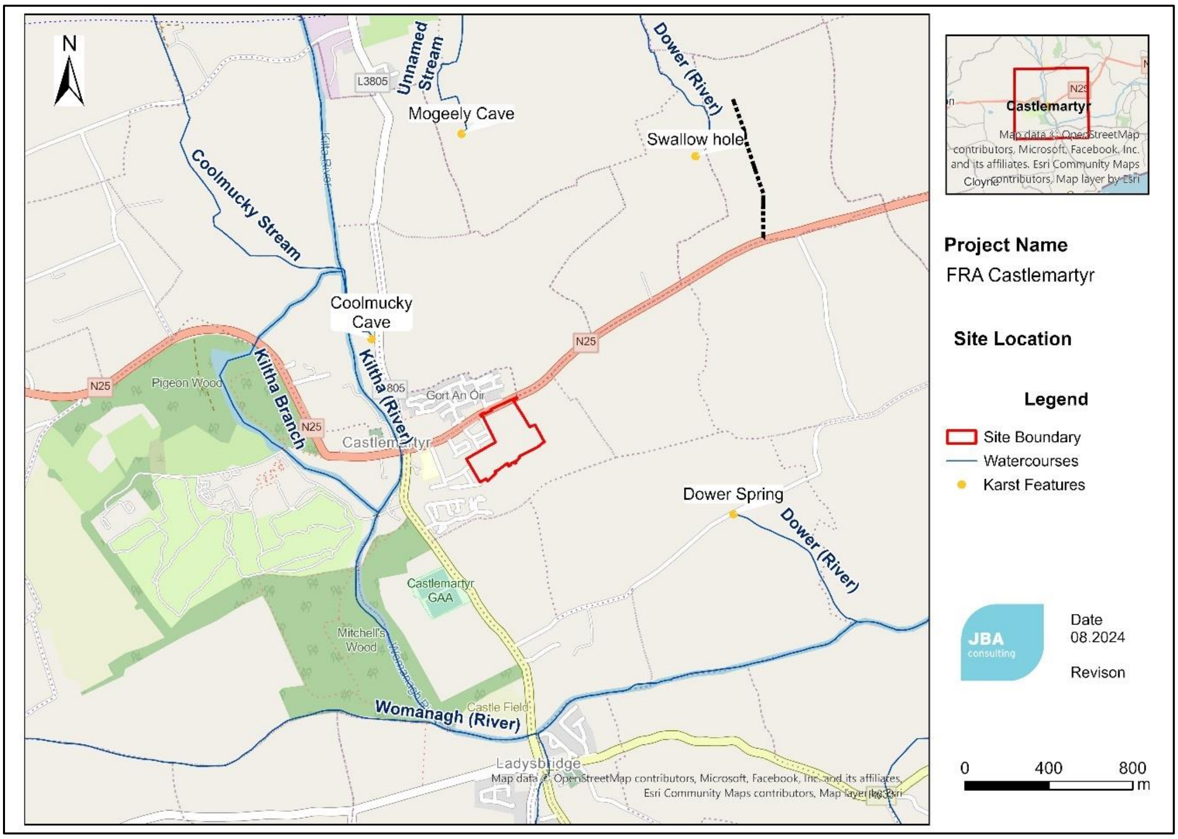


Figure 2-1: Site location and hydrological features

2.2 Watercourses

As shown in Figure 2-1 there are four main watercourses which flow adjacent or towards to the proposed site and all of them were assessed in the current flood risk assessment. Kiltha River is a surface watercourse while Dower River, Coolmuchy Stream and Unnamed stream are connected to the karst formations which are particularly representative for the area adjacent to the site.

The nearest watercourse to the site is the Kiltha River which flows from north to south c.350m west of the subject site. It flows through Castlemartyr town and converges with the Womanagh River c.1 km south of the subject site near Ladysbridge. It is c.15 km in length. The Womanagh River stretches from its source at Carrigour to its tidal outfall at Pilmore into Youghal Bay. Opposite to the proposed site the Kiltha river has a branch on the right bank which is not known if it is natural or manmade and this is connected to Kiltha via a sluice.

The Dower River is located c.700m east of the site and is also a tributary of the Womanagh River. The Dower River is classified as a subterranean river to the east of Castemartyr. The river enters a Swallow Hole approx. 1.4km northeast of the site and resurfaces approx. 800m to the east via spring system, as highlighted in Figure 2-1.

Between the Kiltha River and Dower River, there is an unnamed stream which rises c. 3.5km to the north of the site, flowing from north to south in the site direction. The unnamed stream does not reach the site because at approximately 1.3km north of the site boundary the stream goes in the Mogeely Cave most likely being swallowed in the karst formation.

The fourth watercourse assessed in this study is the Coolmucky stream which is right tributary of Kiltha River flowing from north to south-east direction. It underpasses the Kiltha River and enters Coolmucky Cave which is c. 700m at the northwest of the site.

2.3 Site Topography

The site covers an area of c7.17ha in total. There is a significant slope in a southerly direction i.e. the site slopes upward towards the southern boundary from the N25 on the northern boundary. Based on LIDAR data obtained from TII[1], the site has a high level of approximately 12mOD adjacent to the N25, falling to approximately 10-11m OD to the south of the road and then up to 22-24mOD on the southern boundary.

2.4 Site Geology

The groundwater and geological maps of the site, provided by the Geological Survey of Ireland (GSI), have been studied. The subsoil of the site is Till derived from Devonian sandstones. The underlying rock towards the Northern boundary (close to the N25) is Little Island Formation (LI). The formation is massive calcilutite limestones (mudbank facies) and crinoidal calcilutites. There is a band of Cork Red Marble Formation (CK) in the Northern half of the development site also. This is Red brecciated calcilutite limestone. It is cream, pink and red calcilutite limestones and pseudo-breccias in a red mudstone matrix. The remainder of the development site's subsoil is Waulsortian Limestones (WA). This formation is dominantly pale-grey, crudely bedded or massive limestone. The subsoils at site are presented on Figure 2-2.

Groundwater is most at risk where the subsoils are absent or thin, and in areas of karstic limestone. The groundwater vulnerability for the subject site is described as "moderate" in the northern half. The southern half of the subject site's groundwater vulnerability is described as "high" according to GSI.

There are two karst landforms c.400m to the south of the southern boundary of the subject site. There is an enclosed depression and also Poulnahorka cave exists here. Approximately 900m southeast of the subject site there is another cave with Dower Spring very close by to this cave. There is another cave and swallow hole c.1.2km north of the subject site. There are no karst landforms within the subject site itself.

1 Source - https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=b7c4b0e763964070ad69bf8c1572c9f5

Figure 2-2: Sub-soils (Quaternary Sediments) type (Source: GSI Database)

A specific hydrogeological assessment of the study area has been undertaken by Peter Conroy (HUCT) to identify the hydrogeological features in the area that may impact on the site, refer to Appendix B. With reference to Figure 2-3, the Ballyvorisheen Swallow Hole and Dower Spring are the main karst features adjacent to the site.

The Dower River discharges to the Ballyvorisheen Swallow Hole which is located to the northeast of the site, and it is likely that the waters ultimately discants from the Dower Spring to the southeast of the site.

Figure 2-3 also presents the likely connectivity between the wider karst features and the Dower Spring. This suggests that if the final discharge capacity of the Dower Spring is exceeded, this potentially could remove the intake capacity of the Ballyvorisheen Swallow Hole and could result in a positive flow rate of the swallow hole during an extreme flood event. This has been taken into account during the hydrology (peak flow) assessment and hydraulic modelling works as provided in Section 4.

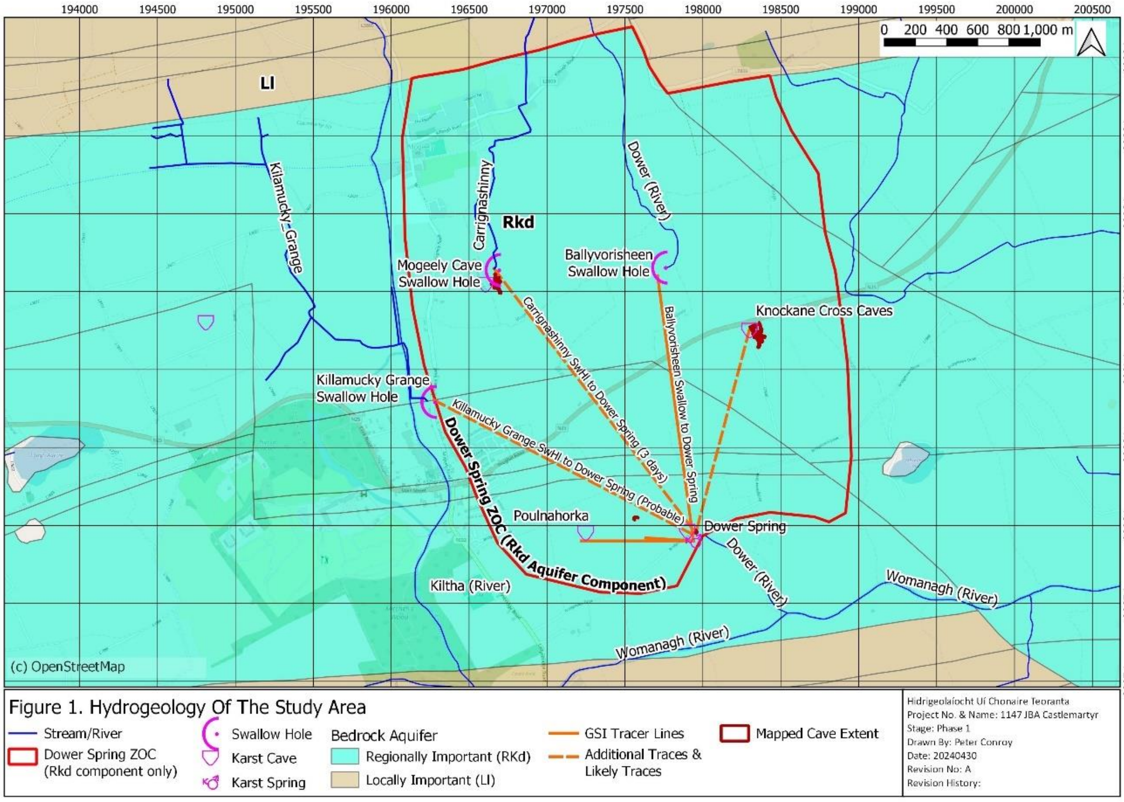


Figure 2-3: Karst Feature Connection

3 Flood Risk Identification

An assessment of the potential for and scale of flood risk at the site is conducted using historical and predictive information. This identifies any sources of potential flood risk to the site and reviews historic flood information. The findings from the flood risk identification stage of the assessment are provided in the following sections.

3.1 Flood History

Several sources of flood information were reviewed to establish any recorded flood history at, or near the site. This includes the OPW's website, www.floodinfo.ie and general internet searches.

3.1.1 Floodinfo.ie

The OPW host a National Flood hazard mapping website, www.floodinfo.ie, which highlights areas at risk of flooding through the collection of recorded data and observed flood events. See Figure 3-1 for historic flood events in the area.

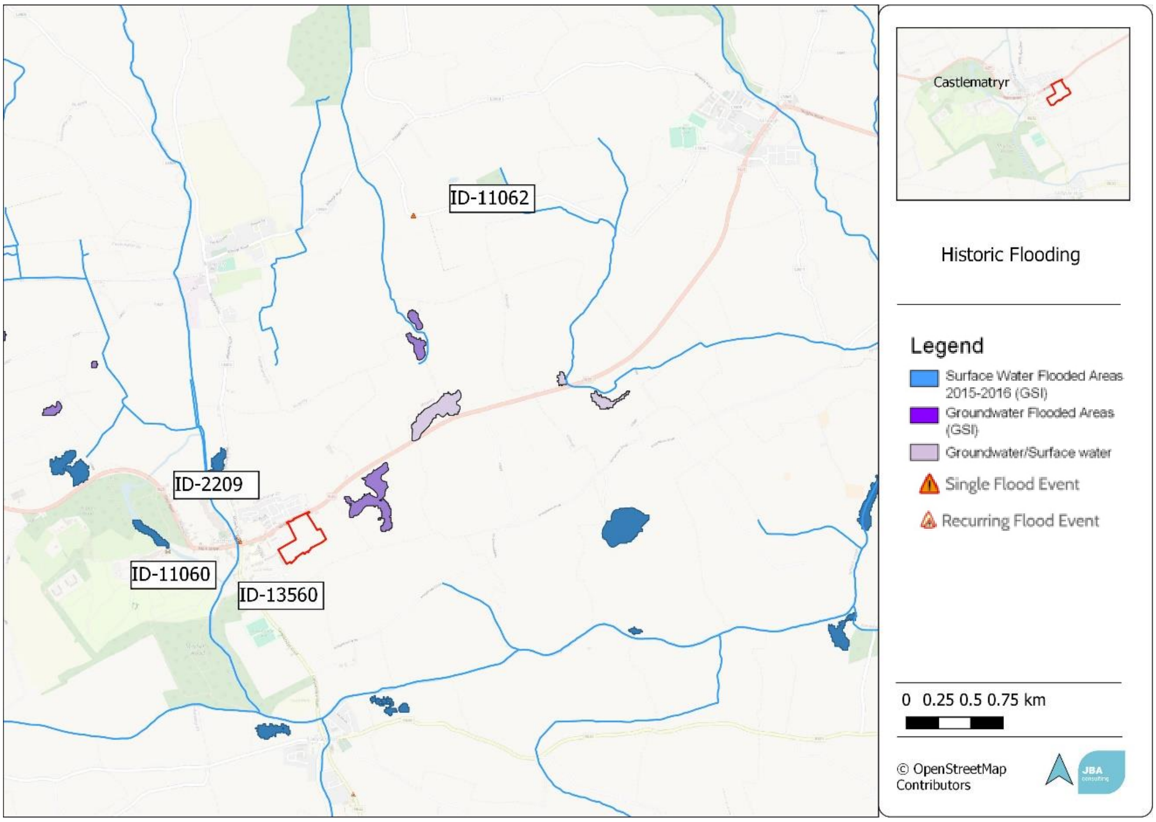


Figure 3-1: Floodinfo.ie

Review of Figure 3-1 shows no instances of recurring or historic floods within the site boundary but there are number of single flood events recorded in Castlemartyr:

- Flood Event: Castlemartyr, Middleton, Co. Cork 19th November 2009
- Flood Event (ID-11062): Garranejames, Killeagh, Co. Cork. 19th Nov 2009
- Flood Event: Castlemartyr, Co. Cork Recurring

The ID-11062 flood event occurred approx. 2.4km to the north of the site and resulted from overtopping of the Dower River. It is noted that the flooding occurred upstream of the swallow hole along the L7836 indicating that the inundation did not occur because of a capacity issue of this system.

The flooding in Castlemartyr in 2009 was reported by OPW that the flood event started on Thursday 19th November which is when the peak flow occurred.

The maximum flood level was 9.75m OD Malin, with a flood depth of 0.25 metres. Three residential properties were affected by the flooding event, 100m of the third class road L3805 was flooded with some pasture land also flooded. See Figure 3-2; a map for the extent of the road flooding that occurred.

Minutes of a meeting with Cork County Council Area Engineer for Youghal dated 20/04/2005 identified the problem area subject to flooding in Castlemartyr at the bridge due to a capacity problem. Properties on the western side were reported to have been affected in the past, with an approximate frequency of once every two years - a recurring flood event

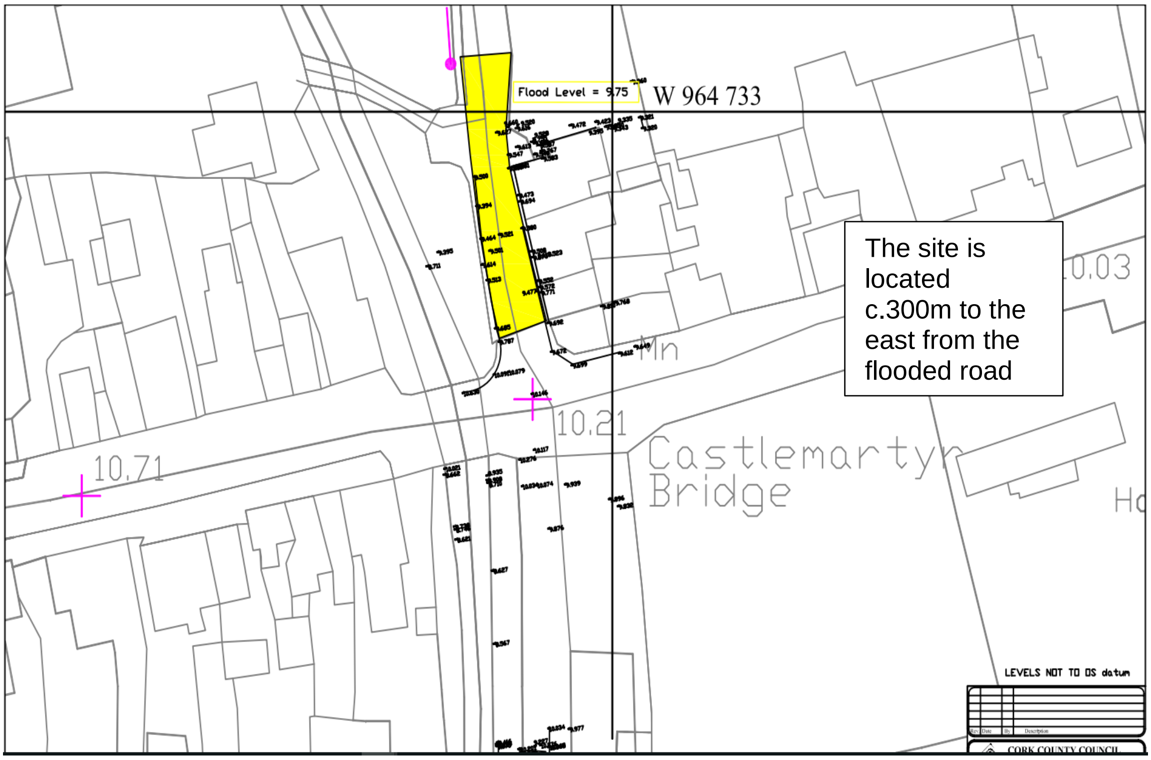


Figure 3-2: Map showing extent of Castlemartyr road flooding 2009. Source: floodmaps.ie

3.1.2 Internet Searches

An internet search was carried out and there were reports of the N25 Cork-Waterford road being closed due to heavy flooding between Castlemartyr and Killeagh and Gardai were unable to put diversions in place due to back roads also being flooded as a result of Storm Frank in December 2015. There were no reports of the subject site itself being inundated, but it is not known where exactly the road was flooded.

Within the OPW Flood Risk Management Plan Lee, Cork Harbour and Youghal Bay 2018 Castlemartyr was included as an Area for Further Assessment and mentions that following prolonged heavy rainfall in November and December 2015, groundwater flooding caused the N25 to be closed for a prolonged period between Castlemartyr and Killeagh. It also mentions that there are potentially viable flood relief works for Castlemartyr that may be implemented in the future. The FRS is still to be progressed.

On 19th October 2017 there were reports of the L3805 Mogeely Road in Castlemartyr being flooded as a result of heavy rainfall. On June 6th 2012 there were reports of flash flooding in Castlemartyr town following a short period of extremely heavy rainfall. There were no reports of flooding in the subject site itself.

In October 2023 there was flooding to the Gleann Fia estate in Mogeely. This was the same event that also flooded Midleton and other parts of Cork.

It is noted that these events did not occur in close proximity to the site.

3.2 Predicative Flooding

The area has been a subject of the following predicative flood mapping or modelling studies and other related studies and plans:

- South Western Catchment Flood Risk Assessment and Management Study (CFRAM)
- National Indicative Flood Mapping Study (NIFM)
- Strategic Flood Risk Assessment (SFRA) for Cork County Development Plan (DP) 2022-2028

The level of detail presented by each method varies according to the quality of the information used and the approaches involved.

3.2.1 South Western Catchment Flood Risk Assessment and Management Study

The primary source of data with which to identify flood risk to the site is the Southwestern CFRAM, which was finalised in Summer 2018. Flood maps have been finalised for Castlemartyr and the extract of the flood map covering the site is presented below in Figure 3-3 overpage.

The CFRAM consists of detailed hydraulic modelling of rivers and their tributaries which includes the Kiltha River. The relevant flood maps are available through the CFRAM website and supersede all previous flood modelling and indicative mapping, including that contained in the SFRA for the Municipal LAP 2017. Review of Figure 3-3 confirms that the site is not located within or adjacent to the 1% AEP and 0.1% AEP flood extents and therefore is at low risk of inundation from the Kiltha River.

The model extent for the Dower River starts downstream of the site, where the system flows from the spring. Due to the complexity of modelling the upstream karst system it was not included within the CFRAM study, upstream the Dower River flows into a swallow hole.

On the wider flood extents, it is noted for the modelled watercourses that there is limited change between the 1% and 0.1 % AEP which give a good indication that there is a well-defined flood plain. Therefore, increases in flows will produce limited changes in the flood extents,

In addition to the flood extent maps, as part of the South West CFRAM programme flood depth maps were also produced.

The modelled flood levels and flows for the nearest 'nodes' to the site (19KILT00156A, 19KILT00162A, 19KILT00121A and 19KILR00081H) are presented in over-page (Table 3-1).

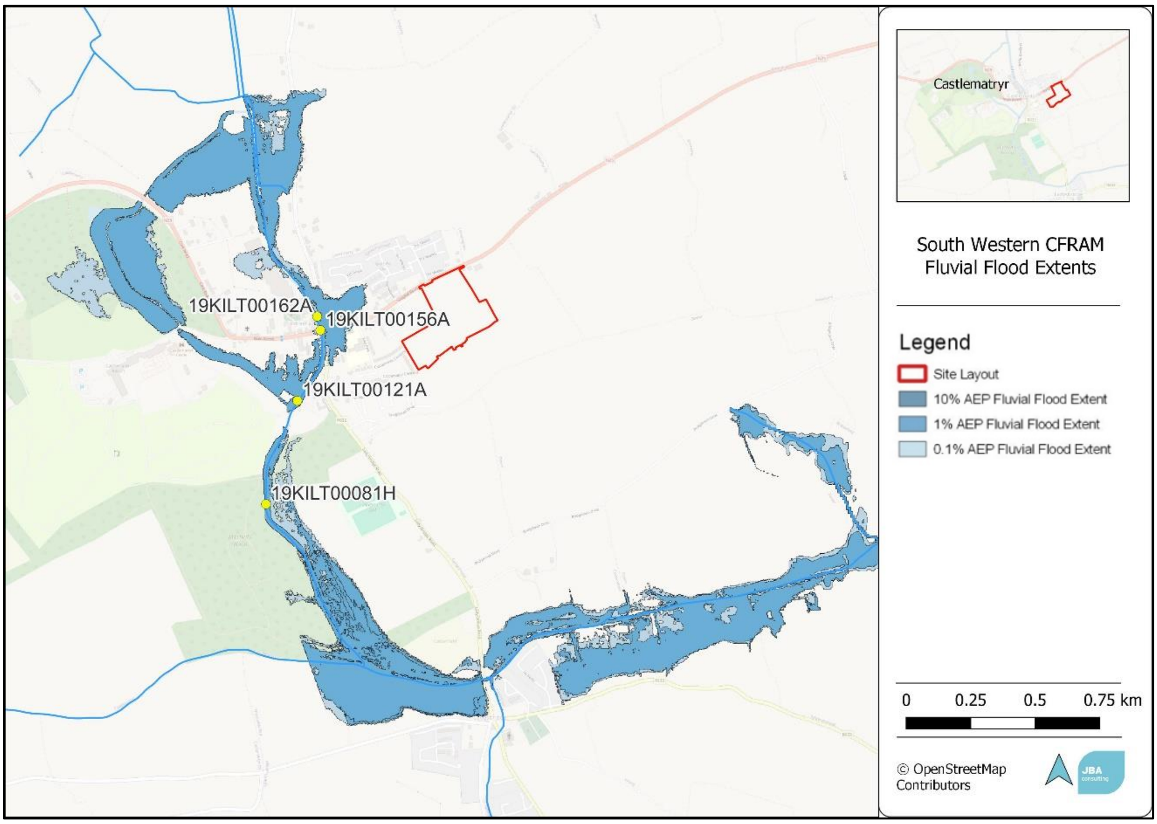


Figure 3-3: SW CFRAM Fluvial Flood Map (Source: Floodinfo.ie)

Table 3-1: SW CFRAM flood levels at site (mOD)

Node Label	1%AEP	0.1%AEP
19KILT00162A	10.26	10.48
19KILT00156A	10.10	10.34
19KILT00121A	8.96	9.17

The actual flood levels reported in the 2009 flood were 9.75 mOD (refer to Section 3.1.1). This is below the levels of the two nearest 'node' measurements (19KILT00162A and 19KILT00156A) to the site for both the 1% AEP flood depth and the 0.1% flood depth. There are no records of the site being inundated during this flood event. As shown in the CFRAM maps the subject site is at low risk of flooding from the Kiltha River. Whilst this is also true for the Dower River the upstream flood extent is not modelled by the CFRAM and risk from the Dower cannot be screened out by the CFRAM study.

3.2.2 National Initiative Flood Mapping Study

Data has been produced for catchments greater than 5km^2 in areas for which flood maps were not produced under the National CFRAM Programme. The NIFM datasets have been edited to remove overlaps with the datasets produced under the National CFRAM Programme and other flood studies. The NIFM datasets should be read in conjunction with the outputs of the National CFRAM Programme and other studies.

The indicative fluvial flood maps were developed using a 2D only hydrodynamic modelling, based on calculated design river flows, relatively course DTM, and other relevant datasets (e.g. land use, data on past floods, etc.). They are not to the same accuracy or provide the same confidence as a site-specific flood model or the CFRAM study, The complex hydraulics of the karst system have not been modelled within the NIFM study and this reduces our confidence in the results. It is likely that the NIFM just makes a direct connection between the swallow hole and the spring, which would be an overly conservative assumption.

The northern part of the site is shown to be in 0.1% AEP (low probability) flood extent (Flood Zone B). Refer to Figure 3-4 overpage for the NIFM flood extents.

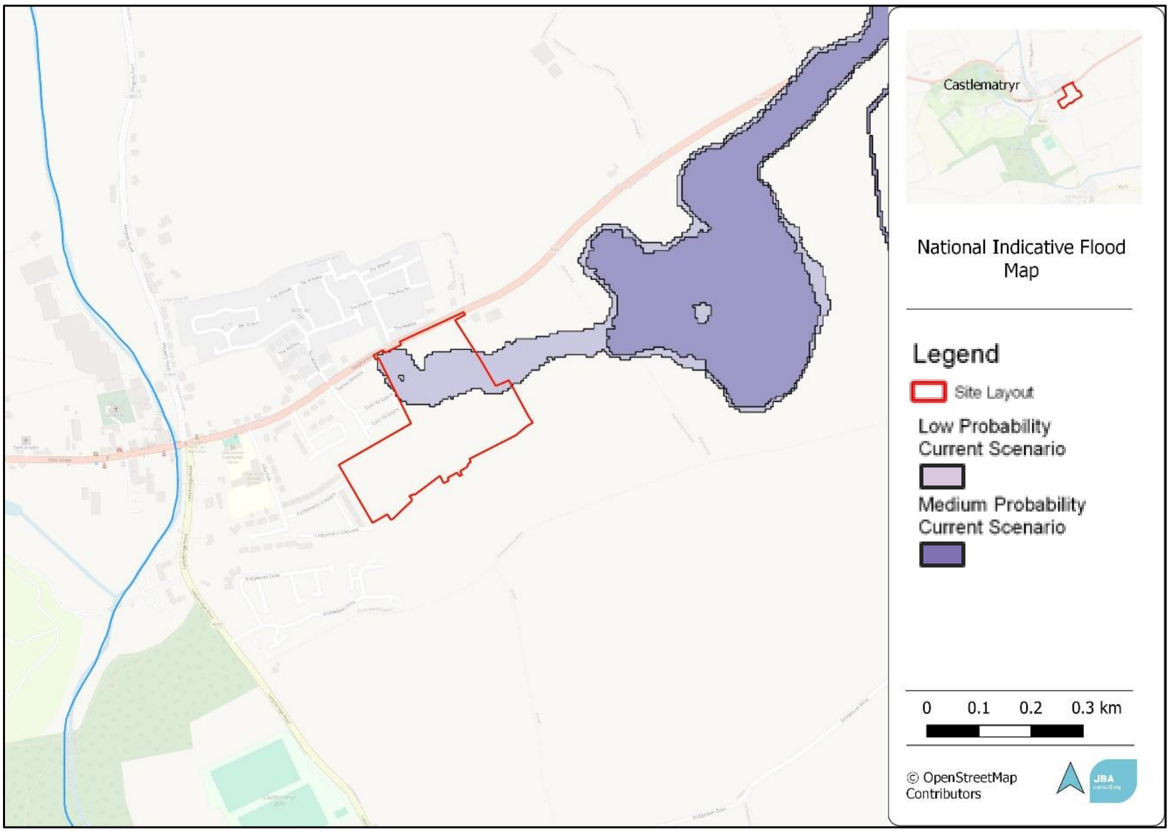


Figure 3-4: National Indicative Flood Mapping (NIFM)

3.2.3 Strategic Flood Risk Assessment for Cork County Development Plan 2022-2028

The SFRA for Cork County Development Plan has been prepared in accordance with the requirements of the DoEHLG and OPW Planning Guidelines, The Planning System and Flood Risk Management; these guidelines were issued under the Planning and Development Act 2000 (as amended) and recognise the significance of proper planning to manage flood risk.

The SFRA has reviewed a number of datasets which record historical and/or predicted flood extents. The main source of flood information is the South Western CFRAM and NIFM which were used to inform the flood risk and confirm the presence of Flood Zone B in the northern part of the site from the Dower River - but this is related to overland flow in between a karst sink hole and spring.

Castlemartyr is identified for a future Flood Relief Scheme, but there has not been any progress on procurement.

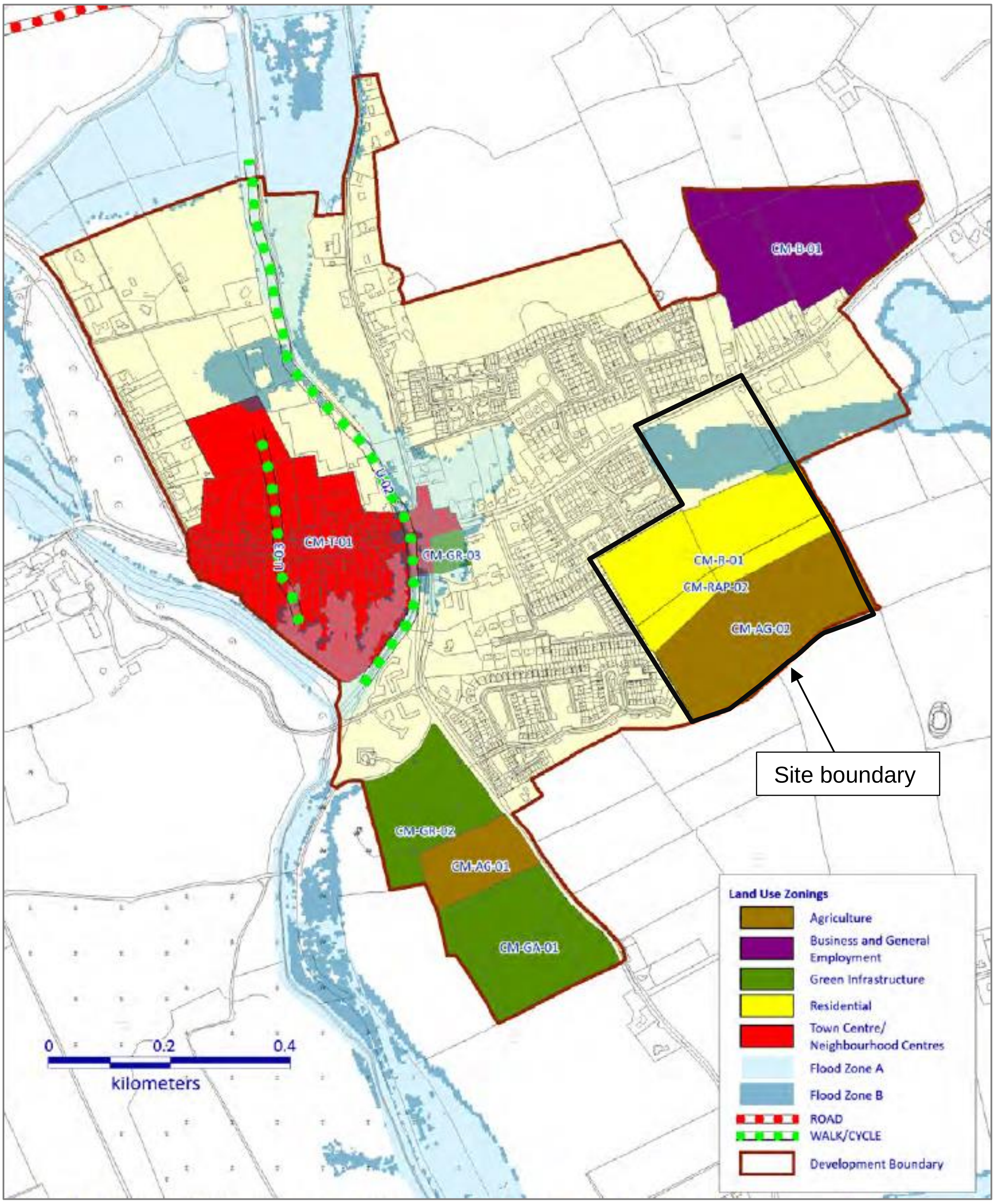


Figure 3-5: Extract from Cork County Development Plan SFRA Flood Zone Map

3.3 Flood Sources

The initial stage of a Flood Risk Assessment requires the identification and consideration of probable sources of flooding. Following the initial phase of this Flood Risk Assessment, it is possible to summarise the level of potential risk posed by each source of flooding. The flood sources are described below.

3.3.1 Fluvial

All available sources of flooding have been researched as part of the FRA and confirms that the site is at low risk of fluvial flooding from the River Kiltha, however the NIFM Flood Zone B extent encroaches across the northern part of the site. The NIFM mapping is an indicative representation of the Dower River which flows into a sink hole northeast of the N25, the NIFM representation is not detailed enough to fully represent the karst system and would require additional analysis to increase confidence in the extent and level.

In order to confirm the flood risk presented by the Dower River and River Kiltha a hydraulic model has been developed. The model build is outlined in Section 4.

3.3.2 Tidal

The site is located far from the tidally influenced areas; therefore, tidal flooding is not considered as presenting a flood risk to the development and is screened out at this stage.

3.3.3 Pluvial/ Surface Water

Pluvial or surface water flooding is the result of rainfall-generated flows that arise before run-off can enter a watercourse or sewer. Due to a slight depression in the northern site, there is potential for ponding however this can be managed through site design and consideration of the treatment of the drainage system and is not an impediment to the development.

The hydraulic model provided in Section 4 has also been used to assess the pluvial flood risk to the development.

The mitigation measures specific to pluvial flooding will be further discussed in Section 4.

3.3.4 Groundwater

Groundwater flooding results from high sub-surface water levels that impact upper levels of the soil strata and overland areas that are usually dry. As seen on Figure 3-1, there is some indication of groundwater flooding to the east of the site, however there is no mapped risk to the site itself.

The interaction between the sink hole and the pathway of the Dower River is discussed in Section 3.3.1 above and would require further assessment as part of a more detailed hydrological and hydrogeological analysis if increased confidence in the flood extents/levels are required.

4 Hydrology & Hydraulics

To assist in estimating the potential flood risk to the proposed development from the four nearby watercourses, this section will provide flow estimates and modelled flood extents as part of a detailed assessment. To further investigate flood risk arising from the River Kiltha, the Dower River, Coolmucky stream and the Unnamed stream, a complete hydrological analysis and development of a hydraulic model was carried out to include all the hydrological features which may have an impact on the site.

4.1 Topographical Data

Cross-sectional survey

Topographical survey used in the CFRAM project was made available for this project and used to build the model. Cross section survey of the River Kiltha, measured in 2019 (OPW CFRAM survey data) were used to define the channel capacity and to stamp the channel bathymetry within the Lidar.

For the Dower River, Coolmucky stream and the small unnamed stream the in-channel topographic survey was not available, however they were represented in the hydraulic model based on the representation of the river channels within the available Lidar. Even though the in-channel survey was not available for these three streams this approach is more conservative for the site as the channel capacity is ignored and more water will flow in the floodplains.

Lidar

Lidar is available from different sources and at different resolution as presented in Table 4-1. To get full coverage for the modelled domain, these Lidar data were processed and blended using GIS tools.

Table 4-1: LiDAR Data

Source of Lidar	Resolution	Year of provenance
OPW	2m	2011
TII	2m	2010 - 2011
Bluesky	2m	2020
Drone Survey	0.1m	2024

Figure 4-1 presents the coverage of the Lidar from different sources and the areas where new drone survey was produced within the current project for a more accurate representation of potential flow paths from Dower River or surface water towards to the site.

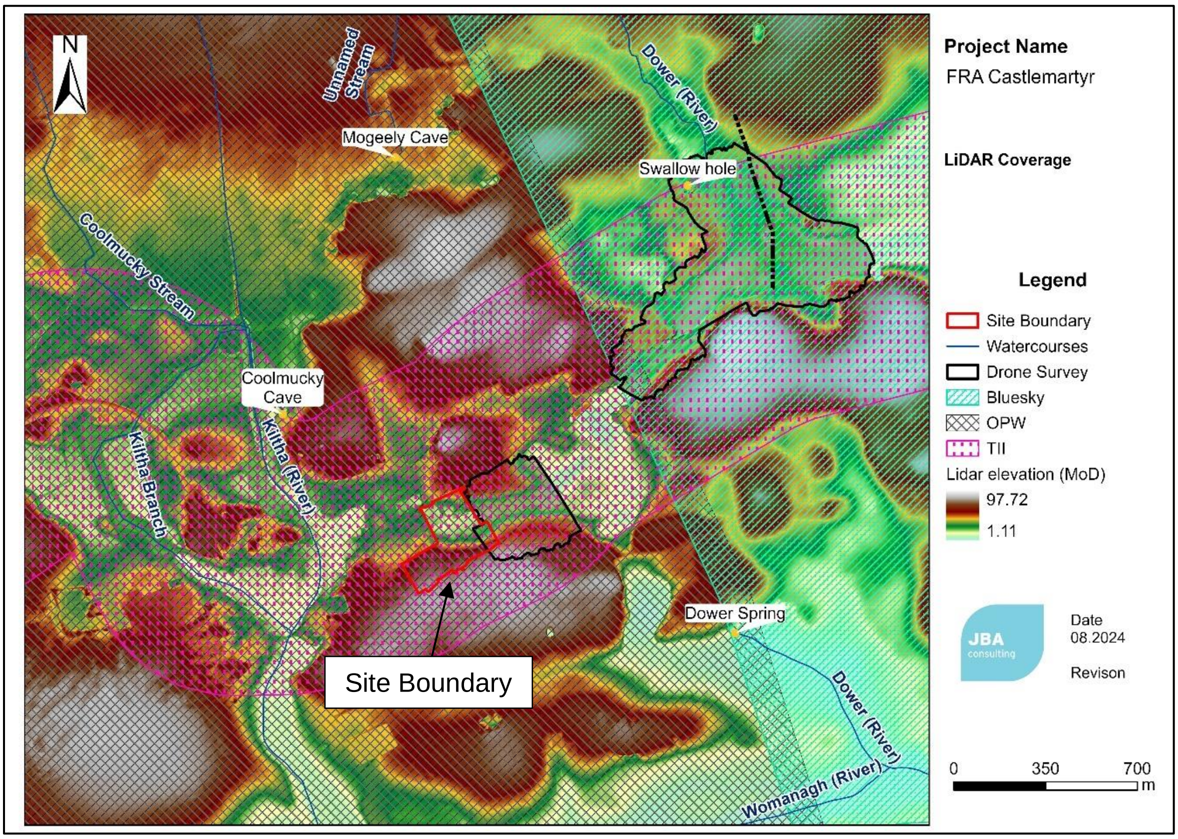


Figure 4-1 LiDAR coverage from different sources

Site survey

A topographic survey of the site was performed by Land Surveys in 2023 and this was used to update the Lidar elevation within the site boundary.

The existing site topography is presented in Figure 4-2. There is a significant slope in a southerly direction i.e. the site slopes upward towards the southern boundary from the N25 on the northern boundary. There is a depression in the northern field, with levels approx. 2m lower than the road level.

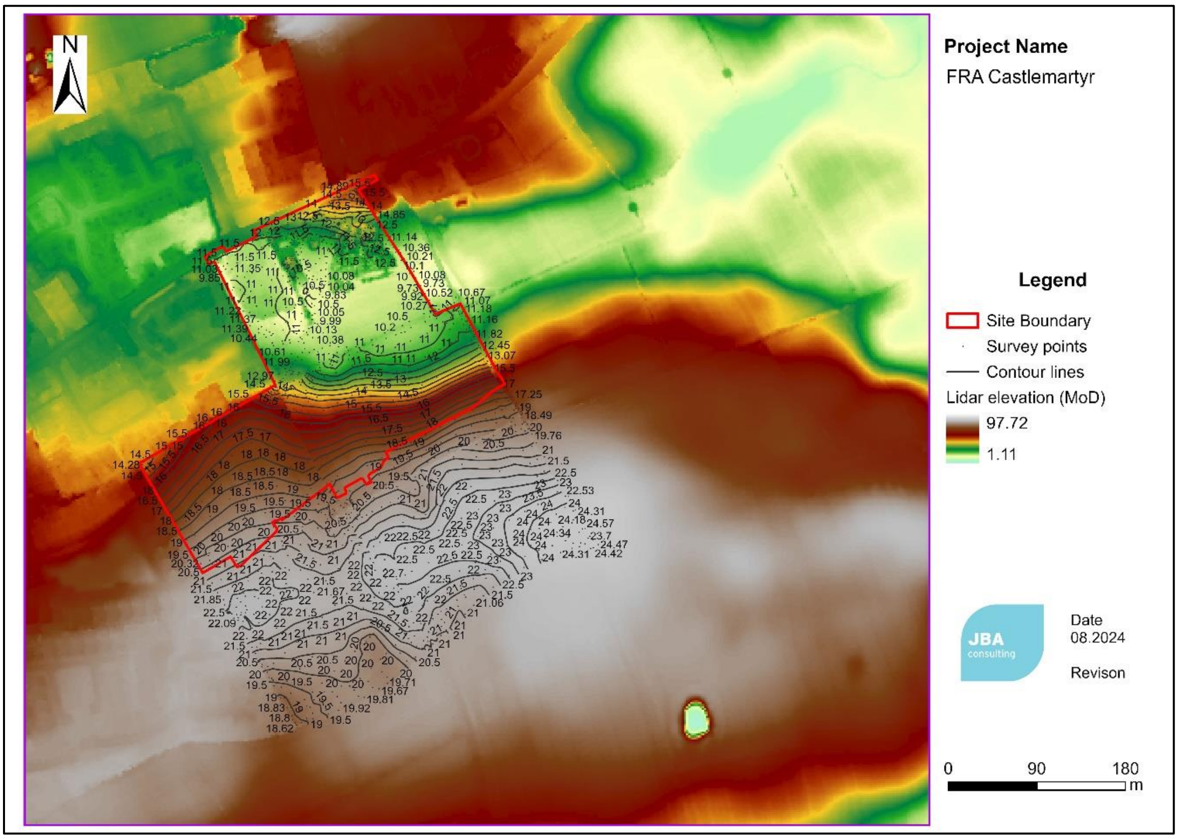


Figure 4-2: Site survey versus Lidar

4.2 Hydrology

The flood risk assessment for the proposed site was conducted considering hypothesis on all flooding sources such as fluvial, pluvial and groundwater.

Flow hydrographs were derived for all watercourses and used as inflows in the model.

To present the worst-case scenario for the site the fluvial model was combined with a direct rainfall runoff model to get a complete understanding of the extreme flood risk for the site. Rainfall hyetographs were also derived based on the depth duration frequency model developed by Met Eireann.

4.2.1 Catchment Characteristics

Four watercourses are subject of the hydrological calculations: Kiltha River, the Dower River, the Coolmucky Stream and Unnamed Stream. The Dower River, Coolmucky and Unnamed Stream all flow into swallow holes at different locations and only Dower River is known to resurface and this is believed to collect flow from the other swallow holes.

Catchment boundaries have been reviewed and drawn using LIDAR data to allow the establishment of catchment areas for the Coolmucky and Unnamed Streams and to update the FSU catchments for the Dower and Kiltha Rivers to avoid double counting, see Figure 4-3.

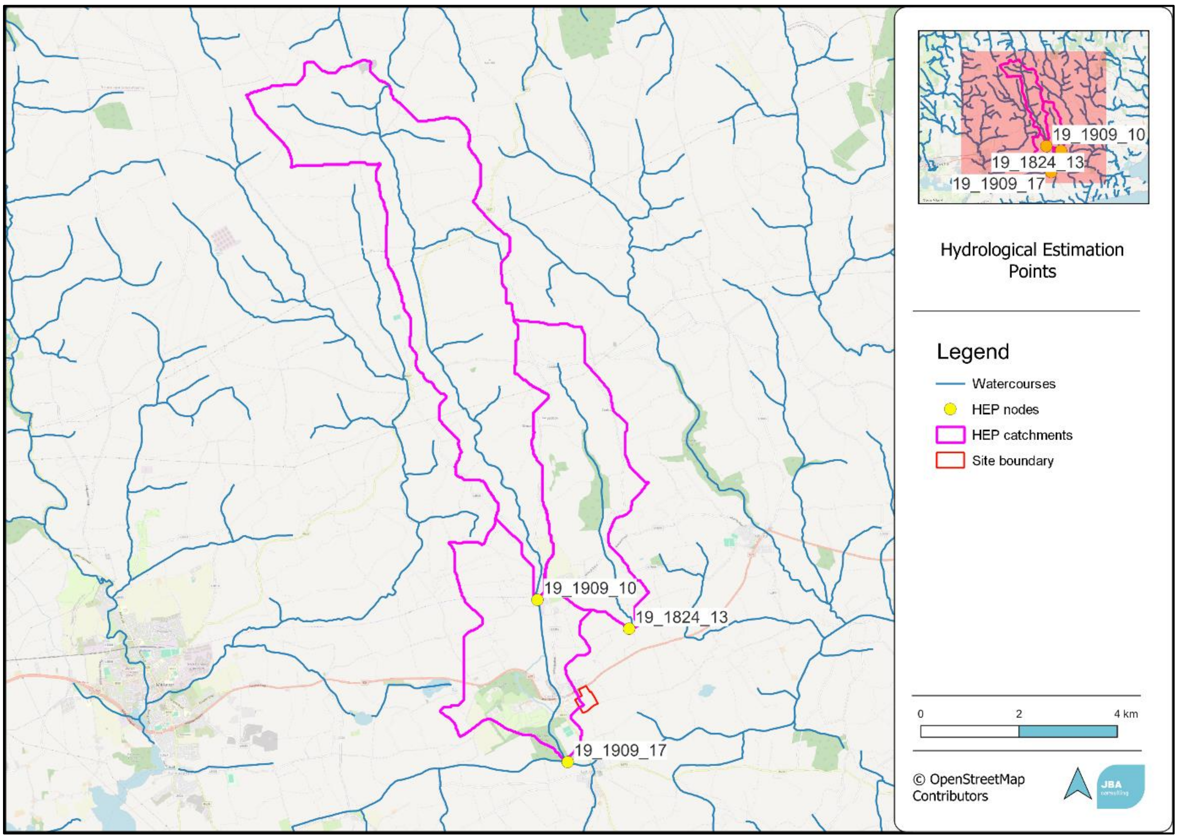


Figure 4-3: Catchment overview

The following table lists the parameters pertinent to the hydrology calculations used for flow estimation for each of the rivers.

Table 4-2 Key Catchments Characteristics

Watercourse	Kiltha	Kiltha	Dower	Dower	Coolmucky	Unnamed
FSU Node	19_1909_10	19_1909_17	19_1824_13	19_1824_19	NA	NA
Area	20.88	29.34 (includes Coolmucky)	7.88	13.53 (includes Unnamed)	3.55	1.63
SAAR1971-00	1209.39	1172.37	1161.98	1139.27	1209.39	1161.98
SAAR1991-20	1278.62	1221.59	1183.57	1136.11	1278.62	1183.57
FARL	1.00	1.00	1.00	1.00	1.00	1.00
BFI Soil	0.67	0.67	0.71	0.71	0.67	0.71
URBEXT	0.00	0.01	0.00	0.00	0.00	0.00
MSL	13.28	16.85	6.00	8.71	3.29	2.59
S1085	7.94	7.60	21.66	14.11	4.54	8.34
DrainD	1.02	0.85	0.76	0.56	0.93	1.59
ArtDrain2	0.00	0.00	0.00	0.00	0.00	0.00
Soil (number)	2.00 (100%)	2.00 (100%)	2.00 (100%)	2.00 (100%)	2.00 (100%)	2.00 (100%)

4.2.2 Flow Estimation

The FSU catchment descriptor method is considered appropriate for catchment areas larger than 25 km^2, however it can be used for smaller catchments. The method is to derive an index flood (QMED) from catchment descriptors which is then adjusted, if appropriate, to a donor gauged QMED estimate and the area of urban land cover within the catchment. The index flood is multiplied by a growth curve to derive peak flow estimates for a range of flood probabilities.

Table 4-3 shows the calculated flows for the Kiltha River, the FSU method estimates with the SWCFRAM growth curve are recommended for use.

Table 4-3: Kiltha River estimates

Flow [m^3/s]	50% AEP	10% AEP	1% AEP	0.1% AEP
19_1909_10	7.59	10.93	16.40	24.67
19_1909_17	9.31	13.40	20.11	30.25

Table 4-4 compares the FSU Small Catchments (FSU SC) and FSR RR flow estimates for the Dower River. Comparing the estimate the FSU SC flows are higher than the FSR RR due to the difference in the base Qmed estimate as both use the SWCFRAM growth curve. As a conservative approach and as the FSU method is more up to date it is recommended that the FSU SC flows be applied for this study with an FSE of 1.67 applied to the flows.

Table 4-4: Dower River (19_1824_13) estimates

Flow [m^3/s]	50% AEP	10% AEP	1% AEP	0.1% AEP
FSU SC	4.85	6.98	10.47	15.75
FSR RR	3.05	4.39	6.59	9.91
FSU SC with FSE	8.09	11.66	17.48	26.31

For the smaller watercourses again as a conservative approach the FSU SC flows are recommended as they are higher and still considered representative. Still for hydrograph shape the FSR RR method is used, being more appropriate for the smaller watercourses.

Table 4-5: Coolmucky Stream estimates

Flow [m^3/s]	50% AEP	10% AEP	1% AEP	0.1% AEP
FSU SC	1.83	2.63	3.94	5.93
FSR RR	1.47	2.12	3.18	4.78

Table 4-6: Unnamed Stream estimates

Flow [m^3/s]	50% AEP	10% AEP	1% AEP	0.1% AEP
FSU SC	0.89	1.28	1.92	2.89
FSR RR	0.66	0.95	1.43	2.15

4.2.3 Hydrograph shape

The hydrographs used as inflow in the model for the Kiltha River, Dower River, Coolmucky Stream and Unnamed Stream are presented in Figure 4-4 to Figure 4-7.

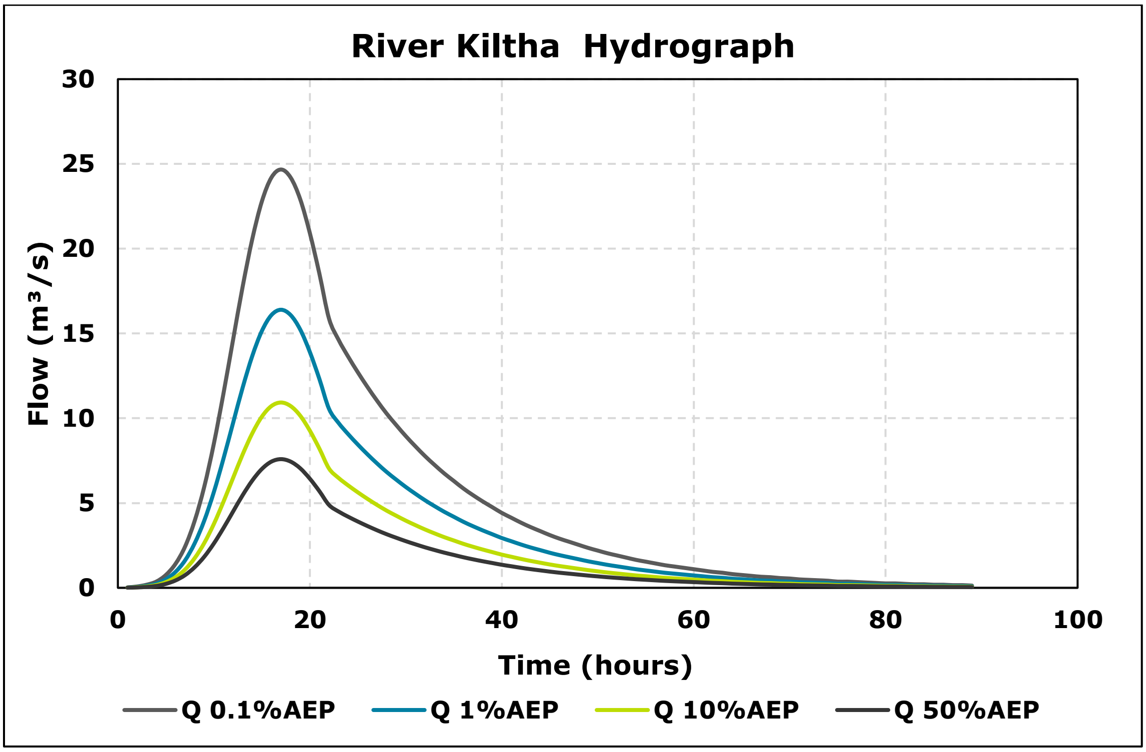


Figure 4-4: Inflow hydrographs for Kiltha River

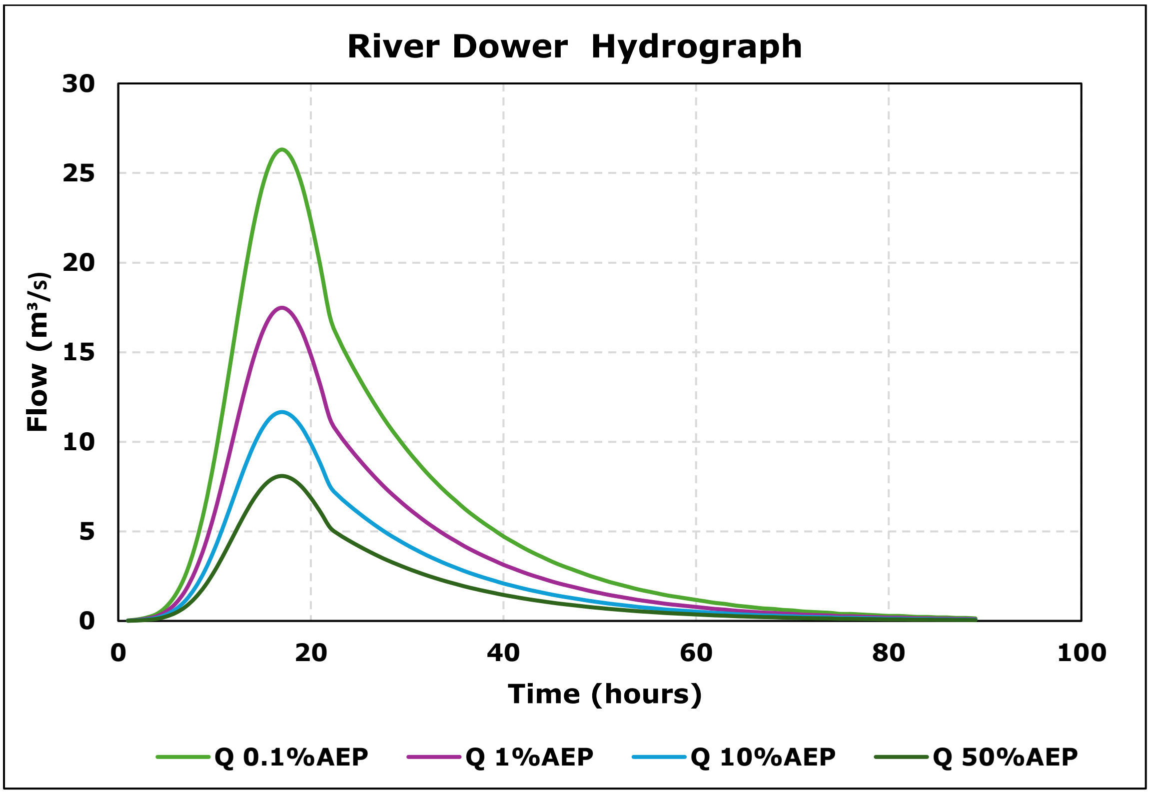


Figure 4-5: Inflow hydrographs for Dower River

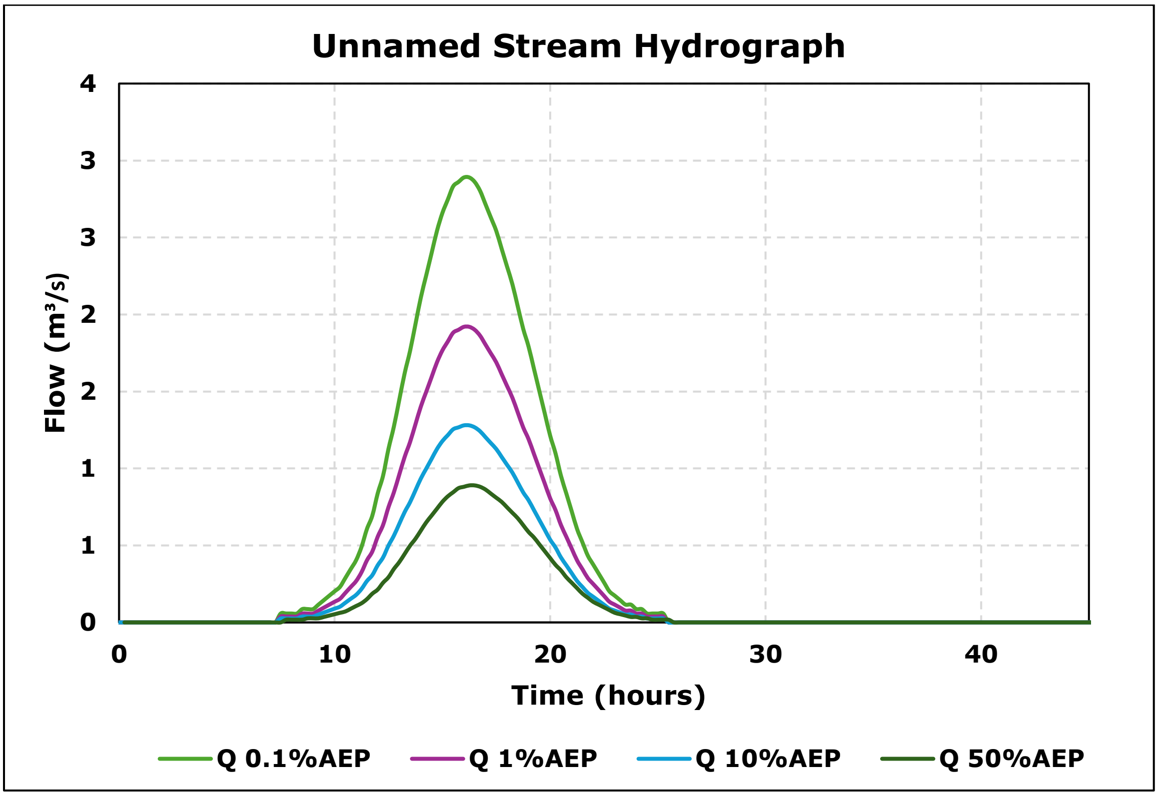


Figure 4-6: Inflow hydrographs for Unnamed Stream

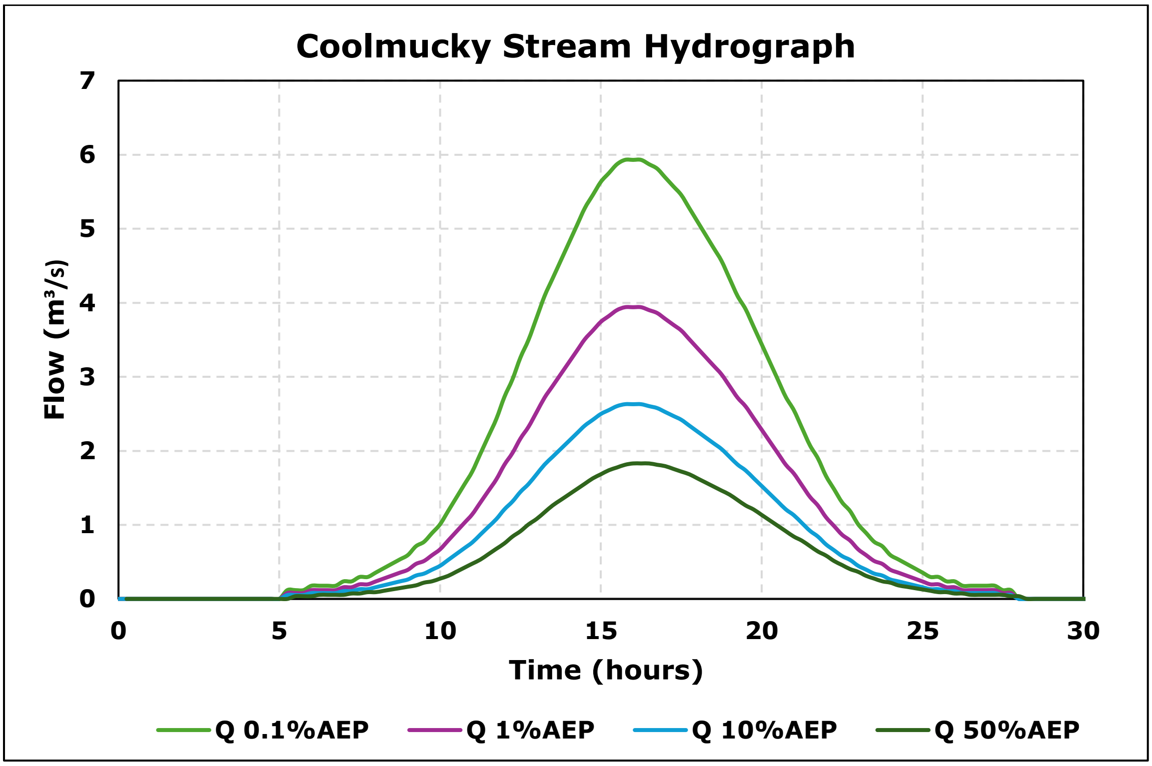


Figure 4-7: Inflow hydrographs for Coolmucky Stream

4.2.4 Hyetographs

As well as fluvial inputs a rain on grid model is also being developed to assess potential overland flow pathways that might impact flood risk on the site. In order to do the direct rainfall model, hyetographs have to be developed.

The total rainfall depths for a given storm duration and return period were sourced from the MET Éireann Depth Duration Frequency (DDF) data set published in 2023. This dataset is based on modelling carried out to estimate rainfall depths.

Three storm durations were considered – the 3, 6 and 9-hours - for the 1% AEP and 0.1%AEP rainfall events Table 4-7 shows the total rainfall depths from the DDF data for the selected durations.

Table 4-7: Total rainfall depths for the 1% AEP event

Storm Duration (hours)	DDF 1% AEP Total Rainfall Depth (mm)	DDF 0.1% AEP Total Rainfall Depth (mm)
3	47.20	73.37
6	63.60	98.85
9	75.70	117.67

With the rainfall depths established input hyetographs for the storms were then generated. Figure 4-8Figure 4-8 shows an example hyetograph used.

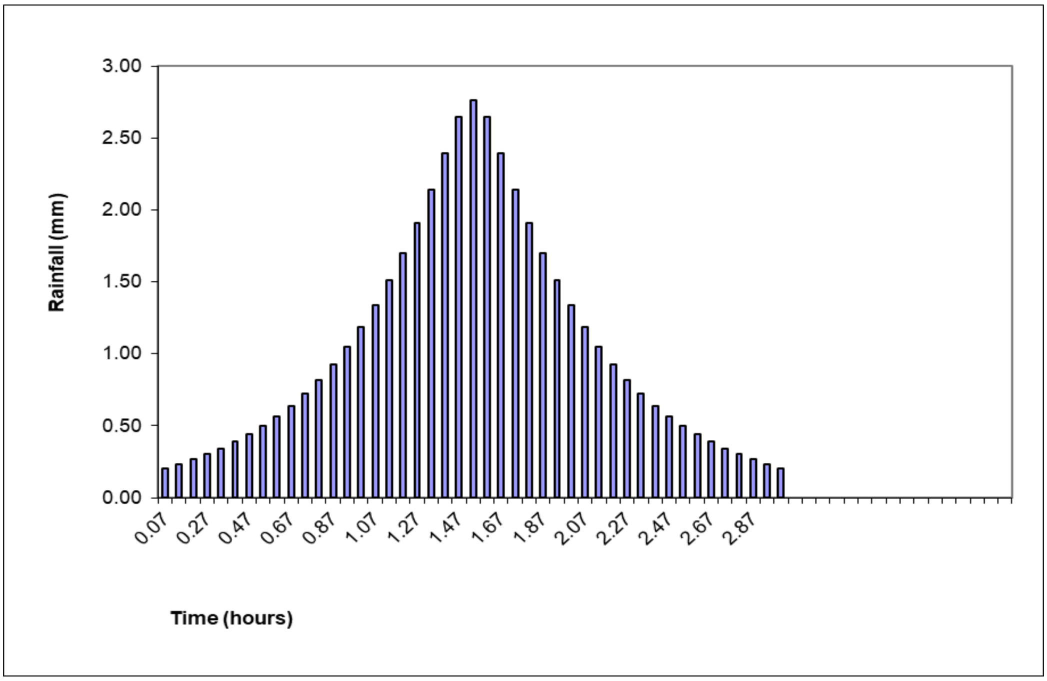


Figure 4-8: Rainfall hyetograph for the 1% AEP and 3-hour duration storm

4.3 Hydraulics

The hydraulic model has been run with a baseline scenario which, where appropriate, identifies the need for further post-development modelling, and thereafter identifying the necessary design approach.

To assess the fluvial flood risk to the site due to all four watercourses a 2D HEC RAS hydrodynamic model was produced to allow the detailed representation of flood extents and water within and around the site boundary.

HEC-RAS is designed to perform one-dimensional steady flow and one and two-dimensional unsteady flow calculations for a complex river network of natural and constructed channels, overbank/floodplain areas, levees protected areas, dams' operation, breaching etc.

The software allows the efficient setup of multiple scenarios and analysis of outputs. HEC-RAS has a user-friendly interface with GIS compatibilities, numerous data entry capabilities, hydraulic analysis components, data storage and data management capabilities.

4.3.1 Baseline Modelling

4.3.1.1 Fluvial source

The baseline scenario was run to re-define flood extents for Flood Zones A (1% AEP Event) and B (0.1% AEP Event) at the proposed site. The simulations were performed considering a very conservative approach, the hypothesises used in the model being as listed below:

- Concurrent inflows from all 4 watercourses are applied in the model and considering a pessimistic situation where the hydrographs overlap on the peak providing maximum flows that can reach the site;
- The swallow holes which should collect the flows from Dower River, Coolmucky Stream and Unnamed stream are considered completely blocked. Therefore, no flow abstraction was considered due to the karst formation allowing for a more pessimistic scenario where all the flood water will remain at the surface conveying more flow towards to the site;
- According to the report named Dower Spring (Whitegate Regional Water Supply Scheme) - Groundwater Source Protection Zones prepared by Geological Survey of Ireland, the maximum discharge of the Dower Spring for the years 1978-1983 is 1.4m^3/s. To be more conservative this flow was applied as surface flow at the Dower Swallow hole to account for the flow from the karst formation but making the assumption that the water will remain at the surface instead of being stored in the karst system.

The modelling results show that Kiltha River overtops the riverbanks in some locations but mainly on the west side in the floodplain commonly shared with Coolmucky Stream where extended agricultural lands are. Downstream of Coolmucky Stream the Kiltha channel splits the flow between the main channel and its west branch the flow being divert on the branch via a concrete sluice. In order to obtain a higher flow at the section adjacent to the site it was considered that the Coolmuchy Cave and the Mogeely Cave do not abstract any flows.

Downstream of the confluence between the Kiltha River and the Unnamed Stream the bank is overtopped along its right bank (west) the greenfields upstream of Castlemartyr being flooded.

On the east overbank of Kiltha River adjacent to the site the houses and yards in Castlemartyr are flooded immediately upstream and downstream of N25 but there are now flood paths towards to the site. Between the site and Kiltha east floodplain and the site there is some high ground at approx. 1 m above the maximum flood level (0.1%AEP). Therefore, there it is unlikely for the site to get flooded due to the Kiltha river even for more extreme scenarios than the modelled ones.

No flooding occurs on the site from the Dower River up to a 0.1% AEP event, even during an extreme scenario whereby the swallow hole is completely blocked. It should be noted that the Dower River was modelled extremely conservatively with 1.67 FSE applied to the peak flow and the swallow hole was completely blocked in the baseline scenario-i.e. having no flow abstraction.

Figure 4-9 provides an overview of site location and the flood extent maps for all modelled rivers (River Kiltha, Dower River, Unnamed Stream and Coolmucky Stream).

The site is located in the Flood Zone C even when an extremely conservative approach is adopted.

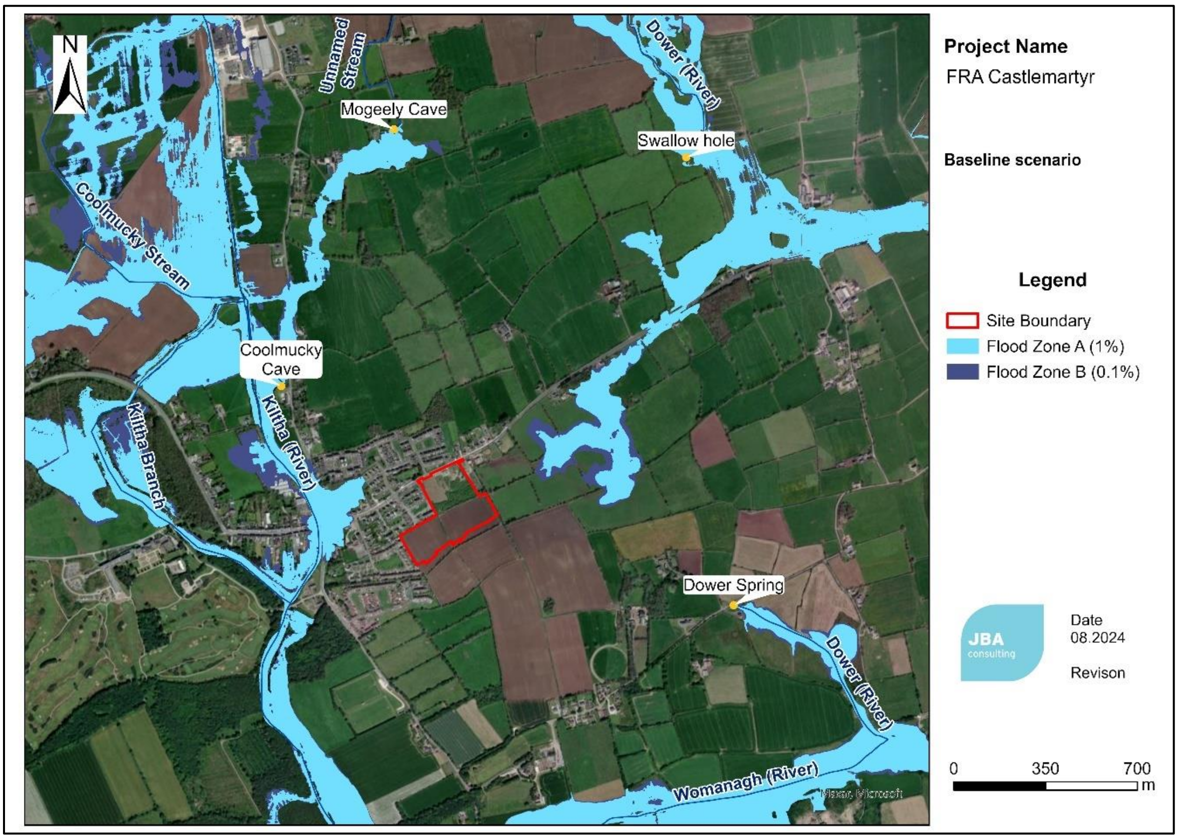


Figure 4-9: 1% and 0.1% AEP Flood Extents (Baseline)

4.3.1.2 Modelled versus CFRAM results

Comparison of the modelling results from the site-specific model versus CFRAM model is provided on flows in Table 4-8 and levels in Table 4-9 for representative nodes adjacent to the site. Also, a comparison of the flood extent maps is presented in Figure 4-10 for 1%AEP and in Figure 4-11 for 0.1%AEP. The results validation was performed only for the Kiltha River, as the other watercourses considered in this FRA were not modelled in CFRAM.

Table 4-8: Discharge comparison -Site specific model vs South-Western CFRAM

Location	Flow 1%AEP [m³/s]			Flow 0.1%AEP [m³/s]		
	Site-specific	CFRAM	Deviation from CFRAM [m³/s]	Site-specific	CFRAM	Deviation from CFRAM [m³/s]
19KILT00162A	15.8	8	+7.8	24.37	8.26	+16.11
19KILT00156A	15.85	11.4	+4.45	24.42	11.9	+12.52
19KILT00121A	17.64	13.6	+4.04	26.48	20.2	+6.28

Table 4-9: Water level comparison -Site specific model vs South-Western CFRAM

Location	Water level 1%AEP [mOD]			Water level 0.1%AEP [mOD]		
	Site-specific	CFRAM	Deviation from CFRAM [m]	Site-specific	CFRAM	Deviation from CFRAM [m]
19KILT00162A	10.49	10.26	+0.23	10.7	10.48	+0.22
19KILT00156A	10.27	10.1	+0.17	10.65	10.34	+0.31
19KILT00121A	9.3	8.96	+0.34	9.5	9.17	+0.33

The increase on the modelled levels reflects higher flows due to the contribution of Coolmucky and the Unnamed stream which were additionally modelled compared to the CFRAM programme.

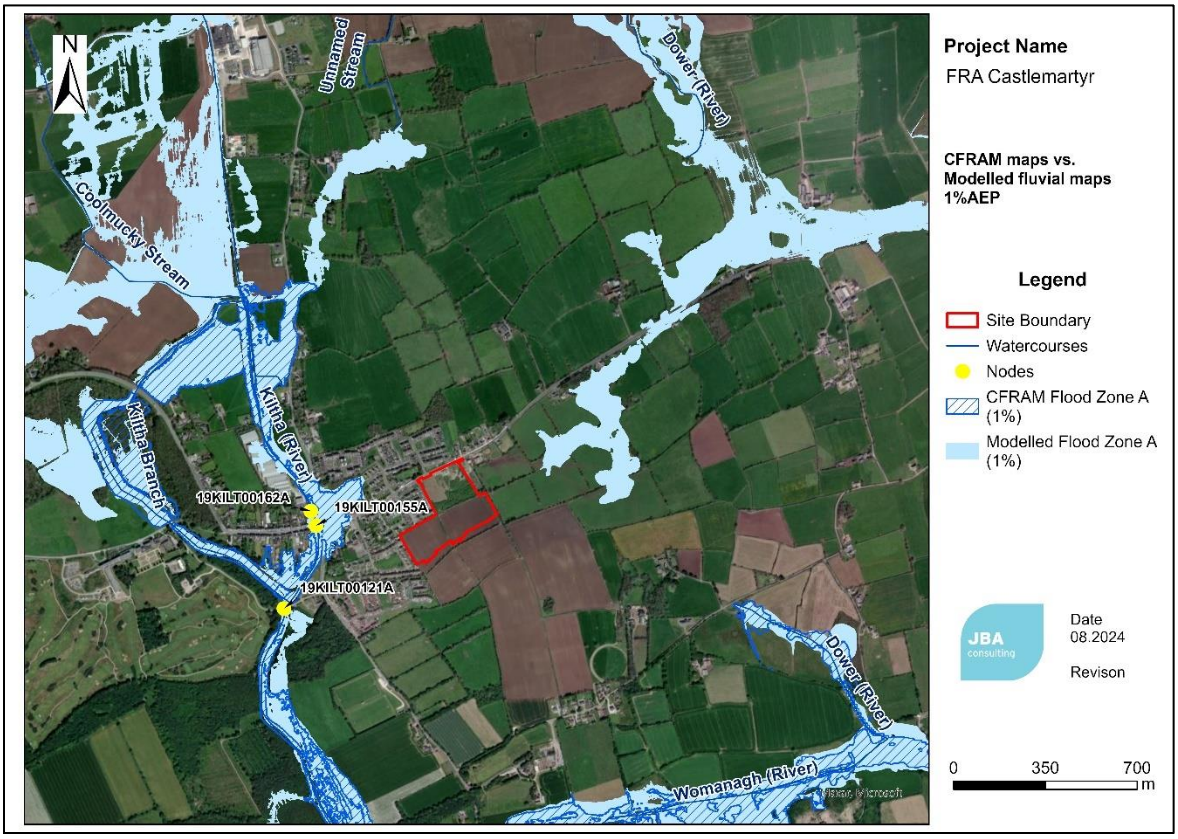


Figure 4-10: Comparison of site-specific flood extent versus CFRAM, 1%AEP

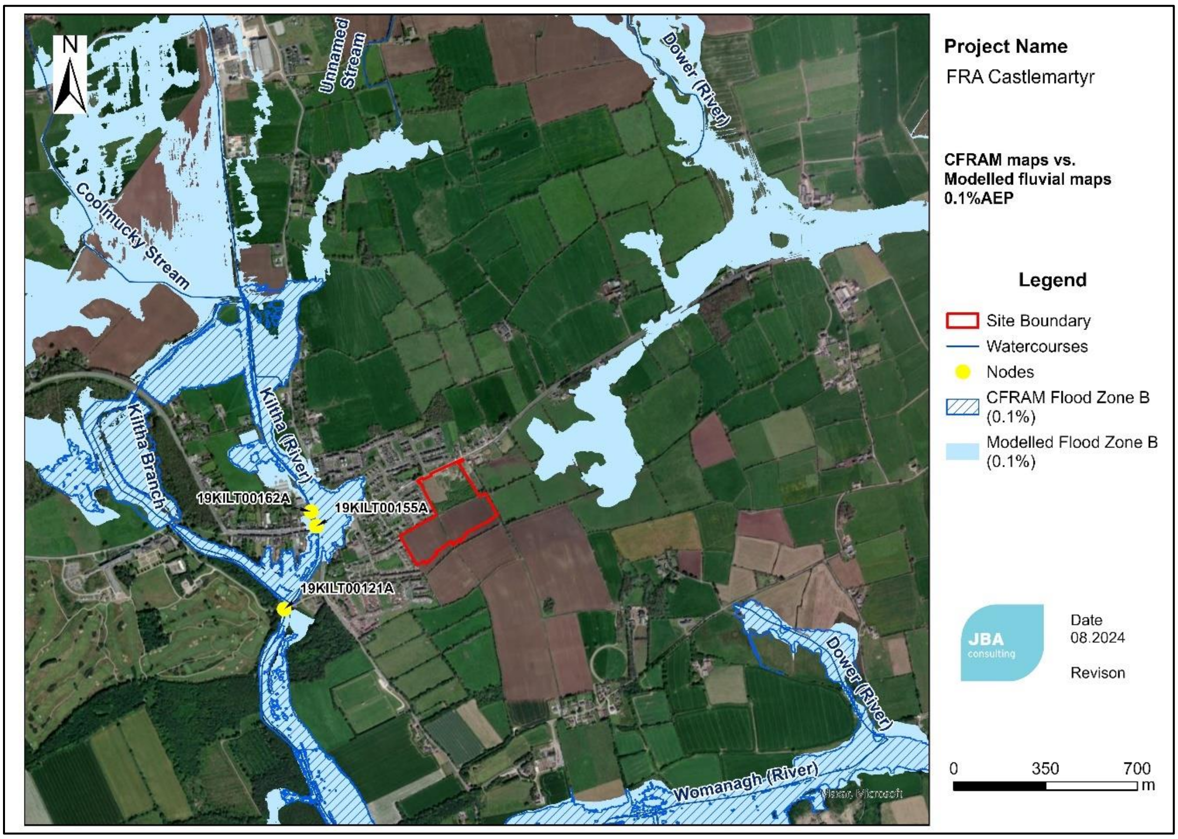


Figure 4-11: Comparison CFRAM vs. Site-specific flood extent, 0.1%AEP

4.3.1.3 Combined fluvial and surface water risk

The hydraulic model confirms that the site is not at risk of inundation from a fluvial source up to the 0.1% AEP event. A full assessment of the potential impact of a combined pluvial and fluvial flood event, an additional scenario was tested considering that a rainfall event will occur in the lower catchment on top of the fluvial event (coincidence of fluvial and pluvial). The fluvial inflows as presented in the previous sections in addition to the "direct rainfall" is applied within this model scenario.

The "direct rainfall" concept assumes that rainfall is applied to each mesh element in the hydraulic model and routed across the mesh surface, identifying flooding pathways and areas where ponding will occur. The depth duration frequency model developed by Met Eireann for the estimation of point rainfall frequencies for a range of durations in any location in Ireland was used and the points closest to the site were extracted. Representative return periods were assessed based on this 2023 Depth-Duration-Frequency data which gives the rainfall totals for a range of probabilities and storm durations from rain gauges across the country using data from 1991 to 2020.

Hyetographs for 100yr, 1000yr and climate change conditions (MEFS with 20% increase) were derived from the DDF curves at the extracted points. The storm duration was considered equal to twice the concentration time of lower catchment which resulted in 3hr duration. Sensitivity tests were done for lower and higher duration (1hr and 6hr) but also for summer and winter rainfall profiles of the hyetograph. The critical storm resulted from the sensitivity tests is 6hr duration and summer profile revealing higher flood depths for the site, and this was used further for all modelled return periods.

Infiltration rates were associated to the modelling domain using the SCS Curve Number which was correlated with the subsoil vulnerability map.

Figure 4-12 presents the flood extent maps for 1% AEP and 0.1% AEP while Figure 4-13 shows the maximum flood depths within the site for 0.1% AEP. Note: the flood maps for the combined fluvial & pluvial event do not represent the Flood Zone A & B extents for the site and surrounding area. The inundation within the redline boundary can be managed by the proposed stormwater system which has been designed to the appropriate standards, refer to Section 5.2.3.

According to this scenario the site floods only due to the surface water and the maximum water depth within the site in the extreme event of 0.1%AEP rainfall event reaches 0.4m to 0.8m but only in limited area at the lowest locations of the site (in a pre-development scenario).

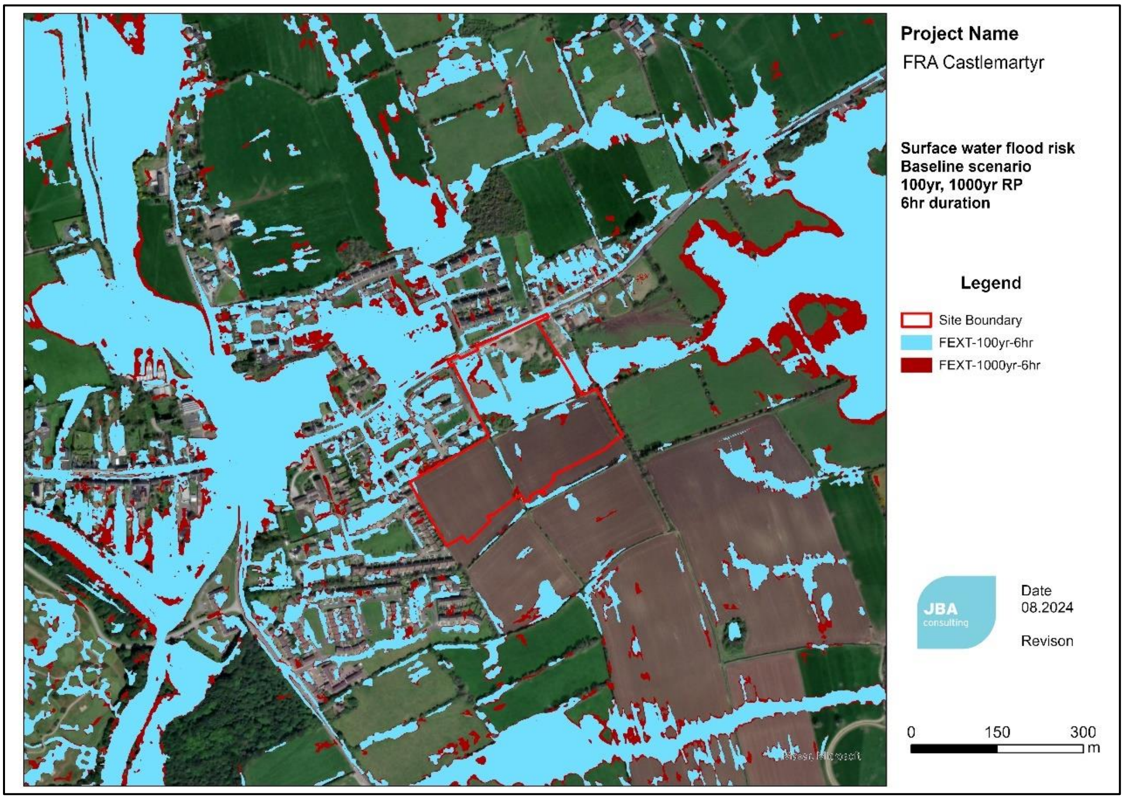


Figure 4-12: Fluvial and surface water risk - Flood extents maps

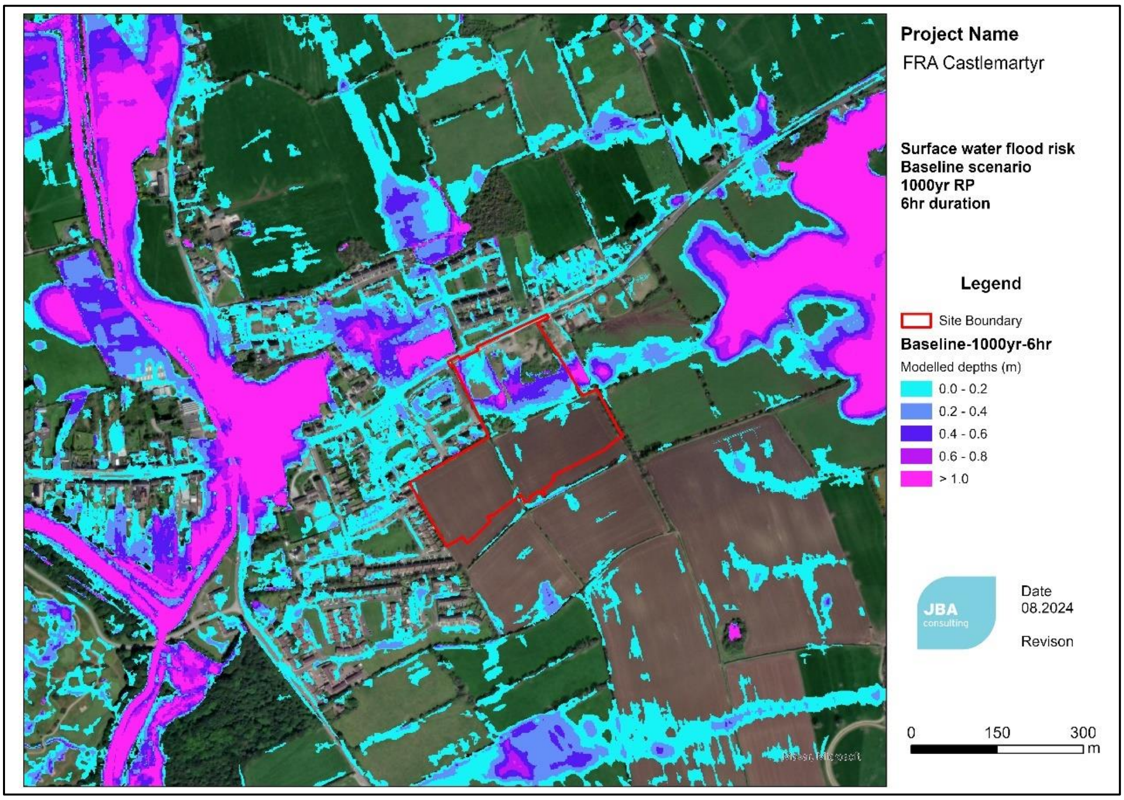


Figure 4-13: Fluvial and surface water risk - Flood depth map, 0.1%AEP

4.3.2 Climate Change Scenario

4.3.2.1 Fluvial source

The climate change scenario was run for all four rivers applying a 20% increase in 1% AEP flows. As the climate change flows are smaller than 0.1%AEP flows for all four rivers and the site is not flooded for the 0.1%AEP flows then it can be concluded that the site is not at the flood risk under the medium future range scenario for this event.

Figure 4-14 provides an overview of the flood extent maps for the climate change scenario.

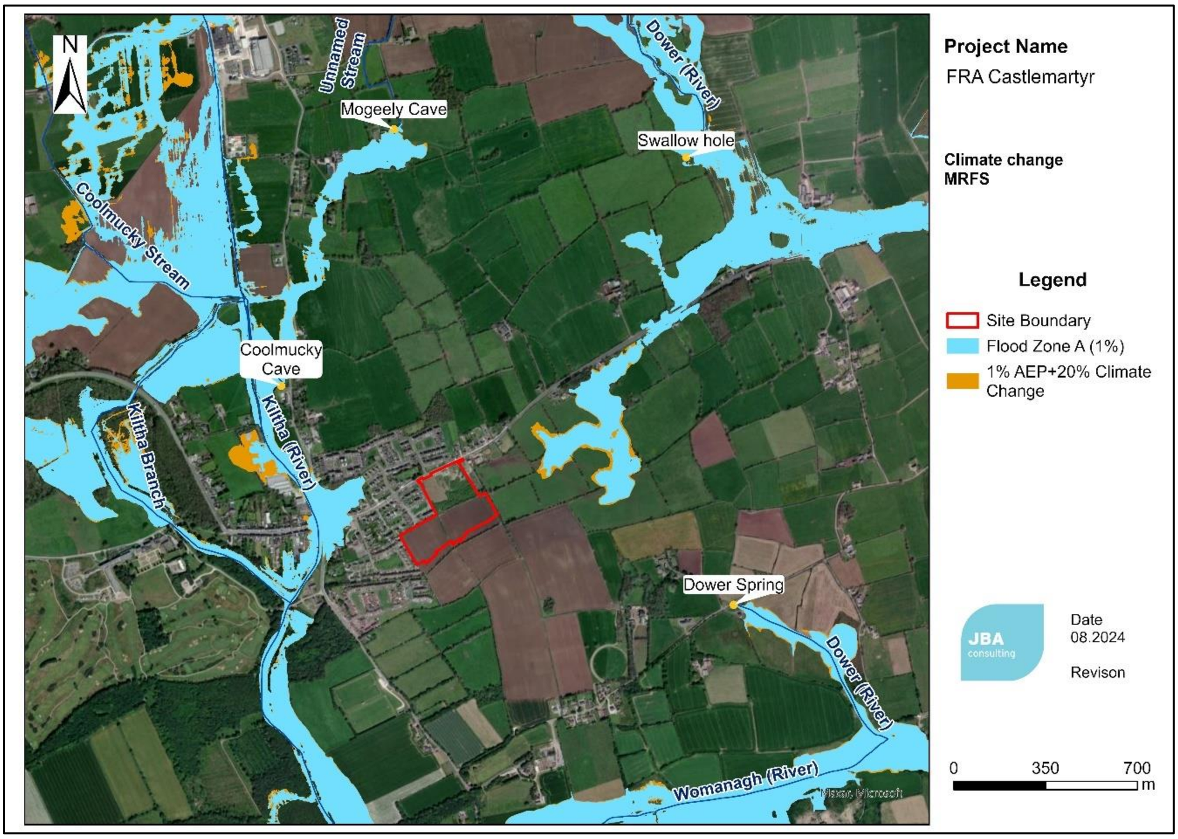


Figure 4-14: 1% AEP + Climate Change flood extents - Fluvial

4.3.2.2 Combined fluvial and surface water risk

Figure 4-15 shows the peak flood levels within the site boundary during the 1% AEP with (+20%) climate change event. This shows that during the future climate change event only the northern area of the site is flooded.

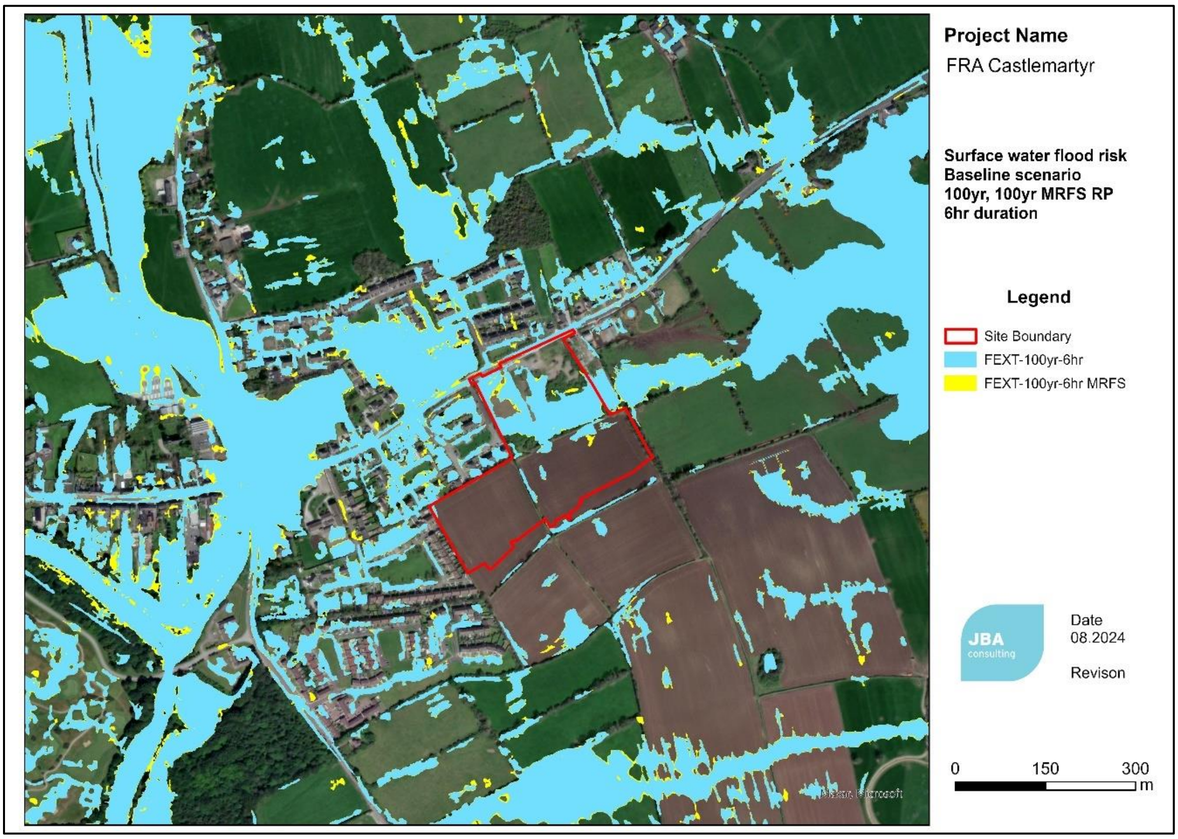


Figure 4-15: 1% AEP + Climate Change flood extents - - Fluvial and surface water

4.3.3 Residual Risks

4.3.3.1 Bridge Blockage

There are five bridges on the modelled sector of Kiltha River adjacent to the site and all were included in the new hydraulic model. Bridge 121, bridge 155 and bridge 162 (Figure 4-16) are the closest to the site and the potential residual risk due to blockage was assessed in modelling. There are no bridges on Dower River, Coolmucky Stream or Unnamed stream which may pose a risk for the site.

Normally this sensitivity test is performed for 1%AEP event but in order to be pessimistic this blockage scenario was run considering 67% blockage happening at the same time at bridge 121, bridge 155 and bridge 162 when 0.1% AEP event occurs.

Such an extensive blockage was considered for the mentioned bridges, but the modelling results show that the blockage generates a maximum afflux up to 1.32m which cause larger increases in flood extends within the west floodplain at the properties between the Kiltha River and its branch and reduced increase in flooding on the left overbank adjacent to the site. Table 4-10 presents the afflux generated at each bridge section due to the 67% blockage of the flowing area.

Table 4-10: Afflux at the bridges under the blockage scenario, 0.1%AEP

Bridge ID	Water level - Baseline [mOD]	Water level - Blockage [mOD]	Afflux [m]
162	10.80	11.13	+0.33
155	10.67	11.07	+0.4
121	9.66	10.98	+1.32

Figure 4-16 provides an overview on the bridge's location and the flood extent map under the blockage scenario compared to baseline.

There is no flood risk for the proposed site due to the blockage of the bridges.

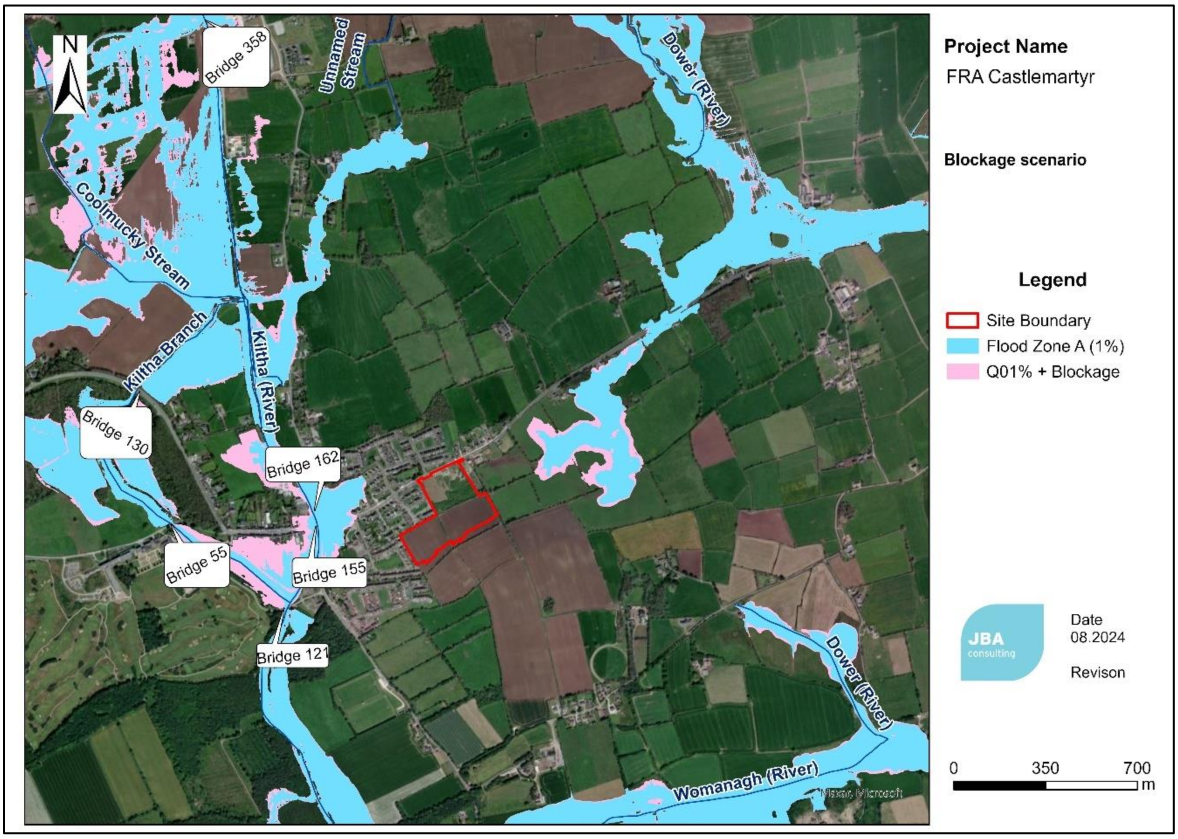


Figure 4-16: Baseline versus Blockage, 0.1%AEP

4.3.3.2 Blockage of the eastern flow path on Dower River

After passing the location of the swallow hole, adjacent to the N25 national road the Dower flow splits in two flow paths, one in eastern direction and the second in western direction towards to Castlemartyr.

Another residual risk scenario was tested considering complete blockage of the eastern flow path on the Dower River (except N25 national road), allowing for all the Dower flow to discharge towards the site in a westerly direction. To model this blockage scenario a high barrier was implemented in the model to completely obstruct the eastern flow along the agricultural lands while the existing levels along the N25 have been maintained, see dashed black line marked in Figure 4-17 and Figure 4-18.

Figure 4-17 and Figure 4-18 shows the comparison of the baseline flood extent maps versus flood extent maps when blockage of the flow path is considered, for 1%AEP and 0.1%AEP events.

In case that the Dower flow is diverted towards to Castlemartyr direction, the site will be flooded only in the northern part of the site which is retained to the existing ground levels.

The maximum water levels in this flooded area are 11.27mOD for 1% AEP and 11.41mOD for 0.1AEP events, and the minimum ground elevation is 10.20mOD.

The above analysis is considered extremely unlikely as the entire extent of the agricultural lands would need to be raised sufficiently to completely cut off this flow path.

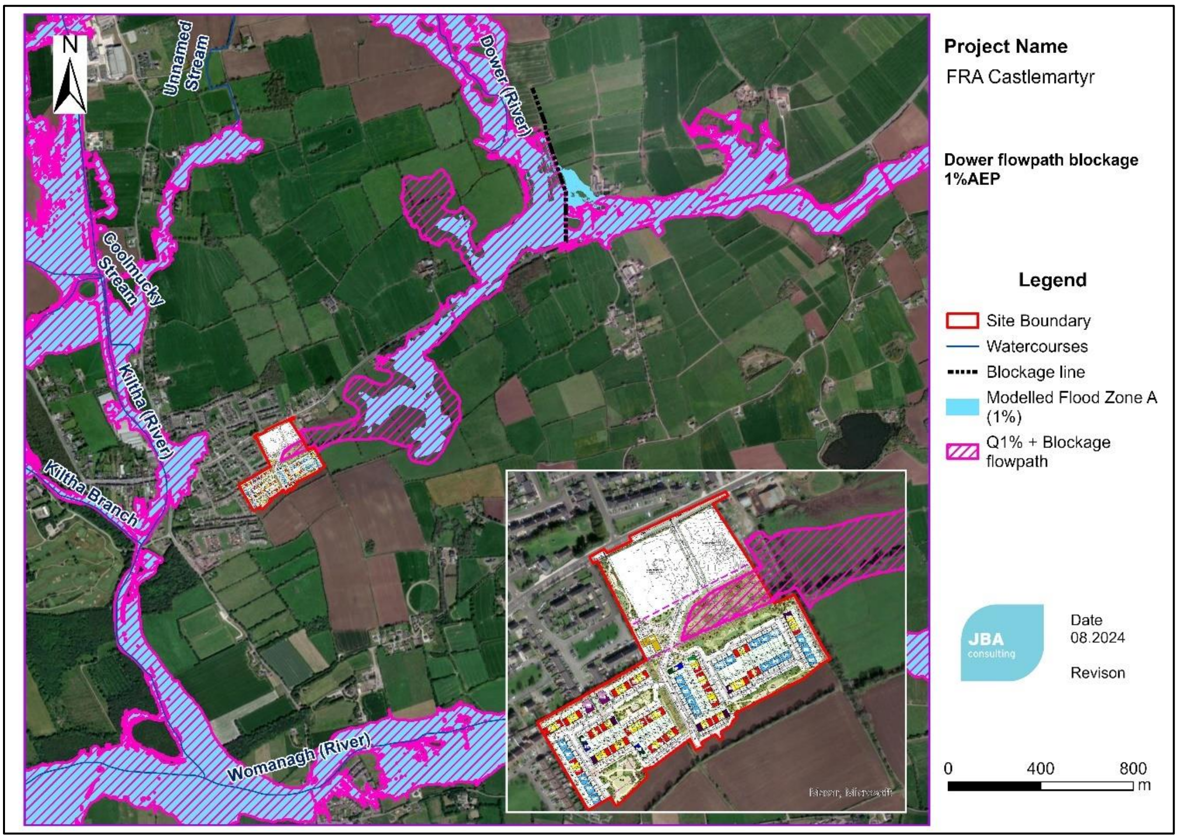


Figure 4-17: Baseline versus Blockage of eastern flow path on Dower River, 1%AEP

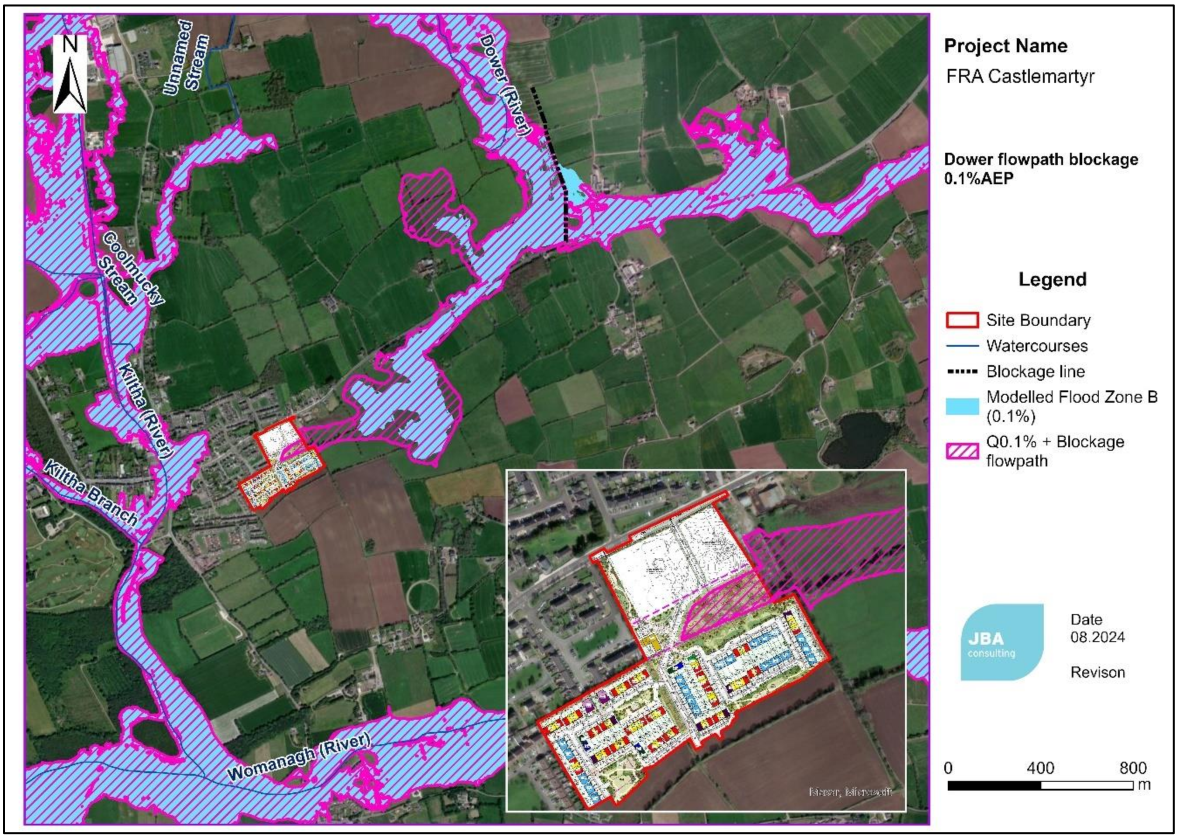


Figure 4-18: Baseline versus Blockage of eastern flow path on Dower River, 0.1%AEP

5 Flood Risk Assessment and Mitigation

5.1 Flood Risk

Having reviewed the indicative flood maps provided by the OPW NIFM study, a area north of the site was indicated to be within Flood Zone B. However, the flood maps are known to be indicative in nature and generally over-represent flood risk.

Following detailed survey, hydrological assessment and hydraulic modelling of the Kiltha River, the Dower River, the unnamed stream and the Coolmucky stream; the site has been demonstrated to be wholly within Flood Zone C.

5.2 Mitigation Measures

In response to the identified flood risks a number of mitigation measures have been identified. Under the Planning System and Flood Risk Management Guidelines the residential development is classified as highly vulnerable, and the development is appropriate being located fully within Flood Zone C and the Justification Test does not apply. The development proposal will not increase the risk of fluvial flooding elsewhere in the catchment.

To manage the risk of pluvial flooding to the site surface water run-off needs to be managed to ensure no increased risk to neighbouring lands.

5.2.1 Site layout and access

As noted above, the site is fully within Flood Zone C, so the development layout presented Figure 1-1 is appropriate. Further, the modelling has shown the N25 Killeagh Road is flooded nearby the main channel of Kiltha River, but in the eastern direction the road is unimpeded providing safe access to the site.

5.2.2 Finished Floor Levels

The buildings footprints are located within Flood Zone C, in accordance with the sequential approach of the Flood Risk Management Guidelines for Planning Authorities

The minimum ground level within the site area is 9.90mOD (in the northern side of the site boundary), the site being at least 200m away from the maximum flood extent. There is no flood risk to the site due to the Kiltha River, Dower River, Coolmuchy Stream or unnamed stream.

The proposed minimum FFL within the site is 12.25mOD, with reference to Section 4.3.3.2 which covers the blockage scenario and produces the highest flood level at 11.41mOD during the 0.1 % AEP event. The minimum FFL of 12.25mOD provides a freeboard of 0.84m above the 0.1 % AEP residual risk event.

To provide mitigation against surface water flooding and overland flow paths it is recommended that finished floor levels are raised a minimum of 300mm above surrounding ground levels.

5.2.3 Surface Water

The proposed development will include a dedicated stormwater design system that will manage surface water flows within the site. The proposed layout is provided in Appendix C. The stormwater design has been undertaken in accordance with the governing Cork County Council Development Plan.

Refer to the DOBA design report "RP-C-005-S2.P02_Drainage Impact Assessment" and associated design figures for the detailed design information, which is contained in the wider planning application.

6 Conclusions

JBA Consulting has undertaken a detailed Flood Risk Assessment for a proposed residential development for a site located in Castlemartyr, Co Cork. The development will include development of the housing units and all associated works. The minimum FFL within the site is 12.25mOD.

After reviewing the existing OPW NIFM flood mapping which presents flood risk at the site it was concluded that the flood outlines were indicative in nature and did not adequately represent flood risk at the site. Furthermore the Unnamed watercourse which runs at the north of the site between Kiltha and Dower Rivers was not part of the OPW NIFM. To improve the existing estimate of the Flood Zones a detailed hydrological and hydraulic modelling study has been completed, for all hydrological features that may have an impact on the site area such as Kiltha River, Dower River, Coolmuchy Stream and Unnamed stream.

The main conclusions reflected by the hydrological and hydraulic analysis are:

- The modelled flow and levels are generally higher on the Kiltha River compared to the CFRAM results as a more conservative approach was adopted where the hydrograph peak overlaps the peaks of its tributaries Coolmuchy and Unnamed Stream (Unnamed Stream being modelled as surface water stream with the swallow hole blocked).
- For the Dower River a 1.67 FSE was applied to the flows and the site still does not flood for any of the simulated fluvial events.
- The proposed site is completely within Flood Zone C and is not at risk of fluvial flooding from any of the modelled watercourses.
- There is no risk of flooding to the site under the climate change and residual risk (blockage) scenarios.
- A minimum freeboard of 0.84m has been provided above the peak flood event which is the 0.1% AEP residual risk scenario i.e. the near complete blockage of the Dower eastern flow path.

The Flood Risk Assessment was undertaken in accordance with 'The Planning System and Flood Risk Management' guidelines and confirm that the development resides in Flood Zone C and is in agreement with the core principles contained within.

Appendices

A Appendix - Understanding Flood Risk

Flood Risk is generally accepted to be a combination of the likelihood (or probability) of flooding and the potential consequences arising. Flood Risk can be expressed in terms of the following relationship:

Flood Risk = Probability of Flooding x Consequences of Flooding

A.1 Probability of Flooding

The likelihood or probability of a flood event (whether tidal or fluvial) is classified by its Annual Exceedance Probability (AEP) or return period years, a 1% AEP flood 1 in 100 chance of occurring in any given year. In this report, flood frequency will primarily be expressed in terms of AEP, which is the inverse of the return period, as shown in the table below and explained above. This can helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval and is the terminology which will be used throughout this report.

Table: Conversion between return periods and annual exceedance probabilities

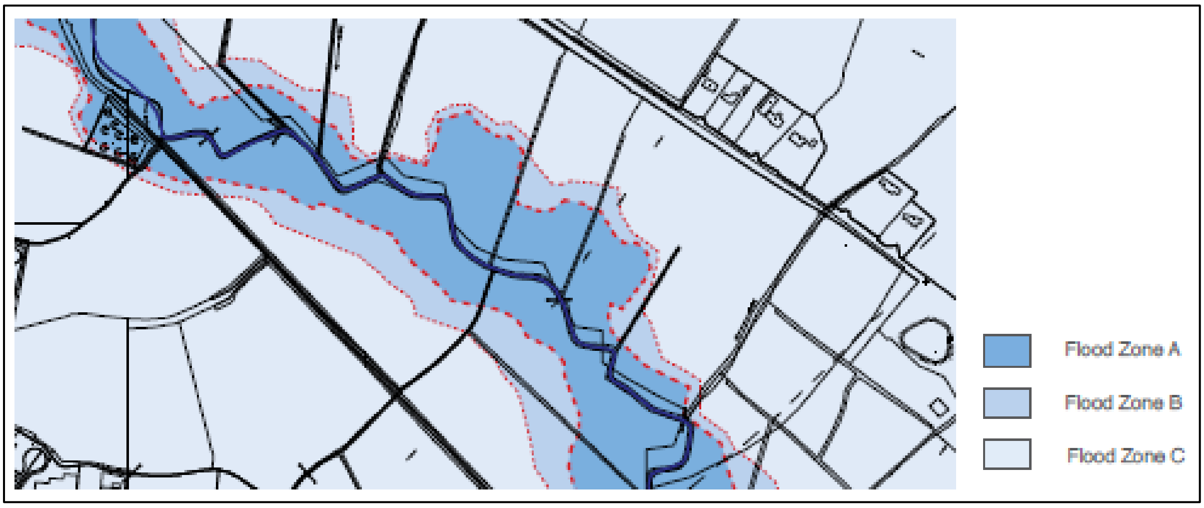
Return period (years)	Annual exceedance probability (%)
2	50
10	10
50	2
100	1
200	0.5
1000	0.1

A.2 Flood Zones

Flood Zones are geographical areas illustrating the probability of flooding. For the purpose of the Planning Guidelines, there are 3 types of levels of flood zones, A, B and C.

Zone	Description
Flood Zone A	Where the probability of flooding is highest, greater than 1% (1 in 100) from river flooding or 0.5% (1 in 200) for coastal/ tidal Flooding
Flood Zone B	Moderate probability of flooding, between 1% and 0.1% from rivers and between 0.5% and 0.1% from coastal/ tidal.
Flood Zone C	Lowest probability of flooding, less than 0.1% from both rivers and coastal/ tidal.

It is important to note that the definition of the flood zones is based on an undefended scenario and does not take into account the presence of flood protection structures such as flood walls or embankments. This is to allow for the fact that there is a residual risk of flooding behind the defences will be maintained in perpetuity.



A.3 Consequences of Flooding

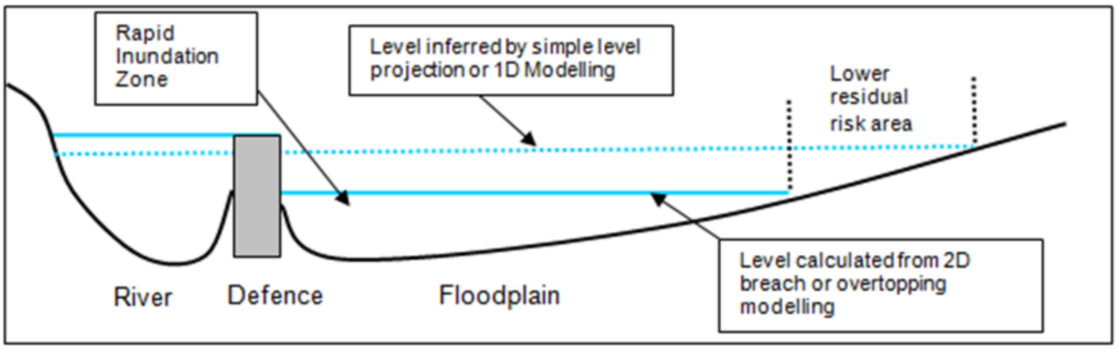
Consequences of flooding depend on the Hazards caused by flooding (depth of water, speed of flow. Rate of onset, duration, wave-action effects, water quality) and the vulnerability of receptors (type of development, nature, e.g. age-structure of the population, presence and reliability of mitigation measures etc.)

The 'Planning System and Flood Risk Management' provides three vulnerability categories, based on type of development, nature, which are detailed in Table 3.1 of the Guidelines, and are summarised as:

- **Highly vulnerable**, including residential properties, essential infrastructure, and emergency service facilities
- **Less vulnerable**, such as retail and commercial and local transport infrastructure, such as changing rooms.
- **Water compatible**, including open space, outdoor recreation and associated essential infrastructure.

A.4 Residual Risk

The presence of flood defences, by their very nature, hinder the movement of flood water across the floodplain and prevent flooding unless river levels rise above the defence crest level or a breach occurs. This known as residual risk:



B HUCT Hydrogelogy Report

Hidrigeolaíocht Uí Chonaire Teoranta **Project: 1147 – JBA Castlemartyr**

Client: JBA Consulting Engineers

To: Ross Bryant **From: Peter Conroy**

Subject: Hydrogeological Component of Castlemartyr FRA **29 April 2024**

The study area in the vicinity of Castlemartyr and Mogeely is underlain by bedrock units comprising Dinantian pure unbedded limestone (DPUL) and occasional Dinantian pure bedded limestone (DPBL). These bedrock units are classified as Regionally Important Karst Aquifer (Rk_d) by the Geological Survey of Ireland (GSI). In the higher ground to the north and south of the DPUL and DPBL, the bedrock units are predominantly comprised of Devonian old red sandstone (DORS), which are classified as a locally important (LI) aquifer by the GSI (Figure 01).

Groundwater flow in the Ll aquifer is expected to occur in a diffuse, thin zone of weathered rock at the top surface of the bedrock and in an underlying network of fractures up to depths of about 30 m below the top of the rock. Groundwater flow paths in the Ll aquifer are likely to be short and groundwater flow is expected to be directed towards and discharging into the generally north-south oriented surface watercourses crossing the aquifer surface.

In contrast, groundwater flow in the Rk_d aquifer is expected to be dominated by preferential flow in solutionally enlarged fractures and conduits. Groundwater flow in these conduits is fed by diffuse groundwater recharge across the aquifer footprint, with the recharge flowing locally towards the conduit preferential pathways via a network of smaller bedrock fractures and fissures.

The diffuse aquifer recharge is supplemented by point recharge via surface karst features, which occur frequently across the study area in the form of swallow holes, and also enclosed depressions.

There are four known swallow holes within the study area, each of which allows a significant surface water feature to sink into the Rk_d aquifer as point recharge. From east to west these are the Knockane Cross caves, the Ballyvorisheen (Dower) swallow hole, the Mogeely Cave swallow hole, and the Killamucky Grange swallow hole. Surface water drainage from the local reach of the N25 national primary road discharges directly into the Rk_d aquifer via the Knockane Cross caves. The Dower River sinks into the Ballyvorisheen swallow hole. The stream called the Carrignashinny Stream here sinks into the Mogeely Cave swallow hole. The stream called the Killamucky Grange Stream here sinks into the Killamucky Grange swallow hole. The sinking streams and swallow holes are shown on Figure 01.

Further, localised point recharge occurs via enclosed depressions. Rainfall runoff, within the topographic catchment of enclosed depressions within the karst landscape, ponds within the enclosed depression and infiltrates into the Rk_d aquifer via a preferential pathway linking the base of the depression to the aquifer. In general, the magnitude of point recharge via the enclosed depressions is likely to be far less than that which occurs via streams sinking into swallow holes.

Groundwater flow in the Rk_d aquifer conduit system is regional in scale and flow paths of up to several kilometres in length are expected. The groundwater flow in the Rk_d aquifer within the study area is known to discharge to the Dower Spring, located approximately 1.1 km east-southeast of the site. It is possible that other unknown discharge locations exist in addition to the Dower Spring.

A tracer test is a type of groundwater investigation whereby fluorescent dye is mixed into the water sinking into the aquifer at a karst feature. Groundwater discharge locations downgradient of the input karst feature are subsequently monitored to see if the dye is detected at the discharge locations. If the dye is subsequently detected at a discharge location, it shows that there is a groundwater flow path between the input karst feature and the discharge location.

Historical tracer tests show that the sinking streams at the Ballyvorisheen and Mogeely Cave swallow holes; and, the drainage at the Poulnahorka Quarry Sink West, all have a component that discharges at the Dower Spring. It is likely that a component of the Killamucky Grange sinking stream and of the sinking road drainage at the Knockane Cross Caves also discharges at the Dower Spring. No tracer test has been carried out at the Killamucky Grange swallow hole or at the Knockane Cross Caves to date. The traced connections and the likely connections are shown schematically on Figure 01.

Historical monitoring of the Dower Spring by Cork County Council, the GSI and the Environmental Protection Agency (EPA) records discharges of up to 119,719 m^3/day (1.42 m^3/sec). The spring discharge comprises groundwater deriving from point recharge, at swallow holes in particular; and, from diffuse recharge across the Rk_d aquifer Zone of Contribution (ZOC) to the spring. The ZOC for the spring is equivalent to the groundwater catchment of the spring.

The magnitude of point recharge to the Dower Spring ZOC from sinking streams and drainage at the four known swallow holes, has been estimated using surface water modelling techniques in Section XX of this report.

The magnitude of diffuse recharge to the Dower Spring is estimated from the amount of rainfall recharge occurring across the Rk_d aquifer component of the footprint of the Dower Spring ZOC. Diffuse recharge to the ZOC outside the Rk_d aquifer footprint is assumed to discharge to surface water features crossing the ZOC, which subsequently sink into the Rk_d aquifer at swallow holes. A ZOC for the spring was delineated by the GSI in 2002. The Rk_d aquifer component of the ZOC has a footprint of approximately 8.1 km^2 and is shown in Figure 01. The GSI ZOC report for the Dower Spring estimates that the annual average diffuse recharge to the Rk_d component of the ZOC is 616 mm/yr. This amounts to approximately 4,990,000 m^3 of diffuse recharge per year, or approximately 0.16 m^3/sec.

Groundwater Flooding Conceptual Model, Worst-case scenario

For the groundwater flooding worst-case scenario it is envisaged that all diffuse and point recharge to the Rk_d aquifer within the study area flows to the Dower Spring via the Rk_d aquifer karst conduit network.

In the case of a total blockage of the Dower Spring discharge, diffuse and point recharge to the aquifer will be ongoing but no discharge will be possible via the Dower Spring discharge point. As a result, groundwater will begin to accumulate in the aquifer up gradient of the spring, resulting in ongoing increases in the groundwater level within the up gradient aquifer. Once the groundwater level in the aquifer exceeds the invert elevation of swallow holes upgradient of the Dower Spring, these swallow holes be converted into springs that discharge groundwater to the previously influent surface water courses.

For the worst-case scenario it is further envisaged that for the duration of the blockage all of the groundwater discharge from the Rk_d aquifer occurs via the Ballyvorisheen swallow hole. In this way, for the duration of the blockage, all of the diffuse recharge to the Dower Spring catchment, and all of the point recharge to the Knockane Cross Cave, the Mogeely Cave swallow hole, and the Killamucky Grange swallow hole discharges to the ground surface at the Ballyvorisheen swallow Hole. In addition, all of the surface water flow in the Dower River remains on the ground surface and does not sink at the Ballyvorisheen swallow hole.

All of the flow in the Dower River plus all of the groundwater discharge from the Ballyvorisheen swallow hole is then envisaged to flow along the overland pathway south from the area of the Ballyvorisheen swallow hole in the direction of the site.

In reality, it is unlikely that all of the groundwater recharge to the Dower Spring catchment would discharge from the Ballyvorisheen swallow hole, in the event of a blockage of the Dower Spring. It is more likely that discharge would begin to occur from numerous overflow points (karst features) within the karst landscape of the study area, of which the Ballyvorisheen swallow hole might be one. Hence, the worst-case scenario represents an unlikely, upper-envelope estimate of the amount of water that might flow along the overland pathway between the Ballyvorisheen swallow hole and the site, during a flood event.

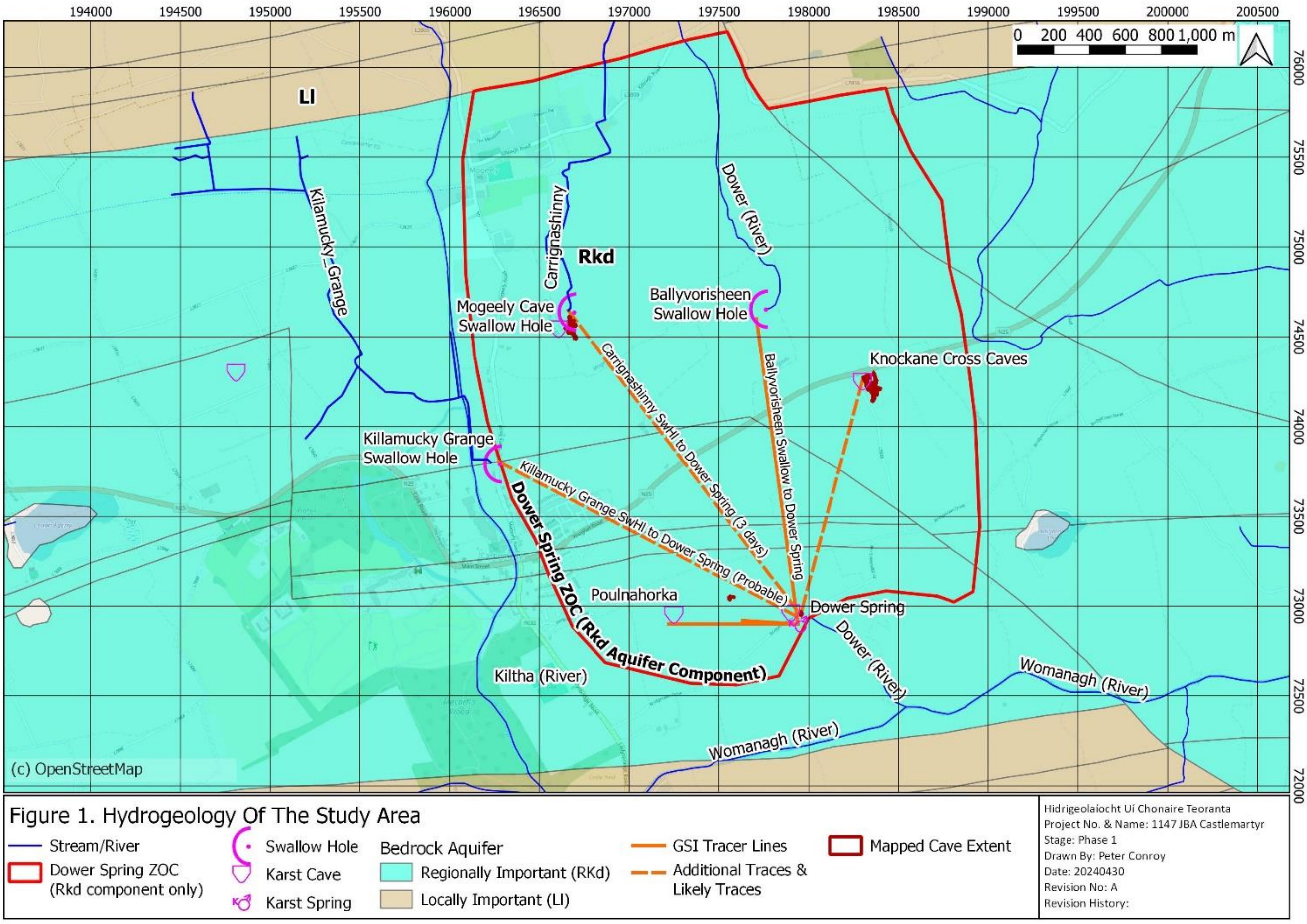
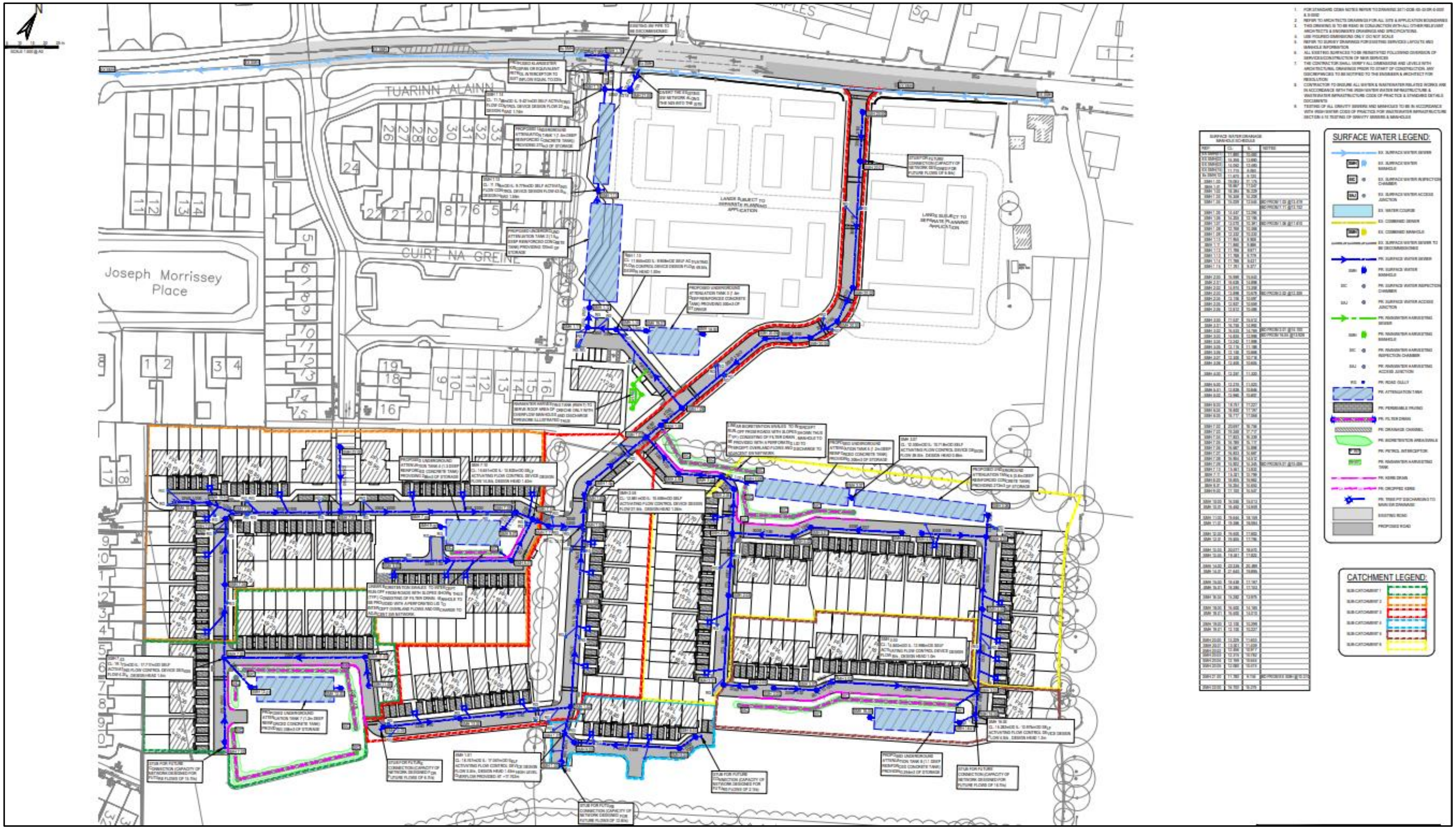


Figure 1. Hydrogeology Of The Study Area

C Stormwater Layout



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