Residential Development Baldoyle GA2, Flood Risk Assessment

Final Report

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Contract

This report describes work commissioned by Jerome O'Brien of JB Barry, on behalf of Lismore Homes Ltd. Lismore Homes Ltd's representative for the contract was Antoinette Kennedy. David Casey and Anastasiya Ilyasova of JBA Consulting carried out this work.

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Purpose

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Abbreviations

1D .... One Dimensional (modelling)
2D .... Two Dimensional (modelling)
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 Levels
FRA .... Flood Risk Assessment
FSR .... Flood Studies Report
FSU .... Flood Studies Update
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) 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 have been commissioned by Lismore Homes to prepare a Flood Risk Assessment (FRA) to accompany a planning application for a proposed residential development identified as Baldoyle GA2 in Baldoyle, Dublin 13.

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 the client the risk of flooding to land, property and people and the measures that would be recommended to manage the risk in order to facilitate the development of the site.

The objectives of the 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;
- 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 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

A Strategic Housing Development for the construction of 1,007 residential apartments (consisting of 58 no. studio units, 247 no. 1 bedroom units, 94 no. 2 bedroom 3 person units, 563 no. 2 bedroom 4 person units, and 45 no. 3 bedroom units), communal residential community rooms, and a ground floor creche in 16 no. buildings with heights varying from 4 to 12 storeys, basement and surface level car parking, secure bicycle parking, landscaping, water supply connection at Red Arches Road, and all ancillary site development works on a site located in the townland of Stapolin, Coast Road, Baldoyle, Dublin 13.

The minimum FFL provided on site is 6.2mOD.

Refer to Figure 1-1 for the proposed site layout.

Figure 1-1: 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 hydrology and hydraulic model/results are provided in Section 4. Site specific mitigation measures are outlined in Section 5. Conclusions are provided in Section 6.

2 Site Background

This section describes the proposed development site at Baldoyle, Co. Dublin, including watercourses, geology and the wider geographical area.

2.1 Location

The proposed development is located in Baldoyle, Co. Dublin, approximatively 500m west of the Baldoyle Estuary.

The site is a greenfield with two small roads crossing it. It is bordered by local roads from south and west and The Dublin - Malahide railway line runs in close proximity to the western boundary. Residential developments are located to the south, while to the north and east lies agricultural lands and grasslands.

The site location and watercourses are shown in Figure 2-1 below.

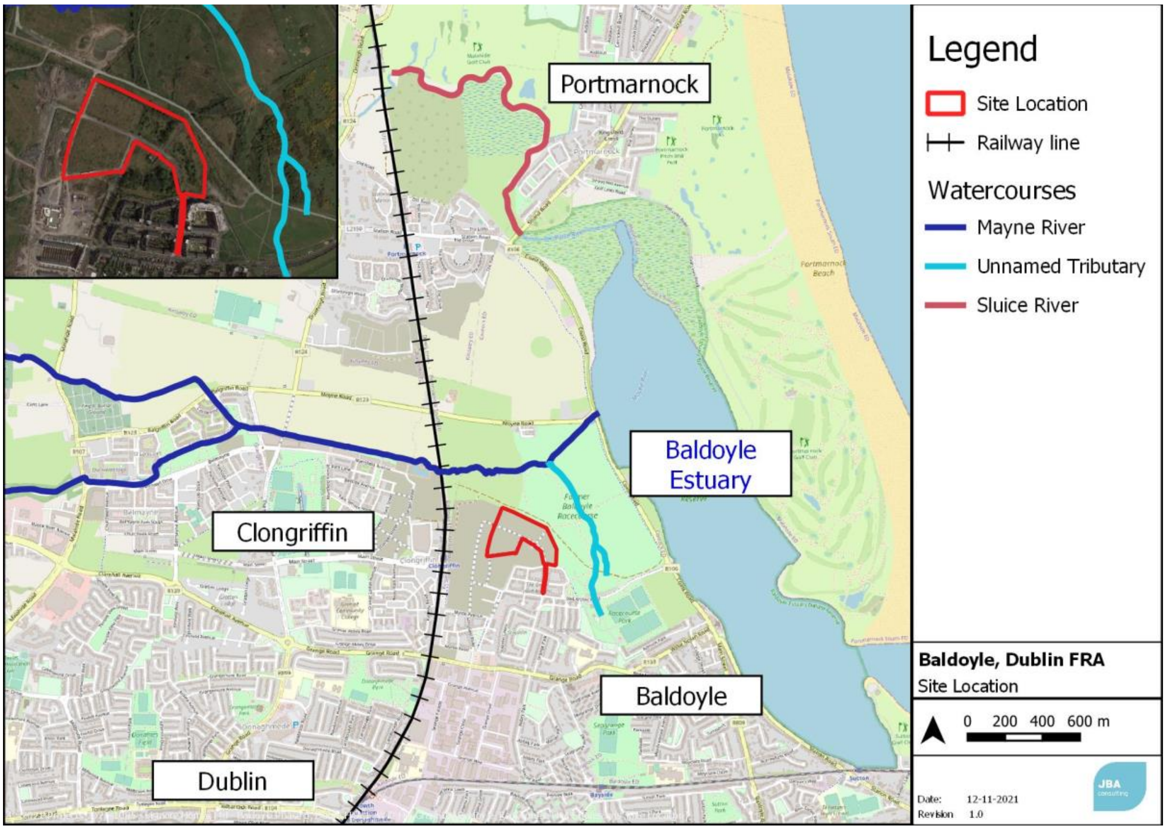


Figure 2-1: Site Location and Watercourses

2.2 Watercourses

The closest watercourse to the site is the River Mayne, which flows in an eastern direction north of the site (see Figure 2-1). The River Mayne discharges into the Baldoyle Estuary Nature Reserve c. 1km to the north-east of the site. The Baldoyle Estuary Nature Reserve opens to the Irish Sea c. 2.0km to the south-east.

The Racecourse Stream, a tributary of the River Mayne flows in a northern direction c. 200 m to the east of the site. The Sluice River discharges to the Baldoyle Estuary Nature Reserve c. 1.4km to the north of the site.

2.3 Site Topography

The general topography of the area is shown in Figure 2-2 below. There is a slight fall from the south-west to the north-east of the site from approximatively 7.58mOD to 3.09mOD.

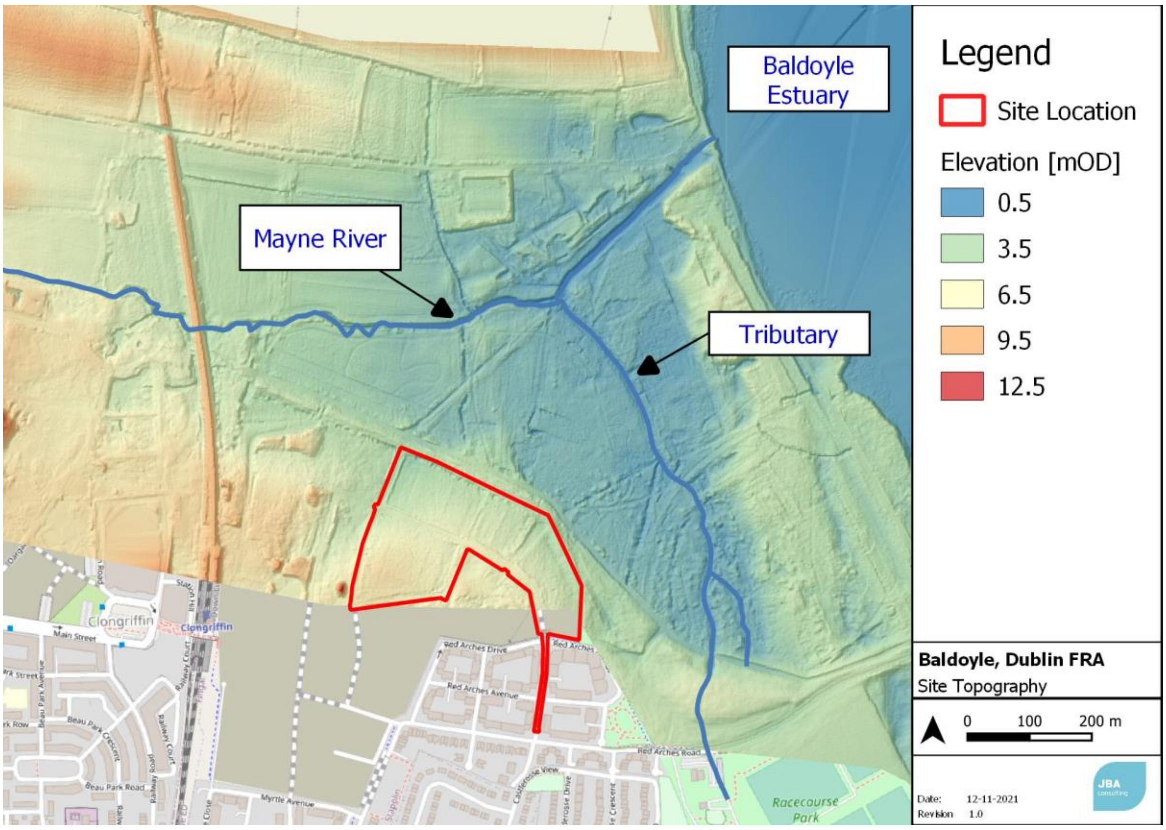


Figure 2-2: Site Topography (source: https://en-ie.topographic-map.com)

2.4 Site Geology

The Geological Survey of Ireland (GSI) groundwater and geological data viewer of the site and local area were reviewed. The underlying bedrock at the site is the Malahide Formation, which is described as Argillaceous bioclastic limestone and shale, as shown in Figure 2-3. The Quaternary Sediments at the site location are Alluvium and Till derived from limestones. It is noted that the presence of alluvium type soils indicated the occurrence of historical flooding, in the absence of other records.

The associated groundwater vulnerability, which is the risk of groundwater infiltrations through the bedrock and risk of groundwater contamination from the site, is classified as 'Low'. The subsoil permeability is deemed 'Low'.

There are no karst features located near the site.

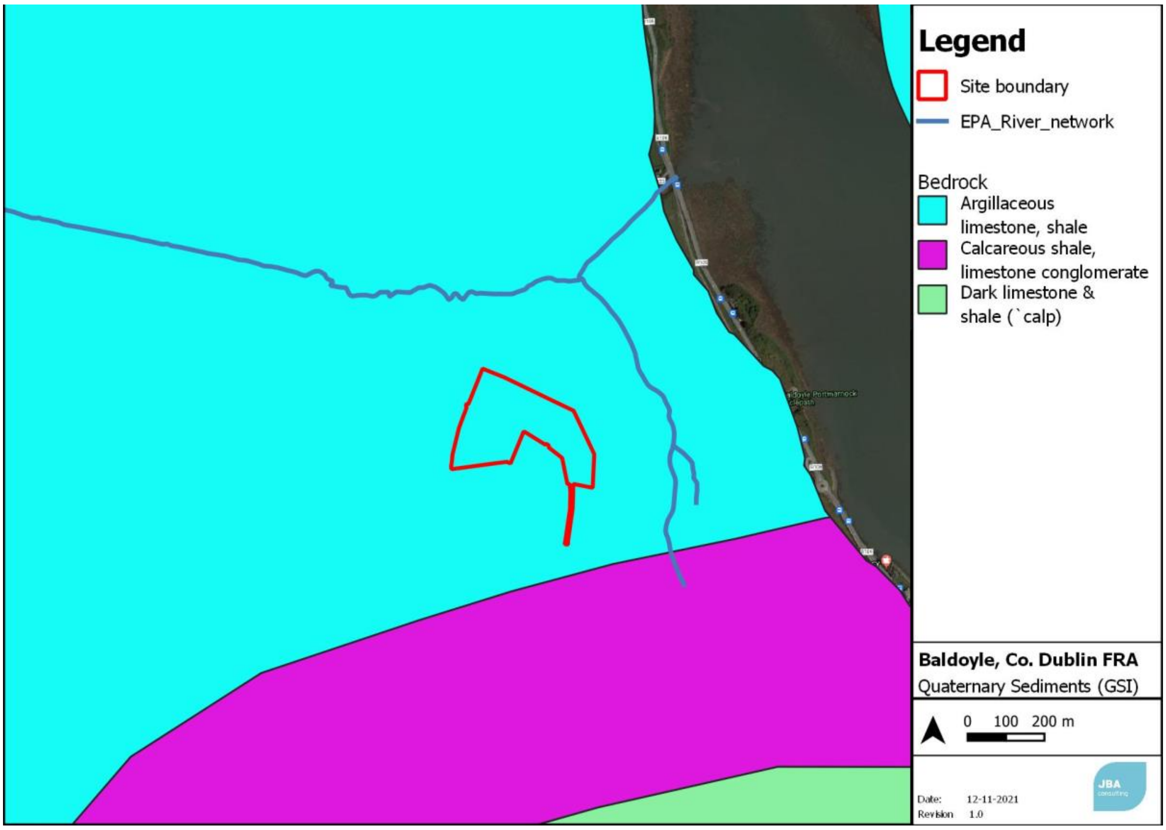


Figure 2-3: Quaternary Sediments (source: GSI)

3 Flood Risk Identification

An assessment of the potential and scale of flood risk at the site was conducted using historical and predictive information. This identifies any sources of potential flood risk to the site and reviews historic flooding information. The findings from the flood risk identification stage of the assessment are provided in the following sections. Further detail on the Planning Guidelines and technical concepts are provided in Appendix A.

3.1 Flood History

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

3.1.1 Floodmaps.ie

The OPW host a national flood hazard mapping database that is now incorporated into www.floodinfo.ie, which highlights areas at risk of flooding through the collection of recorded data and observed flood events. Review of the flood events in the area confirm that there has been no identified historic flood event recorded within the site. The following past flood events in the surrounding area are shown in

Figure 3-1:

- 1 - Recurring: Flooding at Mayne River Bridge, Baldoyle. Approximately 500m to the north-east of the site. Flooding due to incapacity of Mayne River Bridge during high tides. Flood Relief Scheme completed in 2001.
- 2 - October 2011: Flooding at Coast Road, Baldoyle. Approximately 500m to the east of the site. Flood source: runoff from surface water drainage. Two residential properties were affected. No apparent flooding from River Mayne.
- 3 - Recurring: Baldoyle coastal flooding. Approximately 500m to the east of the site. Flood source: Coastal/Estuarine Waters.
- 4 - October 2011: Flooding at Brookstone Road, Baldoyle. Approximately 900m to the south-east of the site. Flood source: surface water. The drainage system was inundated

due to heavy prolonged rainfall. There was no evidence of direct flooding from the watercourse.

- 5 - December 1954: Flooding at Grange Stream Baldoyle. Approximately 1.1km south-east of the site. Flood source: Fluvial. A number of defence assets were put in place since the flood event.
- 6 - October 2002: Flooding at Grange Road, Baldoyle. Approximately 950m south-east of the site. Flood source: surface water. Surface water screens were obstructed with material, which contributed to the flooding of Grange Road. The main cause of the flooding was blocked gullies.
- 7 - November 1982: Flooding at Grange Road, Donaghmede. Approximately 800m south of the site. Flood source: blocked culvert on the Little Dargle stream.
- 8 - June 1993: Balgriffin Park, Raheeny, Dublin 5. Approximately 1.5km west of the site. Flood source: Mayne River. A residential dwelling was damaged.
- 10 - Recurring: Strand Road, Portmarnock. Approximately 1.3km north of the site. Flood source: Sluice River.

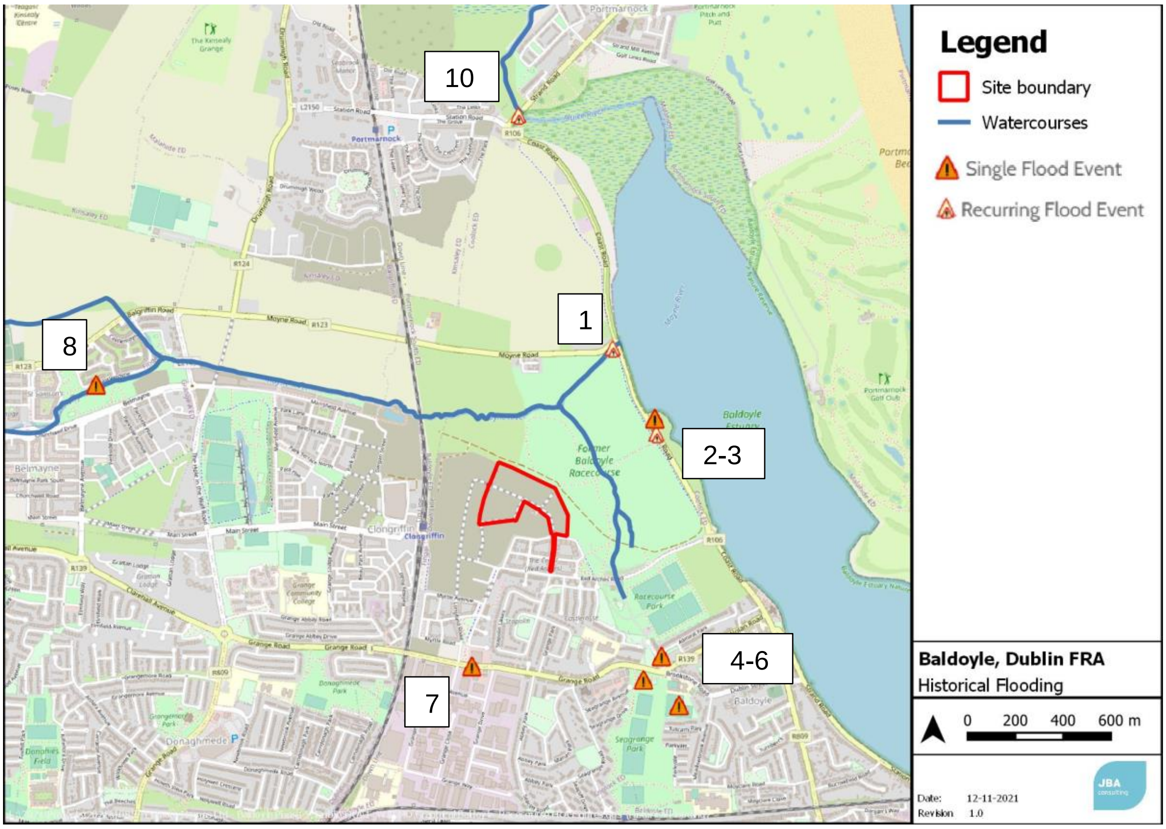


Figure 3-1: Historical Flooding (source: floodinfo.ie)

3.1.2 Internet Searches

An internet search was performed to gather information about whether the site was previously affected by flooding. Reports of repeated tidal flooding along the Baldoyle to Portmarnock walking and cycling greenway were found; the greenway runs alongside the Coast Road, approximately 400m to the east of the site.

No reports indicating flooding at the site were found.

3.2 Predictive Flooding

The area has been subject to a number of predictive flood mapping or modelling studies:

- OPW Preliminary Flood Risk Analysis (PFRA);

- FEM-FRAMS Fingal East Meath Flood Risk Assessment and Management Study;
- Fingal Development Plan 2017-2023 Strategic Flood Risk Assessment (SFRA);
- FloodResilienCity Project.

The level of detail presented by each method varies according to the quality of the information used and the approaches involved. The CFRAM is the most detailed assessment of flood extent and supersedes the fluvial flood outlines presented by the OPW PRFA study.

3.2.1 OPW Preliminary Flood Risk Analysis (PFRA)

The Preliminary Flood Risk Assessment (PFRA) is a requirement of the EU Flood Directive (2007/60/EC). One of the PFRA deliverables is flood probability mapping for various sources: pluvial (surface water), groundwater, fluvial and tidal. The PFRA is a preliminary or 'indicative' assessment and analysis has been undertaken to identify areas potentially prone to flooding. The fluvial and coastal data has largely been superseded by the CFRAMS flood mapping however the PFRA mapping still provides valuable information regarding pluvial and groundwater flooding. At the time of writing, the updated PFRA mapping has not been made public.

3.2.2 FEM-FRAMS Fingal East Meath Flood Risk Assessment and Management study

The FEMFRAM study was a detailed flood mapping study undertaken in the north Dublin region as a pilot study area for the CFRAM programme. Following the detailed hydraulic modelling, flood maps were produced for the 10%, 1%, and 0.1% AEP fluvial flood events. As shown in Figure 3-2, the FEMFRAM mapping confirms that the site is located in Flood Zone C. The peak flood levels and flows for the 1% and 0.1% AEP events for the closest node (1Maa675) are provided in Table 3-1.

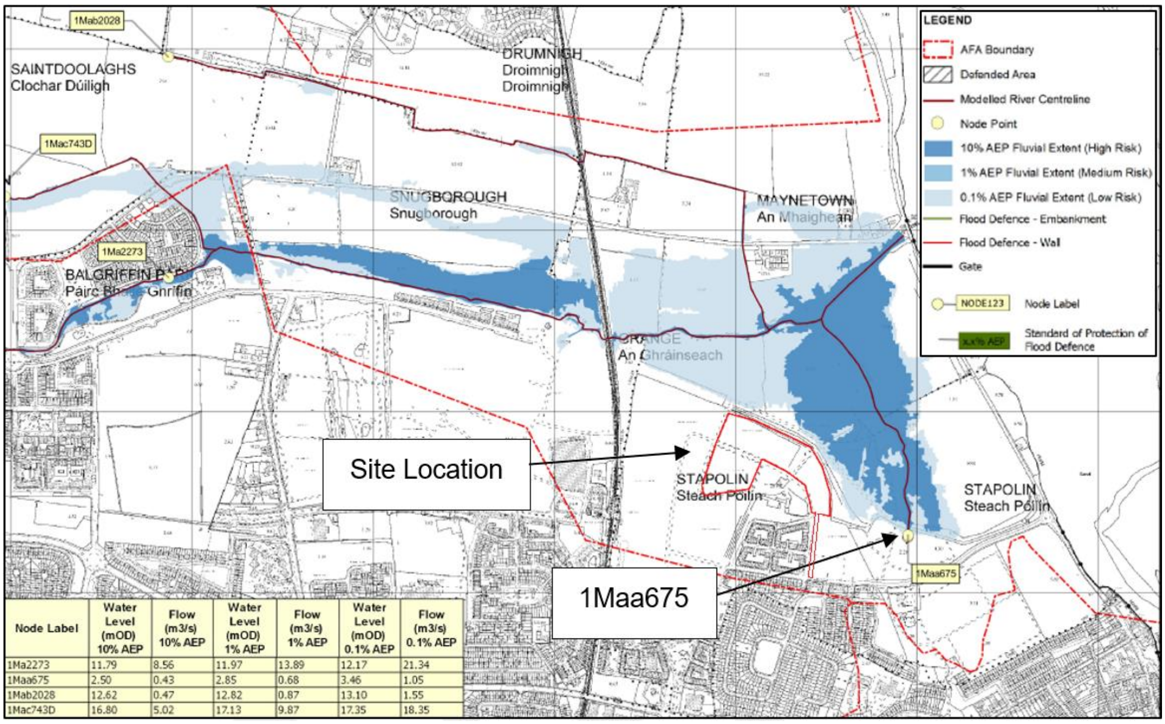


Figure 3-2 FEMFRAM Fluvial Flood Extents (Source: floodinfo.ie)

Table 3-1: FEM FRAM Peak Flow/Levels (Fluvial)

Node	1% AEP		0.1% AEP	
1Maa675	0.68 (m3/s)	2.85mOD	1.05(m3/s)	3.46mOD

Flood maps were also produced for the 10%, 0.5%, and 0.1% AEP tidal flood events. As shown in Figure 3-3, the FEMFRAM mapping places the site outside the 0.1% flood extents. The peak flood levels and flows for the 0.5% and 0.1% AEP events for the closest node are provided in Table 3-2.

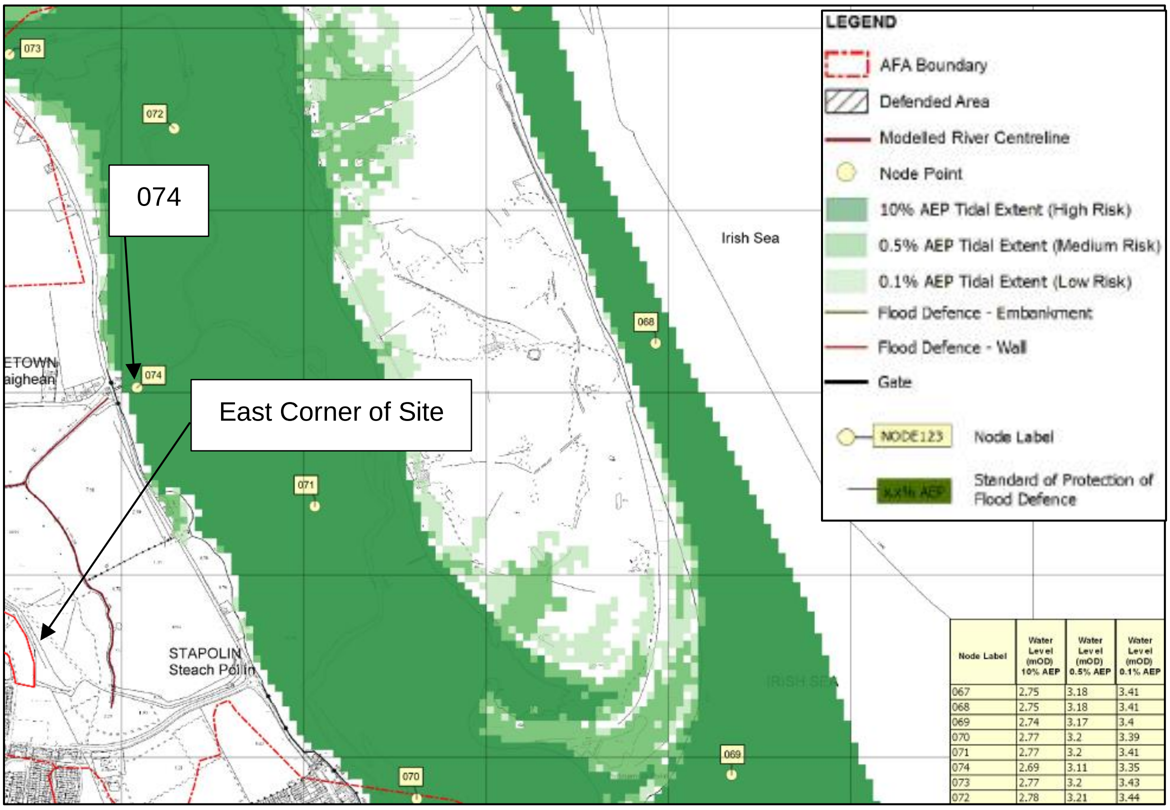


Figure 3-3 FEMFRAM Tidal Flood Extents (Source: floodinfo.ie)

Table 3-2: FEM FRAM Peak Levels (Tidal)

Node	10% AEP	0.5% AEP	0.1% AEP
074	2.69mOD	3.11mOD	3.35mOD

3.2.3 Fingal Development Plan 2017-2023 Strategic Flood Risk Assessment (SFRA)

The Fingal County Council Development Plan (CDP) 2017-2023 is the governing document for development in the area. It aims to set out the priorities and goals of the council over the lifetime of the plan for spatial and sectoral development. Under the Fingal CoCo CDP 2017-2023 the site is zoned as Residential).

As part of the Development Plan, a Strategic Flood Risk Assessment (SFRA) was commissioned to inform development based on flood risk. The SFRA informs the strategic land use planning decisions by providing an assessment of flood risk within the region and enables the application of the sequential approach, including Justification Test. A range of flood sources have been investigated as part of the SFRA (PFRA, FEMFRAM, Eastern CFRAM etc.), however the final flood maps are based on FEMFRAM mapping for the site area. The SFRA is based on the Planning System and Flood Risk Management Guidelines and uses the same sequential approach and Justification Test.

With specific reference to Section 5.9.14 of the SFRA, an FRA is required to be undertaken to demonstrate that developments would not have adverse flood risk impacts.

The baseline mapping is the FEM FRAM flood maps, as presented in Section 3.2.2.

3.2.4 FloodResilienCity Project

A report was undertaken as part of the EU Interreg IVB Flood ResilienCity Project to identify pluvial flooding hazards across Dublin City. The EU Interreg programme is a collaboration between EU partner authorities and organisations of which Dublin City is a member. The aim of the programme is to share knowledge and experience at a European Level. As part of the project, a city-wide pluvial model was developed to provide hazard mapping for Dublin City.

The results are presented in Figure 3-4 below and indicate that pluvial flooding occurs within the site during the 10% AEP pluvial event.

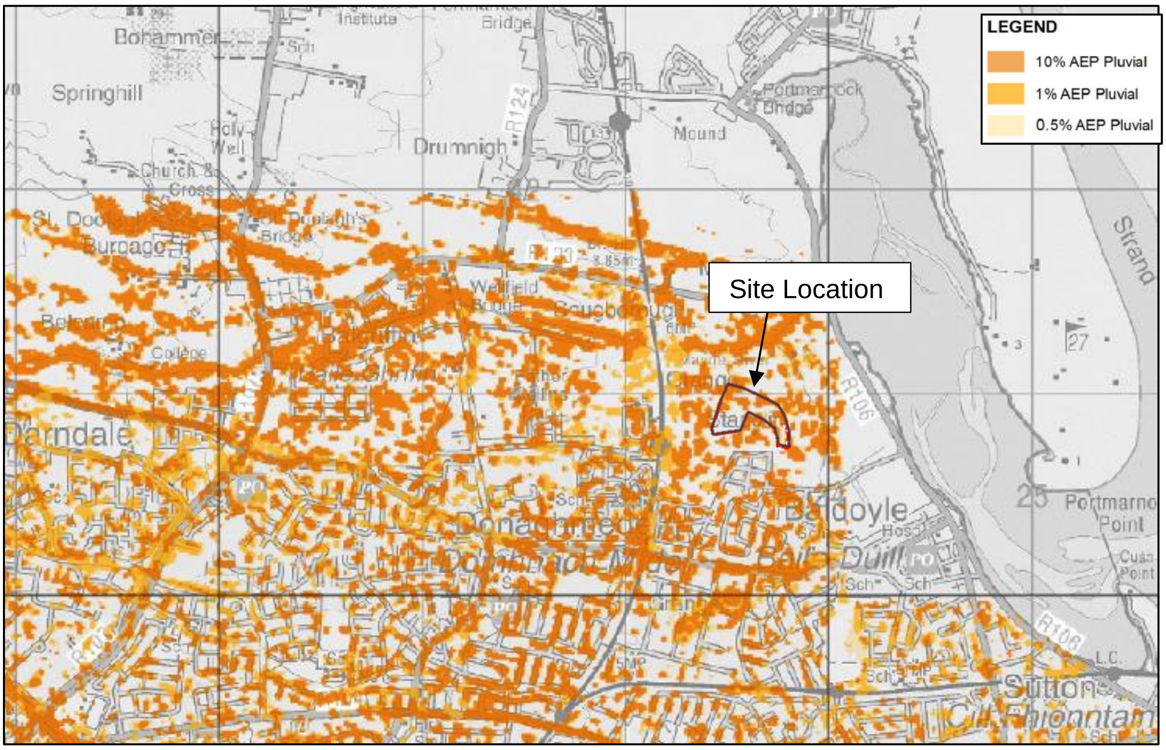


Figure 3-4: FloodResiliencity Pluvial Flood Mapping (source: http://www.floodinfo.ie/)

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

Following review of the available information, the River Mayne and the Racecourse Stream from the south have been identified as the main source of fluvial flood risk to the site. Review of the FEMFRAM fluvial flood extents confirms that the site is within Flood Zone C.

To confirm the flood risk to the development from climate change and residual risks, it was necessary to undertake hydraulic modelling to appraise the potential impacts. Further discussion on the hydraulic model is undertaken in Section 4.

3.3.2 Tidal

Review of the FEM FRAM tidal flood extents shows the site is not at flood risk from the tidal events. However, a more detailed analysis of the tidal flood risk to the site is presented in Section 4.

3.3.3 Pluvial/ Surface Water

Following review of the available information, the site is at risk of pluvial flooding during the 10% AEP event. Localised pluvial impacts at the site corresponds with localised depressions. The pluvial flood risk will be managed by the proposed stormwater system which is detailed further in Section 4.3.1.1.

3.3.4 Groundwater

Review of the site geology shows that the Quaternary Sediments at the site location include Alluvium, indicating historical flooding. Groundwater vulnerability and subsoil permeability are both ‘low’. There is no recorded risk of groundwater flooding onsite and a lack of karst features at the site indicate an overall low risk from groundwater flooding to the site. Therefore, groundwater flooding to the site has been screened out at this stage.

4 Hydraulic Model

4.1 Hydrology Assessment

To assist in the estimation of potential flood risk to the proposed development from the Mayne River, this section provides flow estimates for the 1% and 0.1% AEP flood event flows expected along the watercourse that flows through the northern section of the site. The unnamed tributary has also been included in the assessment. An overview of the hydrology is provided in the following section.

4.1.1 Catchment Characteristics

The physical characteristics of the catchment influence the hydrology, this includes catchment size, soil type, steepness and the average annual rainfall. Table 4-1 outlines the parameters calculated for the site catchment. Figure 4-2 overpage details the catchment area.

Table 4-1: Catchment Characteristics (source: OPW FSU)

Descriptor	09_1505_1	09_1428_02	Mayne Tributary
Centroid X	242090	241940	-
Centroid Y	317780	318770	-
Area	14.90	19.76	1.29
SAAR	714.24	709.38	711.63
FARL	1.00	1.00	1.00
BFI Soil	0.56	0.57	0.56
URBEXT	0.39	0.35	0.01
MSL	6.34	8.52	2.13
S1085	7.89	7.17	4.69
Stream Frequency	7.00	11.00	1.85
DrainD	0.89	0.85	1.00
ArtDrain2	0.00	0.00	0.00
Soil (number)	2.00	2.00	2.00
SMDBAR	7.00	7.00	7.00
M5-2day	56.96	57.02	56.20
M5-1day	44.23	48.32	47.60

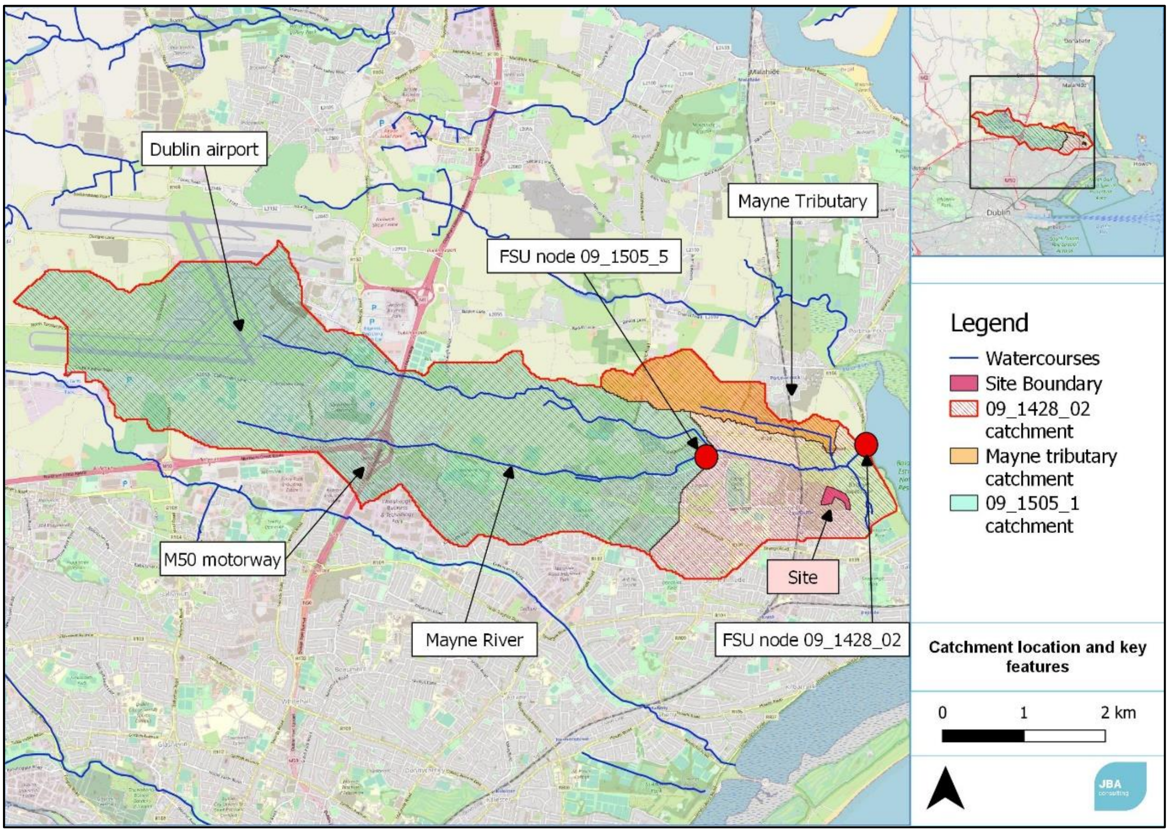


Figure 4-1: Catchment Area

4.1.2 Flow estimation

The flow estimations for the Mayne River and its tributary have been based on a single site analysis based on a 24-year hydrometric data and a weighted average growth curve (refer to Appendix B for more detail). The analysis provides both the Qmed and appropriate growth curves for the determination of the peak flows for the 1%, 0.1% AEP etc. The FSU Small Catchment method has been used to estimate the flows for the Racecourse Stream, due to the size of the catchment. Refer to the attached Hydrology Check file located in Appendix B for a comprehensive overview of the hydrology estimation process.

The final design flows for the Mayne River and its tributary are provided in Table 4-2.

Table 4-2: Design Flows

AEP (%)	09_1505_1 (Point inflow)	Mayne Tributary (Point inflow)	09_1428_02 (Lateral inflow)
50%	5.55	0.13	0.74
20%	8.04	0.19	1.07
10%	9.66	0.22	1.28
4%	11.43	0.27	1.53
2%	13.04	0.30	1.75
1%	14.49	0.34	1.91
0.1%	19.04	0.44	2.54

4.1.3 Tidal levels

The downstream tidal levels have been sourced from the FEM FRAM hydrological report for the 10yr, 50yr, 200yr and 1000yr tidal flood events. The tidal hydrography was sourced from Dublin port, which was provided by the Marine Institute (marine.ie.)

The final tidal peak flood levels used in the hydraulic model are presented in Table 4-3 below.

Table 4-3: Peak Tidal Flood Levels

AEP event (%)	Tidal Levels (mOD)
20% (5yr)	2.46
10% (10yr)	2.55
5% (20yr)	2.64
2% (50yr)	2.76
1% (100yr)	2.86
0.5% (200yr)	3.20
0.1% (1000yr)	3.41

4.1.4 Climate Change

Current OPW guidance requires that the effects of climate change be considered when assessing flood risk. The expected increase in peak flows, rainfall and tidal level is provided in the draft OPW guidance which provides allowances for two different climate change scenarios. These are the Mid-Range Future Scenario (MRFS) and the High-End Forecast Scenario (HEFS). The recommended allowances for climate change are given in Table 4-4 below. The potential implications for the development from climate change are discussed further in Section 4.1.4.

Table 4-4 OPW Climate Change Guidance

	MRFS	HEFS
Extreme Rainfall Depths	+20%	+30%
Flood Flows	+20%	+30%
Mean Sea Level Rise	+500mm	+1000m

4.1.5 Design Flood Events

The main design flood events on which the proposed development will be assessed are the 1% AEP fluvial/ 0.5% AEP tidal and the 0.1% AEP fluvial/tidal scenarios. These provide the Flood Zone A and B extents, and all finish level (Building FFLs) will be reference to these levels. Outside of the baseline events above the design will also be appraised against the potential impact of climate change and residual risks.

To ensure that the necessary fluvial and tidal boundaries have been applied a realistic combination of the upstream fluvial and downstream tidal models need to be determined. A joint probability analysis was undertaken as part of the FEM FRAM study which was based on the Defra/EA Joint Probability – Dependence Mapping and Best Practice (2006). To ensure consistency between the FEM FRAM study and the JBA modelling, the combined events have been sourced from the FEM FRAM hydrological report for the Mayne River system. See Table 4-5 for the combination of events which has been extracted FEM FRAM hydrological report (Table 8 pg57).

Table 4-5: Applied Combination Flood Event (AEP)

Design event (AEP)	Boundary Return Period (AEP)	
	Fluvial Boundary	Sea Level Boundary
50%	50%	50%
50%	50%	50%
20%	20%	50%
20%	50%	20%
10%	10%	50%
10%	50%	10%
4%	4%	50%
4%	50%	4%
2%	2%	50%
2%	50%	2%
1%	1%	20%
1%	20%	1%
0.50%	0.50%	10%
0.50%	10%	0.50%
0.10%	0.10%	2%
0.10%	2%	0.10%

Note: the table was converted from yearly return periods to AEP (%)

The following scenarios have been selected as the design events in the hydraulic model as part of the FRA to test both the fluvial and tidally dominated events.

1. Fluvial
    a. 1% AEP Fluvial + 5% AEP Tidal (Flood Zone A)
    b. 0.1% AEP Fluvial + 2% AEP Tidal (Flood Zone B)
2. Tidal
    a. 0.5% AEP Tidal + 10% AEP Fluvial (Flood Zone A)
    b. 0.1% AEP Tidal + 2% AEP Fluvial (Flood Zone B)

To assess the worst-case scenario, the peak of the fluvial event was set to match the peak tidal level, with two tidal cycles prior to the peak of the fluvial/tidal events. This ensures natural tidal storage is represented in the model prior to flood peak.

As previously stated, in addition to the above main design flood events, sensitivity scenarios will be undertaken to appraise the proposed design against the potential impact of climate change and the residual risk of sluice gate blockage.

4.2 Hydraulic Model

To provide a detailed assessment of flood risk at the site, a 1D-2D ESTRY-TUFLOW hydraulic model was constructed. It allows for the modelling of river channels, streams, floodplains and hydraulic structures to predict water levels for a range of scenarios (see Figure 4-2 for the hydraulic model structure). The hydraulic model was developed in the following stages:

- A 1D-2D ESTRY-TUFLOW model of the Mayne River created using a DTM and available surveyed data;
- The existing structures were inserted into the model based on survey and a baseline condition was established;
- Hydraulic simulations were run to derive the existing flood extents for the 1% and 0.1% AEP flood events;
- The post-development design has been assessed against a range of climate change scenarios (MRFS & HEFS);
- The blockage of the sluice gate downstream was tested to assess the residual risk for the site.

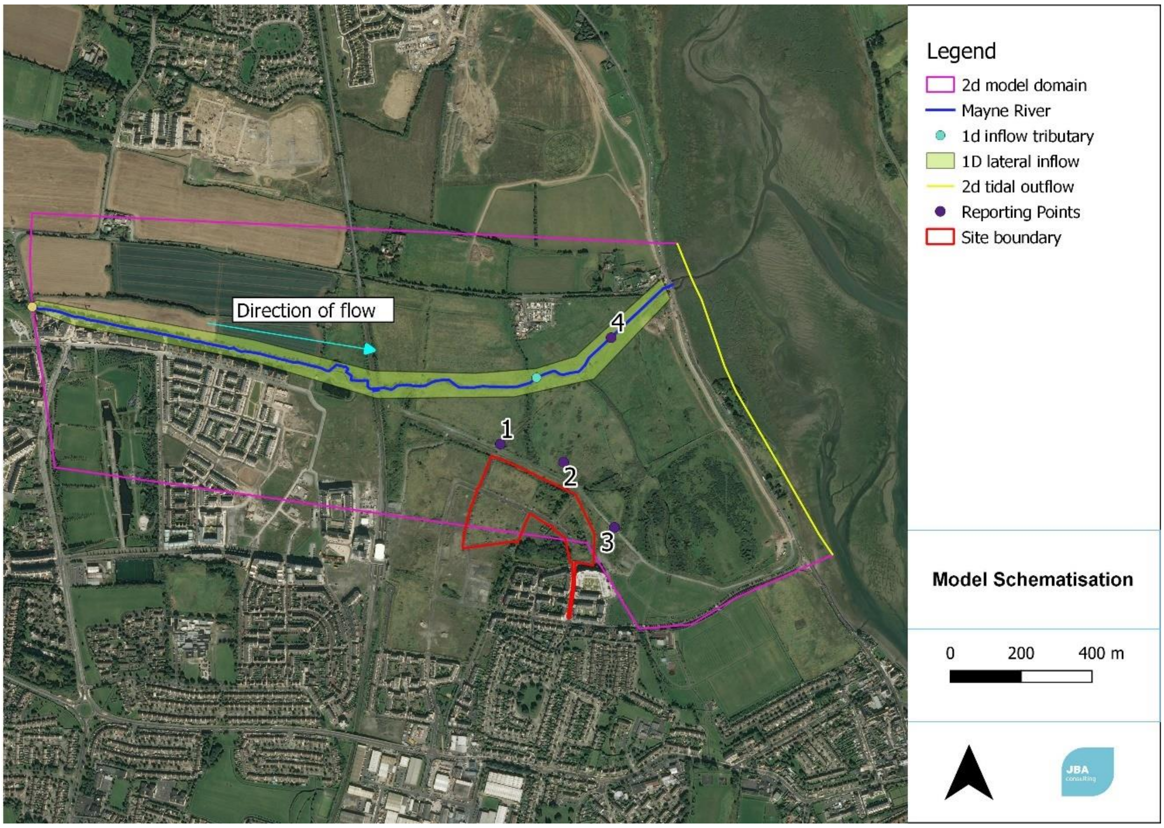


Figure 4-2: Model Schematisation

4.3 Model Results

4.3.1 Pre-Development Scenario

4.3.1.1 Fluvial events

The model results show the site is not impacted by fluvial inundation during both the 1% and 0.1% AEP fluvial flood events. The flood extents are presented in Figure 4-3 and flood levels in Table 4-6.

The main flood mechanism north of the site is flow conveyance rather than flood storage. Floodwaters overtop the riverbank downstream of the railway line and flow past the northern boundary of the site.

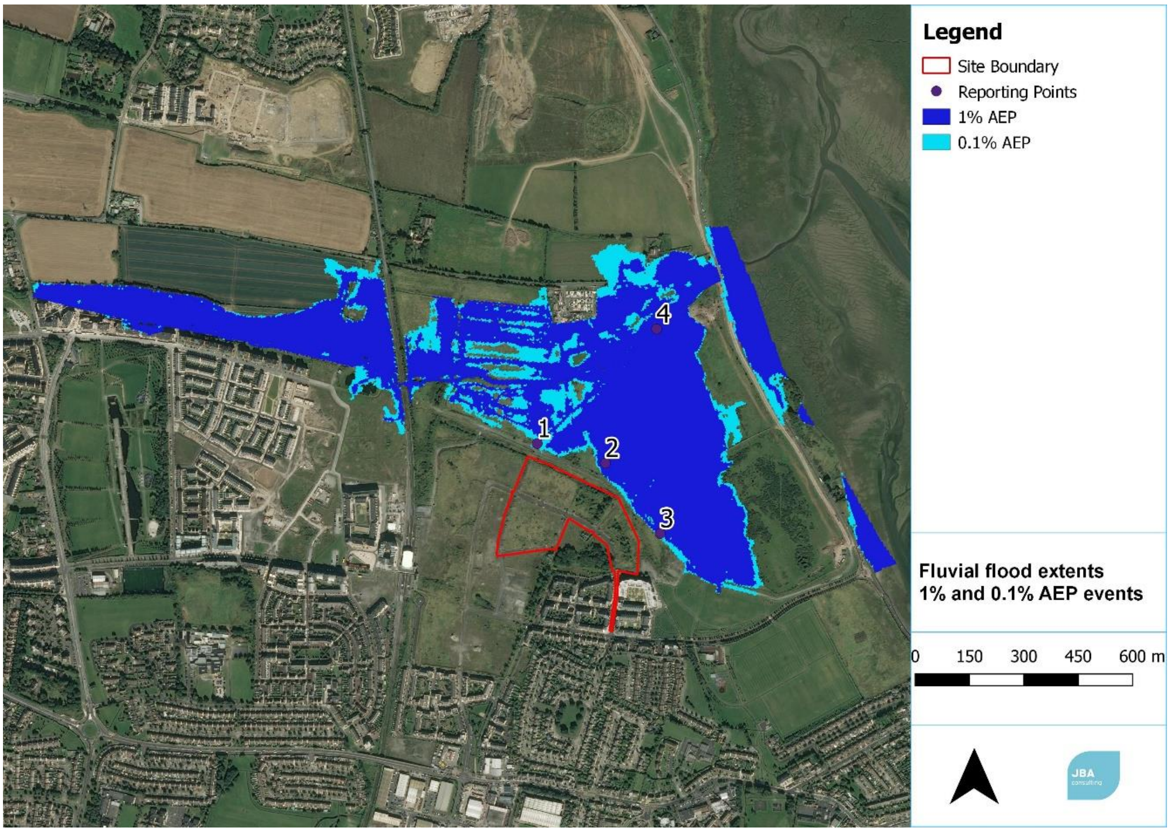


Figure 4-3: 1% and 0.1% AEP fluvial flood extents - pre-development scenario

Table 4-6: 1% and 0.1% AEP fluvial levels- pre-development scenario [mOD]

Reporting Point	Fluvial 1% AEP	Fluvial 0.1% AEP
1	2.63	2.93
2	2.57	2.93
3	2.57	2.93
4	2.57	2.93

4.3.1.2 Tidal events

The modelling results confirm that the site is not at flood risk during the 0.5% AEP and the 0.1% AEP tidal flood events. The flood extents are presented in Figure 4-4 and flood levels in Table 4-7.

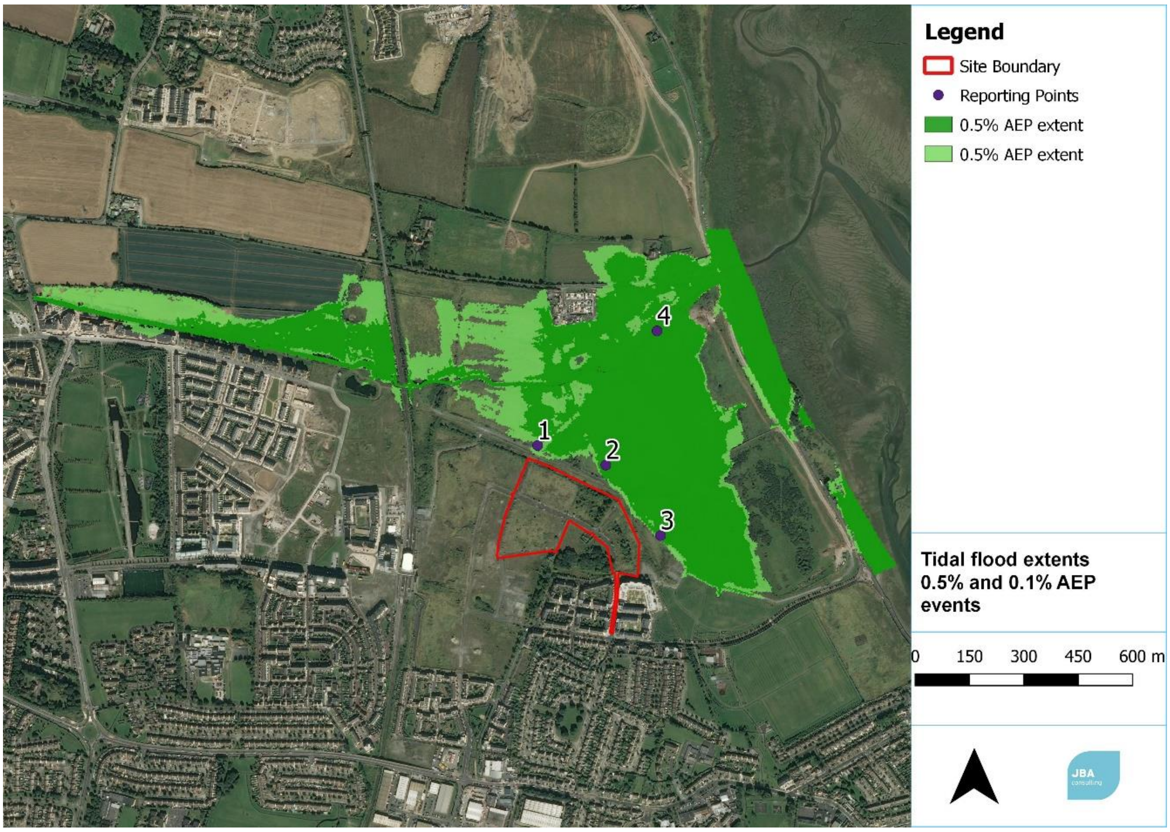


Figure 4-4: 0.5% and 0.1% AEP tidal flood extents - pre-development scenario

Table 4-7: 0.5% and 0.1% AEP tidal levels - pre-development scenario [mOD]

Reporting Point	Tidal 0.5% AEP	Tidal 0.1% AEP
1	2.66	3.15
2	2.66	3.15
3	2.66	3.16
4	2.66	3.13

4.3.2 Post-Development Scenario

A number of flood events have been developed and analysed at the site including a range of pluvial and tidal events. It is important to identify the dominant flood event at the site to guide the development of mitigation measures. For the identification of the Flood Zone A & B onsite, the fluvial 1% AEP and 0.1% AEP events produce the wider flood extents adjacent at the site, when compared to the tidal events. Therefore, Flood Zone A & B delineation is solely based on the fluvial events.

All the relevant flood maps are presented in Appendix C.2. The site is located in Flood Zone C and is appropriate for residential development.

The peak flood levels bordering the site are produced by the climate change (HEFS) scenarios and specifically by the tidal HEFS events. As can be seen in Figure 4-5 below, during the baseline tidal event tidal waters are retained within the estuary by the Coast Road. The volume of floodwaters entering the parklands area is controlled by the elevation along Coast Road. The flood levels are presented in Table 4-8 with the corresponding reporting point 4.

The HEFS event (climate change analysis) requires the addition of 1m above the baseline levels, which also has the effect of lengthening the duration when flood levels are above the Coast Road. This results in a considerably larger volume of tidal waters entering the park land area up the site.

A range of flood levels and profiles for various events are provided in Figure 4-5 and Table 4-8 . As shown in Figure 4-5, the 0.1% AEP HEFS flood event produced the highest flood levels adjacent to the site. The flood level is also consistent across the entire parkland which confirms that the Coast Road has no impact on flood levels during this event. The same can be stated for the duration of the flood event and operation of the sluice gate as the peak flood level recorded adjacent to the site equals the tidal level within the Baldoyle Estuary.

Table 4-8: Water levels [mOD]

Reporting Point	Fluvial 1% AEP	Fluvial 0.1% AEP	Fluvial 1% AEP HEFS	Fluvial 0.1% AEP HEFS	Tidal 0.5% AEP HEFS	Tidal 0.1% AEP HEFS
4	2.57	2.93	2.92	3.11	4.20	**4.42**

Note: Figure 4-5 is intended to highlight the impact of the Coast Road on flood extents through the site. The lowest FFL of the residential buildings is 6.20mOD, which provides a freeboard of 1.78m above the tidal 0.1% HEFS flood event. This event produces the highest flood level in the vicinity of the site.

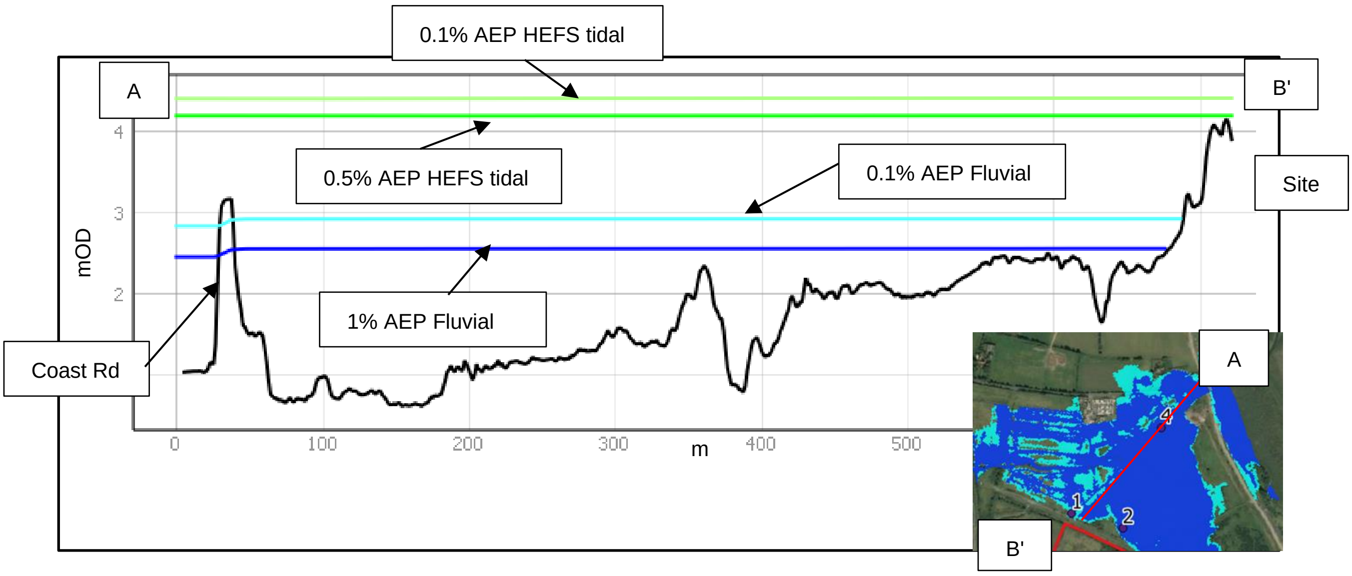


Figure 4-5: Comparison of Flood Levels

5 Flood Risk Assessment

5.1 Flood Risk

From reviewing the available sources of flooding outlined in Section 3, all of the site is located in Flood Zone C. Refer to Appendix C.1 for the flood map.

The aim of the FRA is to ensure that all residential properties are located in Flood Zone C and protected from inundation with an appropriate freeboard, and to ensure no impact from climate change or residual risks.

As outlined in Section 4.3.2, the design event selected to guide the mitigation measures is the 0.1% AEP HEFS tidal event. As noted, during the maximum flood extent, it is not impacted by the elevations along the Coast Road (sluice gate/tidal lock/ event duration etc).

5.2 Mitigation

5.2.1 Finished Floor Levels

As per the Fingal SFRA requirements it is necessary to place residential areas 0.5m above the 0.1% AEP flood event, which equates to 3.66mOD in accordance with the FRA guidelines. The provided minimum residential FFL for the site is 6.2mOD which provides a freeboard of 3.16m above the 0.1% AEP tidal event (3.04mOD).

5.2.2 Access

The primary access route onto the development is from the southern boundary of the site which is connected to the existing road network. The site access is situated within Flood Zone C and therefore access to the site can be maintained during a flood event.

5.3 Climate Change

In accordance with the OPW guidelines, it is necessary to assess the risk associated with climate change. The site has been assessed in accordance to the High End Future Scenario (HEFS) for both fluvial and tidal events, as presented in Table 4-4.

The flood extents for the tidal and fluvial (HEFS) are presented in Appendix C.2. Review of the flood maps confirm that the residential properties are not at risk of inundation from any event including the tidal 0.1% AEP HEFS flood event. Based on the provided FFL of 6.2mOD, a freeboard of 1.79m has been provided above the tidal 0.1% AEP HEFS tidal event (4.41mOD).

Table 5-1: Water levels [mOD] - Climate Change (HEFS) Scenario

Reporting Point	Tidal 0.5% AEP HEFS	Tidal 0.1% AEP HEFS	Fluvial 1% AEP HEFS	Fluvial 0.1% AEP HEFS
+1	4.20	4.42	2.93	3.11
2	4.20	4.41	2.92	3.11
3	4.20	4.41	2.92	3.11
4	4.20	4.41	2.92	3.11

5.3.1 Stormwater design/Fluvial Flooding

A stormwater system is provided onsite to manage fluvial/surface water flows onsite. Refer to the Civil Engineer drawings provided in the application for the detailed design layout.

In accordance with the LAP, no stormwater attenuation has been provided due to the close proximity to the Baldoyle Estuary. The surface water will discharge to the regional wetland north of the site. The volume of the stormwater discharge is minimal in comparsion to the predicred floodwaters during a fluvial/tidal flood events, and furthermore there are no sensitive receptors within the wetland that would be impacted by any minimal increase in stormwater flows. SUDS measures have been incorporated into the proposed design.

Localised pluvial flooding has been identified onsite that corresponds with localised depressions and does not present a flood risk to the development. The proposed stormwater system will manage surface water within the site boundary post development. To further protect against fluvial flooding, a threshold of 150mm is recommended between the FFL and surrounding hardstanding areas.

5.4 Basement

The lowest basement entrance level has been set at 4.65mOD and there is no unsealed openings below this level. The lowest basement FFL has been set at 2.9mOD. With reference to the LAP, the basement entrance level needs to be places at least 0.5m above the 0.5% AEP tidal event (2.66mOD) which has been provided. The access level for the basement (4.65mOD) provides a freeboard of 0.23m above the tidal 0.1% AEP HEFS flood level (4.42mOD), which is the highest predicted flood level. Therefore the flood risk has been minimuise to the basement level.

To avoid potential flooding, basements should be sealed below this level (4.65mO) to comply with Objective FRM4 of the Baldoyle-Stapolin LAP.

5.5 Residual Risk

Residual risks are defined as risks that remain after all risk avoidance, substitution and mitigation measures have been taken. The flood risk assessment identifies the following as the main sources of residual risk to the proposed development as the blockage of the sluice gate.

A scenario has been developed to appraise the potential impact on the development following a blockage of the sluice gate during the 0.1% AEP fluvial flood event. The resulting 0.1% AEP flood level under the blockage scenario is 3.10mOD. This is below the provided FFL of 6.2mOD, therfore the development will not be impacted during the identifed residual risk scenario. Refer to Appendix D for the resulting flood map.

6 Conclusion

It is proposed to develop a residential development identified as Phase 5 in Baldoyle GA2, Co. Dublin. The scheme forms a continuation of existing residential development to the south. The site is currently classified as greenfield.

The River Mayne is the main river waterbody in the study area and is tidally influenced. The Baldoyle Estuary is located to the east of the site.

Review of the historic flood information does not provide any evidence of flooding at the site. The nearest flood event is situated along Coast Road, 600m east of the site.

Review of the FEM FRAM predictive flood maps confirms that site is not at risk of flooding and is fully located in Flood Zone C.

A site specific flood model has been developed that modelled a range of fluvial and tidal events, including residual risks. The results confirm that the proposed development is not at risk of inundation from the modelled flood events and further confirms that the site is in Flood Zone C.

The main design event selected is the 0.1% AEP HEFS tidal event as the HEFS tidal events provide the maximum flood levels onsite and significantly higher than the fluvial equivalent. The tidal HEFS levels are not impacted by the River Mayne sluice gates, Coast Road elevation or flood duration.

Outside of the main flood events, the site has also been assessed for the potential impacts of climate change and residual risks. As part of the climate change assessment, a 30% increase in fluvial flows and 1m in tidal levels have been incorporated into the 1%/0.5% and 0.1% AEP events respectively. The results confirm that the proposed residential development will not be impacted from any of the modelled flood events up to the 0.1% AEP HEFS tidal scenario.

The provided minimum FFL onsite is 6.2mOD which proivdes a freeboard of 1.79m over the 0.1% AEP HEFS tidal flood event, which produces the highet flood level adjacent to the site. This FFL also protects the development from all modelled flood events, including climate change and residual risks.

Considering the above, the Flood Risk Assessment was undertaken in accordance with 'The Planning System and Flood Risk Management' guidelines. The FRA is in agreement with the core principles contained within the Planning Guidelines.

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

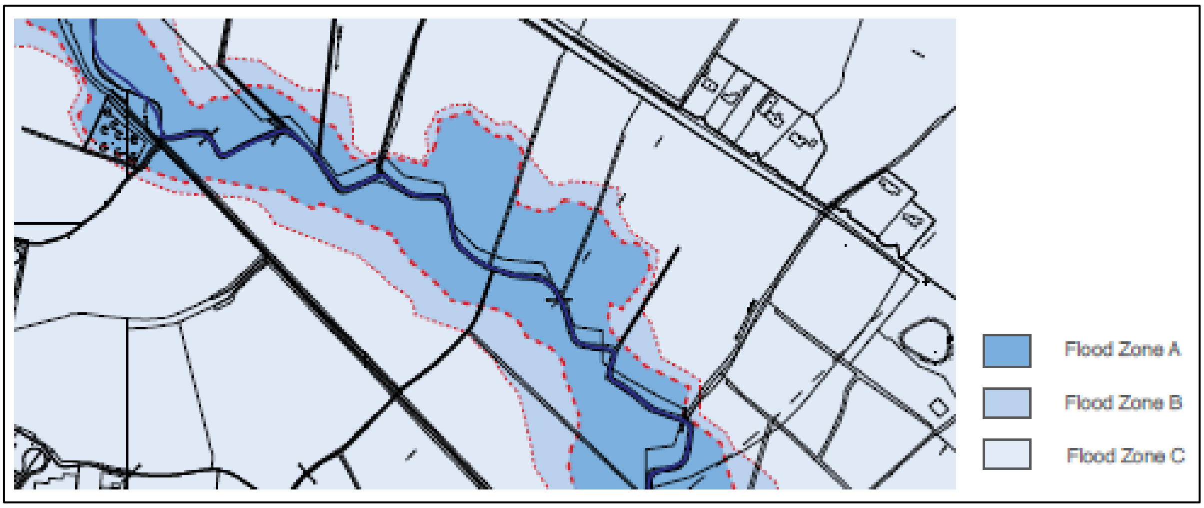
Return period (years)	Annual exceedance probability (%)
2	50
10	10
50	2
100	1
200	0.5
1000	0.1

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

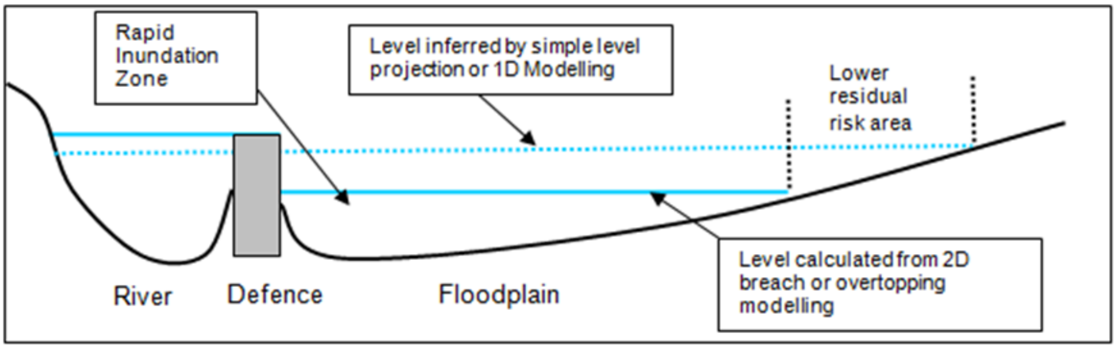
Consequences of flooding depend on the Hazards caused by flooding (depth of water, speed of flow. Rate of onset, duration, wave-action effects, water quality) and the vulnerability of receptors (type of development, nature, e.g., age-structure of the population, presence and reliability of mitigation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

The 'Planning System and Flood Risk Management' provides three vulnerability categories, based on type of development, nature, which are detailed in the FRA 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, such as changing rooms.

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 Appendix - Hydrology Check File

Flood estimation report: 2021s1085 Baldoyle Phase 5 FRA

Approval

	Name and qualifications	Date
Method statement prepared by:	Hannah Moore B.A. mod MSc	22/09/2020
Method statement reviewed by:	Tom Sampson BSc MSc FRGS C.WEM MCIWEM	
Calculations prepared by:	Hannah Moore B.A. mod MSc	22/09/2020
Calculations reviewed by:	Tom Sampson BSc MSc FRGS C.WEM MCIWEM	

Revision History

Revision Ref/Date	Amendments	Issued to
P01.01/ 01/09/2020	First issue for review	Tom Sampson
P01.02/ 22/09/2020	Updates following review and feedback from hydraulic modelling team	Tom Sampson

Contents

Abbreviations

AMAX ....Annual Maximum

AREA ....Catchment area (km^2)

BFI ....Base Flow Index

BFIsoil......................Base Flow Index based on soil type

CFMP ....Catchment Flood Management Plan

CFRAM ....Catchment Flood Risk Assessment and Management

FARL........................FEH index of flood attenuation due to reservoirs and lakes

FEH ....Flood Estimation Handbook

FSR ....Flood Studies Report

QMED ....Median Annual Flood (with return period 2 years)

SAAR ....Standard Average Annual Rainfall (mm)

SPR ....Standard percentage runoff

Tp(0) ....Time to peak of the instantaneous unit hydrograph

URBEXT....................FEH index of fractional urban extent

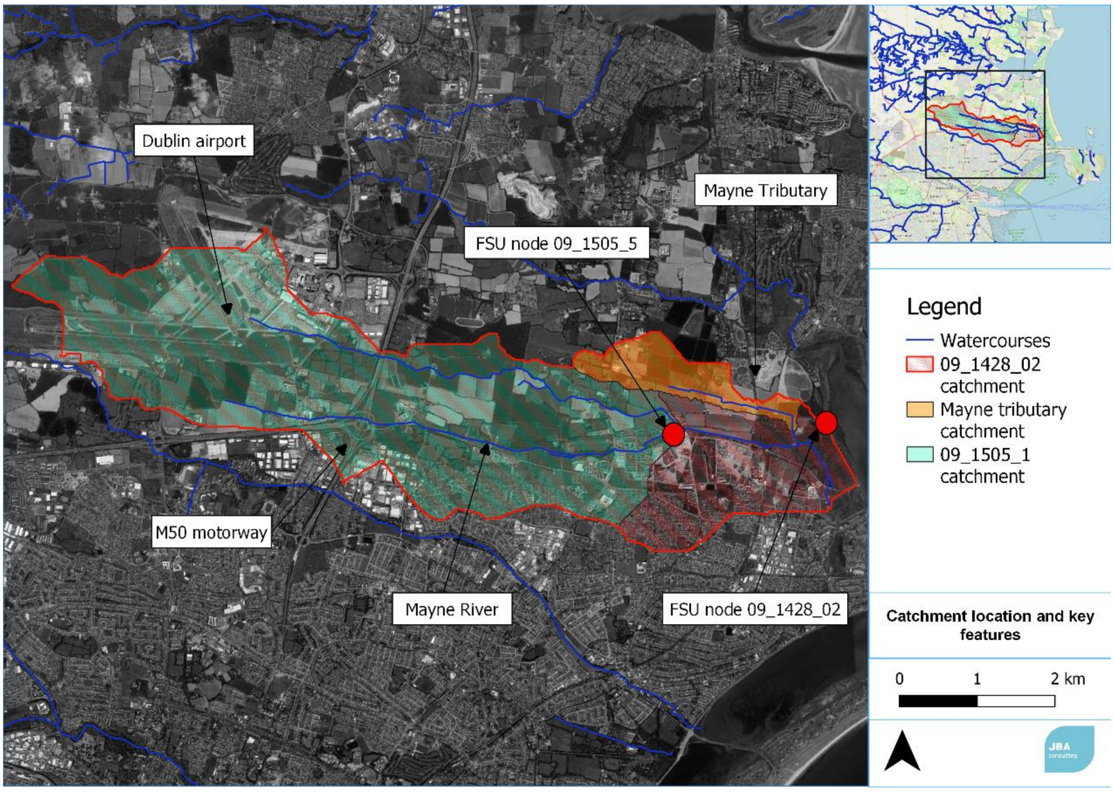
1 Method statement

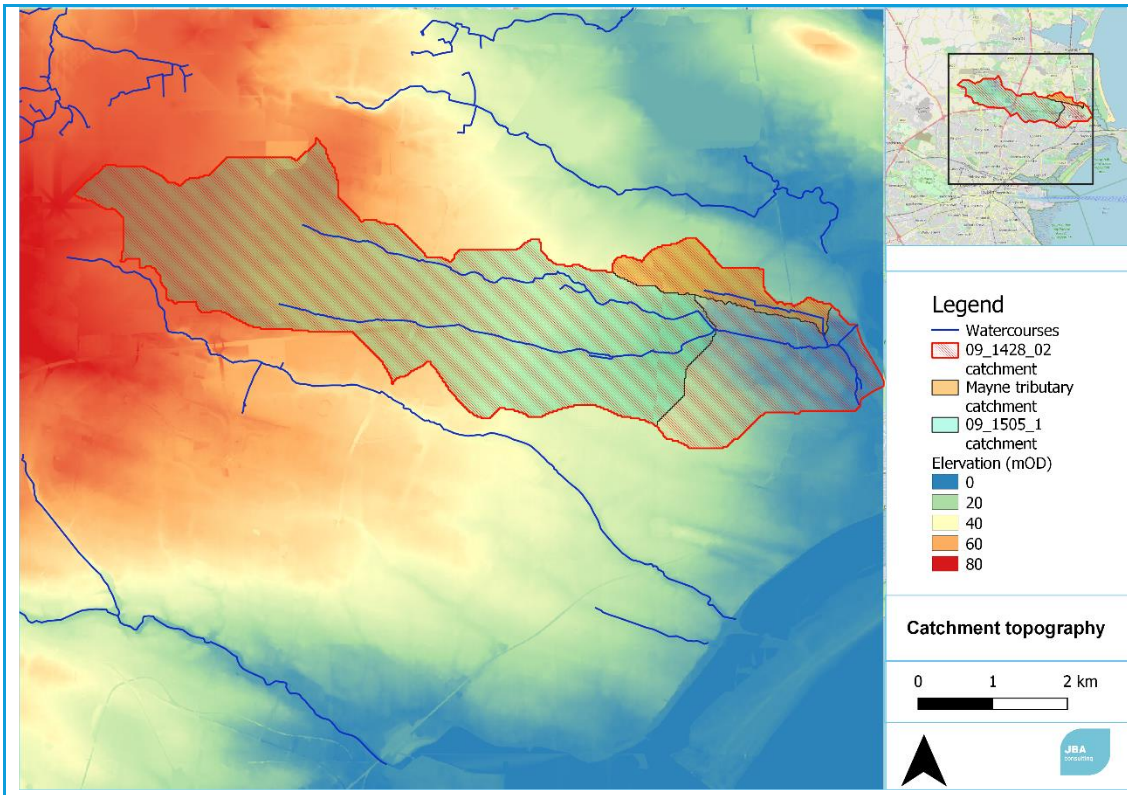
1.1 Requirements for flood estimates

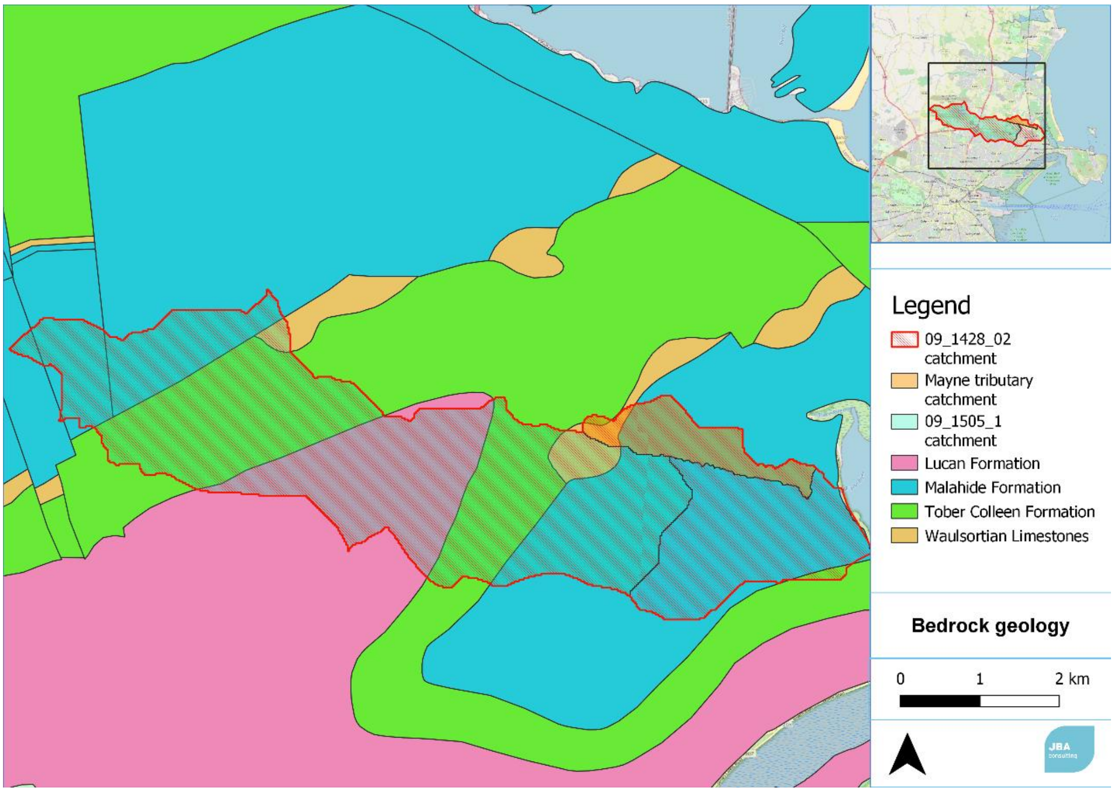
Overview • Purpose of study • Point or catchment flood estimates? • Peak flows or hydrographs? • Range of return periods	Aim of project – flood risk assessment for cut and infill of land within FZ B/C to ensure no adverse impacts. Peak flows required for the 1% and 0.1% AEP events.

1.2 The catchment

Map **(Include river network, catchment boundary and gauging stations)**







Description Include topography, climate, geology, soils, land use and any unusual features that may affect the flood hydrology.	Topography: Catchments slope from west to east at a reasonable gradient with the lowest point near where the river flows into the Baldoyle estuary. Geology and soils: The catchments are situated on a number of geological formations. The formations largely consist of various types of limestone with minor conglomerates and shales. The soil is classified as low indicating that the catchments is poorly draining. Features: The M50 motorway and a railway line cut through

	the 09_1428_02 and 09_1505_1 catchments creating manmade hydrological boundaries. These will impact the movement of flow and will not be taken into consideration in the natural catchment flow estimation methods but may be critical in understanding the storage and response of the catchment. It is also noted a large part of the catchment is urbanised.

1.3 Gauging stations (flow or level)

Water-course	Station name	Gauging authority number	Gauging Authority	Catchment area (km²)	Type (rated / ultrasonic / level…)	Record length
Mayne	Hole in the wall	08006	EPA		Staff gauge	1977 - 1987

1.4 Data available at each flow gauging station

Station name	Start and end of FSU portal flood peak record	Update for this study? (CFRAM or latest data)	OK for QMED?	OK for pooling?	Data quality check needed?	Other comments on station and flow data quality
Hole in the wall	Not included	NA	NA	NA	Yes	See extract from FEM FRAMS hydrology report detailing the gauge. Large amount of uncertainty for a limited record length. Also noted that the area has gone through a considerable amount of urbanisation since gauge record finished so flows unlikely to be representative of current catchment.

Station 08006 Hole in the Wall on the Mayne River consists of approximately 10 years of hydrometric data, i.e., from 09/03/1977 to 01/03/1987. The data consists of several gaps in the years 1977, 1985, 1986 and 1987. The zero datum at the gauge changed four times in 1977, three times in 1978 and one time in 1981 whereas the rating equation changed seven times in the ten years. The station was also not included in the OPW review of gauging stations (Hydro-Logic, 2006) and hence the high flow rating quality of this station was unknown. Therefore the data was not further analysed and not included in the hydrological analysis. However, this station is considered to provide valuable information for the calibration of the hydraulic model of the Mayne River in the future. According to the 'FCC Report on Fingal Hydrometric Stations', the old station at the Hole in the Wall Road is to be renewed subject to funding being made available. It is therefore recommended the reinstallation of the Station 08006 Hole in the Wall Road on a priority basis so that the existing (with rating review) and future hydrometric data at this station could provide useful information for the forecasting of flood flows in the Mayne River.

Extract taken from the FEM FRAMS hydrology report (pg. 9)

1.5 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data	Details
Historic flood data Include chronology and interpretation of flood history in Annex or separate report.	Yes	Yes	Floodinfo.ie	Records of flooding occurring within area surrounding the site from multiple sources (pluvial and fluvial)
CFRAM study method & outputs	Yes	Yes	Floodinfo.ie and FEM FRAMS documents	Hydrology and hydraulics information available for the area as modelled under FEM FRAMS (pilot CFRAM study)
Results from other previous studies	Yes	Yes	Floodinfo.ie and FEM FRAMS documents	Hydrology and hydraulics information available for the area as modelled under FEM FRAMS (pilot CFRAM study)

1.6 Hydrological understanding of catchment

Hydrological interpretation Catchment processes, response time, propagation of flood, contributions from tributaries	From an initial examination of the catchment features the response of the watercourses is expected to be flashy. Runoff entering the watercourses in the upper reaches moves quickly through the system due to the slope. The low soil permeability also potentially increases the amount of runoff within the catchment particularly in prolonged wet periods. The influence of the manmade hydrological barriers is not fully known however they will impact how, when, and where the flow is stored and discharged into the system. The downstream boundary of the system is tidal however the impact of this on flows is regulated and controlled by an existing sluice gate structure.

Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	Site is located along the Mayne River within the wider flood plain area close to where the river flows into the Irish sea. There is a sluice gate at the outflow of the river into the Baldoyle estuary which controls the tidal influence in the channel.
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20%	Railway and M50 motorway cut across catchments creating hydrological barriers potentially altering where flow enters the system.

• highly urbanised – seek local flow data; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully • Karst groundwater • Catchment change • Arterial Drainage / Drainage District	

1.7 Initial choice of approach

Is FSU appropriate? (it may not be for extremely heavily urbanised or complex catchments) If not, describe other methods to be used.	Area of the Mayne river catchments is such that it is worth considering FSU (19km2, 14.9km2) as well as FSU small catchments. Only FSU small catchments considered for Mayne tributary due to its size.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	FSU, FSU small catchments, initial approach is to estimate single point inflow, may consider point and lateral flow after examination with hydraulic model
Software to be used (with version numbers)	FSU Portal / JSpeed / JBA's Flood Estimation Software (JFes) v.8

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

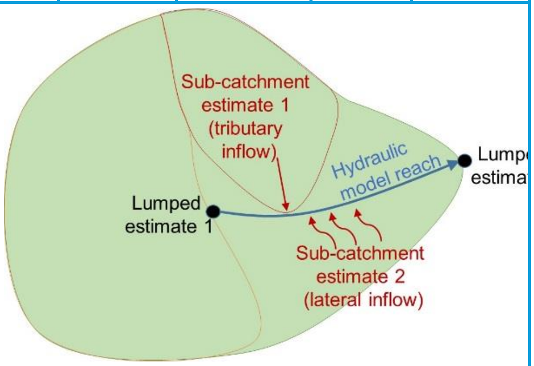
2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA (km^2)	Revised AREA if altered
09_1428_02	L	Mayne					
09_1505_1	L	Mayne					
Mayne trib	S	Mayne Tributary					

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Descriptor	09_1505_1	09_1428_02	Mayne Tributary
Centroid X	242090	241940	-
Centroid Y	317780	318770	-
Area	14.90	19.76	1.29
SAAR	714.24	709.38	711.63
FARL	1.00	1.00	1.00
BFI Soil	0.56	0.57	0.56
URBEXT	0.39	0.35	0.01
MSL	6.34	8.52	2.13
S1085	7.89	7.17	4.69
Stream Frequency	7.00	11.00	1.85
DrainD	0.89	0.85	1.00
ArtDrain2	0.00	0.00	0.00
Soil (number)	2.00	2.00	2.00
SMDBAR	7.00	7.00	7.00
M5-2day	56.96	57.02	56.20
M5-1day	44.23	48.32	47.60

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)	A visual check of the catchment boundaries using the Ireland aligned DTM data was also done. An additional 0.2km2 was added to the catchment area from the original FSU catchment of node 09_1428_02 to account for the fact that an area at the downstream boundary of the watercourse likely drains into the catchment and not the estuary. The Mayne tributary is not included in the FSU database so a catchment was derived using GIS tools.
Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	Catchment descriptors were sourced from FSU database for ungauged node 09_1428_02 and 09_1505_1. A visual inspection of the descriptors was carried out to ensure no odd or unrealistic values were being used to describe the catchment. The descriptors for the Mayne Tributary were derived from first principles and referring to the values from near by FSU nodes
Source of URBEXT	FSU database

3 FSU Statistical method

3.1 Overview of estimation of QMED at subject site

3.1.1 Ungauged QMED estimation

Number	09_1428_02	09_1505_1
Catchment area (km2)	19.57	14.90
Qmed (rural) m^3/s	2.42	1.98
Urban Adjustment Factor	1.55	1.64
Qmed (urban) m^3/s	3.78	3.25
Qmed (small catchments) m^3/s	2.15	1.75

3.2 Data transfer for QMED estimation

Table 3-1. Pivotal gauge options

	Pivotal option A	Pivotal option B	Pivotal option C
Name	Kinsaley Hall	Ballyboghill	Naul
Number	08005	08012	08002
FSU gauge quality ranking	A2	B	A1
Catchment area (km2)	9.17	25.95	33.43
Qmed gauged m3/s	2.49	4.35	5.41
Qmed(rural) m3/s	1.31	4.17	3.78
On same watercourse as subject site (Y/N)	N	N	N
In same catchment as subject site (Y/N)	N	N	N
Hydrological similarity to ungauged location	0.70	0.81	0.80
URBEXT	0.25	0.01	0.01
Any other catchment features (e.g. Arterial Drainage)	Weir removed in 1983	-	-
Gauge type	Weir	Weir	Weir
Operator	EPA	EPA	EPA
Status	Active	Inactive	Active
Reasons for choosing or dismissing	Closest gauge to watercourse, hydrologically similar	B ranked gauge indicating data not highest quality	Gauge at a distance from subject site and has significantly lower URBEXT value which is critical for this catchment

3.2.1 Discussion on gauge data, data transfer and pivotal sites

An investigation of the potential use of a pivotal gauge to further refine the Qmed values estimated using real gauge data was carried out. As the two watercourses are so close to each other a single pivotal gauge will be used for the two watercourses. A list of potential pivotal gauges for the ungauged sites was sourced from the OPW FSU database which includes all reviewed gauges Ireland. Table 3-1 summarises the pivotal site short list.

Of the shortlisted gauges one is a B ranked gauge indicating the data provided is of lesser quality - the Ballyboghill gauge. This gauge is discounted from consideration due to its data quality.

From the remaining gauges the Naul gauge has an A1 data ranking. Comparing the Naul and Kinsaley Hall gauges the Naul gauge has higher quality data but is located at a larger distance from the watercourses considered and has different catchment characteristics such as area and URBEXT. The Kinsaley Hall gauged catchment is close to the watercourses considered and has more similar catchment characteristics and is recommended for use as the pivotal gauge.

Refer to Figure 3-1 for the location of the Kinsaley Hall gauge. Figure 3-2 shows the AMAX series for the gauge. The Kinsaley Hall was an active gauge between 1977 and 2001, two AMAX records for the gauge are available - one from the OPW FSU site (1983-2000) and the second from the EPA hydronet website (1977-2001). With regards to the EPA data although the record is longer there were several changes to the gauge (e.g. weir removal) that occurred prior to 1983. To ensure consistency within the gauge records and rating curve applied it is recommended that the data prior to 1983 not be used in analysis.

Figure 3-1 compares the two AMAX records available. There are notable differences in the peak flows recorded from both data sets. Review of the data sets revealed that different rating curves must have been applied to the recorded water levels. There are no records of any rating review or the actual rating curve used in the OPW FSU data. It was also noted that the AMAX recorded of water levels recorded differed for each data set, there is no information as to why the water levels recorded differ.

It was decided that the EPA AMAX from 1983-2001 be used for analysis because:

- The EPA oversaw the gauge when it was operational;
- There is no information as to how the OPW data was sourced or the rating curve applied to the data;
- The rating curve and full data record is available from the EPA and a clear trail of data collection and application can be seen through the AMAX series and is therefore considered a more reliable data source;
- The EPA data was used in the FEM FRAM study which is the most up to date assessment of the watercourse and flood risk for the area.

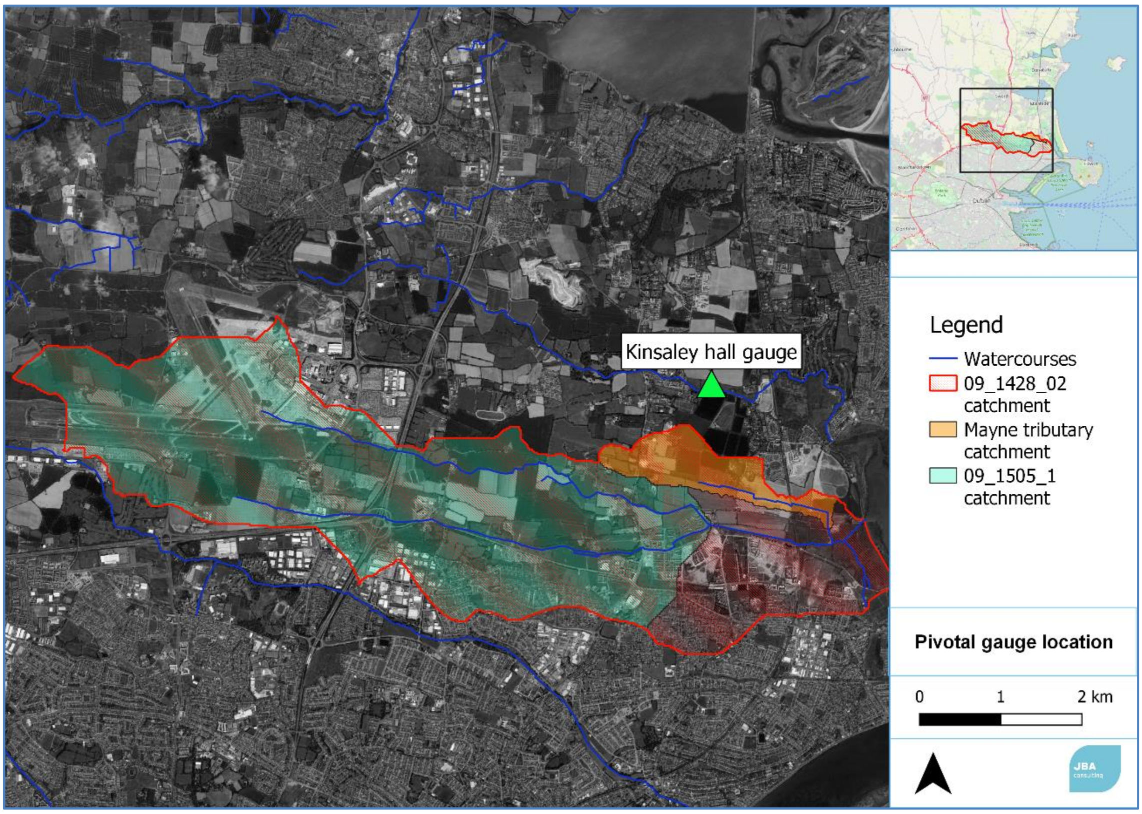


Figure 3-1: Pivotal gauge location

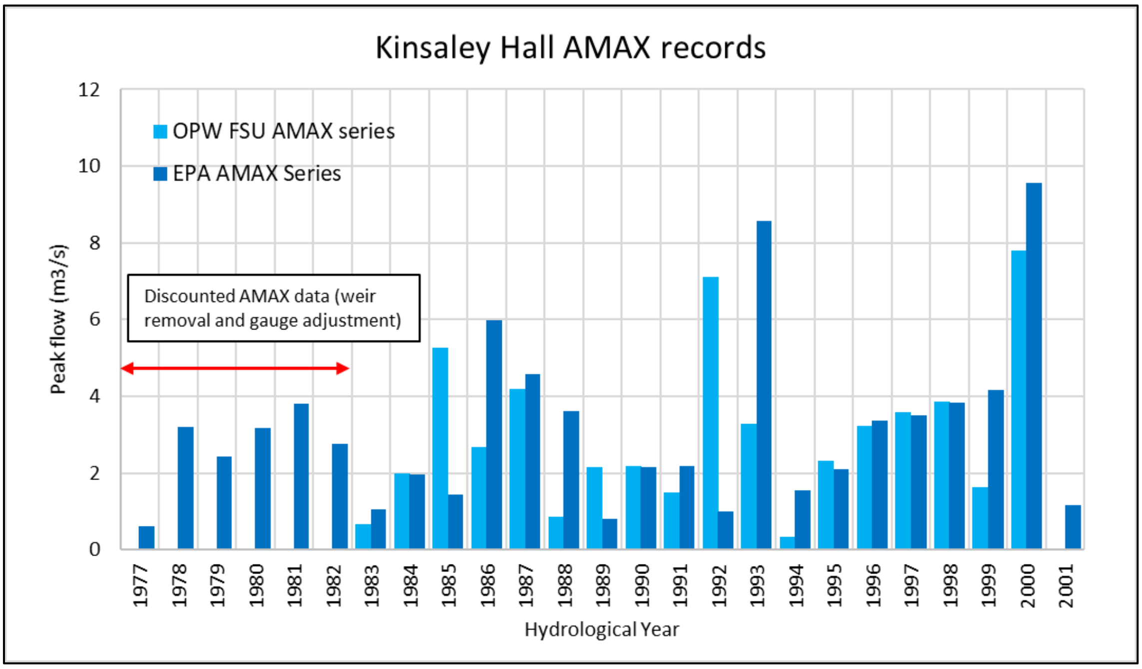


Figure 3-2: Kinsaley Hall AMAX records

The gauged Qmed value from the Kinsaley Hall EPA AMAX series is recorded as 2.76m3/s while the AMAX Qmed (Qmed Stat) for the data set is 1.62m3/s. The gauged Qmed value from the OPW AMAX data was 2.50m3/s.

As part of ECFRAM study the Kinsaley Hall gauge on the Sluice River (08005) was assessed and underwent a rating review. The FEM FRAMs have calculated a Qmed of 3.17m^3/s for the gauge. This was increased from the EPA rating of 2.76m^3/s. The rating review was undertaken by building an ISIS model of the Sluice River and calibrated with the historic flow data. The ISIS model provided a rating curve at the cross-section. The review found that below 2.60m3/s the ISIS curve underestimated flows therefore, the EPA curve was used for flows <2.60m3/s while the ISIS rating curve used on the higher flows (refer to Figure 3-2).

The adjusted rating curve has been based on the ISIS model developed for the Sluice River, with the aim of replicating the recorded water levels and associated flows. The gauge is located downstream of a culvert system. The details of the rating review have not been provided but based on the approach undertaken. Accepting that this rating review was undertaken by competent personnel, who would be tasked with undertaking an exercise of this type, it was decided to incorporate the Qmed value of 3.17m3/s into the final design flows.

Table 3-2: Rating equations for the Kinsaley Hall gauge

Rating Equation in the form: $Q(h) = C*(h+a)^b$						
Section	Min stage (m)	Max stage(m)	C	a	b	Rating curve
1	0.161	0.190	65689900	0	12.95	EPA
2	0.190	0.287	72.42	0	4.68	EPA
3	0.287	0.550	4.04	0	2.37	EPA
4	0.550	0.770	3.50	0	2.0	HB
5	0.770	0.950	5.25	0	3.70	HB
6	0.950	1.200	4.75	0	1.95	HB
7	1.200	1.500	3.70	0	3.10	HB

Therefore, the pivotal gauge with updated FEM FRAMS Qmed and rating curve will be used to calculated adjusted Qmed for the statistical methods used. Table 3-3 compares the gauged and ungauged catchments.

Table 3-3. Pivotal sites chosen and QMED adjustment factors

Descriptor	09_1428_02	09_1505_1	Pivotal site
Area	19.52	14.90	9.17
SAAR	709.38	714.24	710.76
FARL	1.00	1.00	1.00
BFI Soil	0.57	0.56	0.52
URBEXT	0.35	0.39	0.25
S1085	7.17	7.89	6.89
DrainD	0.85	0.89	0.91
ArtDrain2	0.00	0.00	0.00
FSU Gauge ranking	-	-	A2
Hydrological similarity	-	-	0.70
FSU record	-	-	1983 – 2019
Qmed(rural) m3/s	2.42	1.98	1.31
Qmed (URBEXT) m3/s	3.76	3.25	1.83
Qmed(gauged) m3/s	-	-	3.17
Qmed stat	-	-	1.62
Adjustment factor	-	-	1.71
Adjusted Qmed m3/s	6.42	5.55	-
FINAL SELECTED QMED m3/s	6.42	5.55	-

3.3 Growth Curves

3.3.1 Single site analysis

A single site analysis can be carried out on the Kinsaley Hall gauges to estimate the peak flows for the site. The EPA AMAX series data with the updated FEM FRAMS rating curve from 1983-2001 was used for the analysis. The inhouse AMAX analysis software package JSpeed was used to carry out the analysis. Refer to Table 3-4 for peak flow estimates and Figure 3-3 for the AMAX plot. An Extreme Value type 1 (EV1) distribution was used for analysis as it best fit the AMAX data.

Table 3-4: Single site peak flow estimates - Sluice River

AEP event (%)	Growth curve
50%	1.00
20%	1.84
10%	2.41
5%	2.94
2%	3.63
1%	4.16
0.1%	5.87

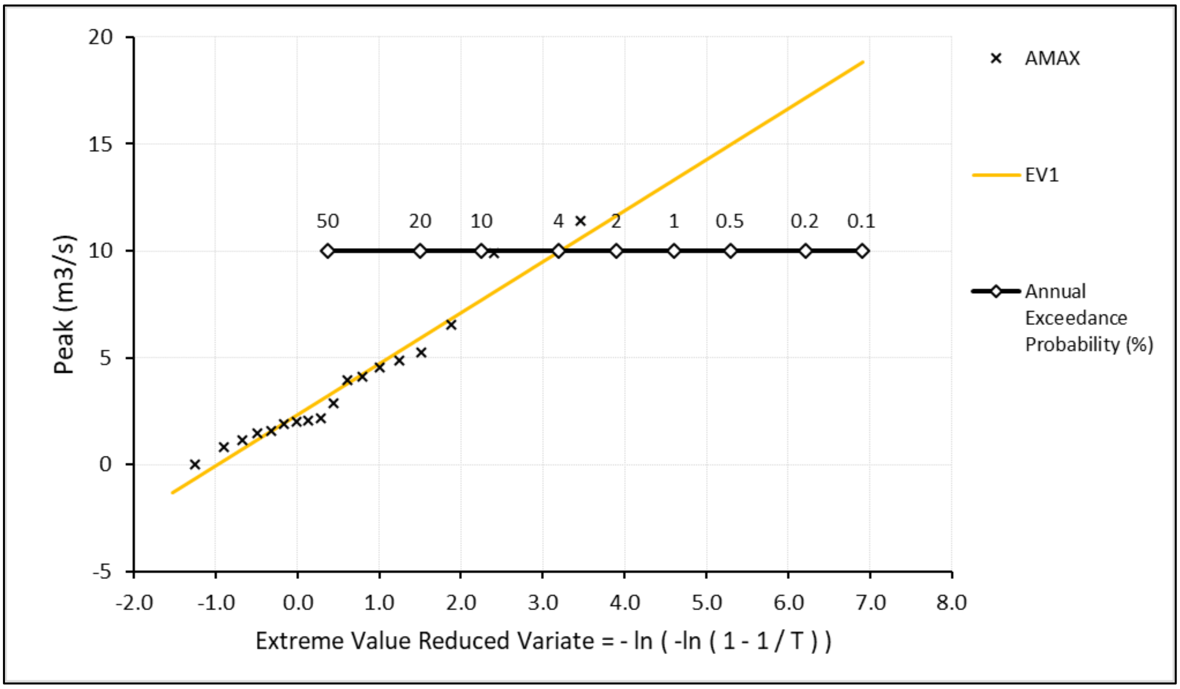


Figure 3-3: JSpeed single site analysis growth curve - Sluice River

3.3.2 Derivation of pooling groups

Refer to Appendix A.1 for more detail of the site specific pooling group derived.

Table 3-5. Pooling group details

Name of group	No. of pooled years	No. of stations	Changes made to default pooling group, with reasons	Distribution	Shape	Scale
Mayne River	539	16	Review of pooling group found no changes necessary	GEV	0.035	0.31

3.3.3 Discussion on growth curves

Table 3-6 compares the growth curves derived with the FEM FRAMS hydrology report growth curve. What is apparent from the table is that the single site and FEM FRAMS curves are extremely steep which is generally associated with steep sloped catchments. While the catchment has a slope, it is not overly steep, and a large proportion of the catchment is located within a flat low-lying area particularly at the lower end of the catchment. Based on this the upper portions of the single site and FEM FRAMS growth curves are not considered representative or appropriate to use for higher flow estimation however given that the single site analysis growth curve is based on real data and has a data quality ranking that gives confidence in lower return period estimations it is proposed that this data also be incorporated into the growth curve selected. To ensure that a comprehensive approach is undertaken in the estimation of the growth curves, it has been decided to combine the single site analysis and FSU pooled growth curve values to be weighed 20% to the single site analysis and 80% to the FSU growth curve.

Table 3-6: Growth curve comparison

AEP (%)	Single site – Kinsaley Hall	FSU growth curve	FEM FRAMS growth curve (pg. 30 of FEM FRAMS hydrology report)	Weighted growth curve
50%	1.00	1.00	1.00	1.00
20%	1.84	1.35	1.52	1.45
10%	2.41	1.57	1.89	1.74
4%	2.94	1.84	2.38	2.06
2%	3.63	2.03	2.76	2.35
1%	4.16	2.22	3.16	2.61
0.1%	5.87	2.82	4.60	3.43

3.4 Final flow estimates – FSU method

Table 3-7: Peak flow estimates – FSU method

AEP (%)	Peak flow (m3/s)	
	09_1428_2	09_1505_1
50%	6.42	5.55
20%	9.30	8.04
10%	11.16	9.66
4%	13.23	11.43
2%	15.09	13.04
1%	16.74	14.49
0.1%	22.02	19.04

4 FSU small catchments method

Refer to Appendix A for a summary of the FSU small catchments method. The weighted growth curve derived for the full FSU statistical method has been applied to generate flows for higher return periods.

Table 4-1: Peak flow estimates – FSU SC method

AEP (%)	Peak flow (m3/s)		
	09_1428_2	09_1505_1	Mayne tributary
50%	2.15	1.75	0.13
20%	3.11	2.54	0.19
10%	3.74	3.04	0.22
4%	4.43	3.60	0.27
2%	5.05	4.11	0.30
1%	5.61	4.56	0.34
0.1%	7.37	6.00	0.44

5 Comparison of flow estimates

Table 5-1 compares the peak flow estimates from the FSU and FSU SC methods. From the table the FSU method generates the highest flows for the watercourse. This is due to the higher Qmed value in the FSU method. As the catchment is less than 25km2 it is generally recommended that the FSU SC method be used as the FSU statistical method was developed for catchments greater than 25km2. However, review of the data and expected catchment response suggests that the FSU SC method underestimates flows. Although the catchment is outside the recommended range for the FSU method the flows estimated using it are preferred as they are considered more representative of the catchment response.

Table 5-1: Comparison of peak flow estimates 09_1428_2

AEP (%)	FSU (m3/s)	FSU SC (m3/s)	Growth curve
50%	6.42	2.15	1.00
20%	9.30	3.11	1.45
10%	11.16	3.74	1.74
4%	13.23	4.43	2.06
2%	15.09	5.05	2.35
1%	16.74	5.61	2.61
0.1%	22.02	7.37	3.43

Table 5-2: Comparison of peak flow estimates 09_1505_1

AEP (%)	FSU (m3/s)	FSU SC (m3/s)	Growth curve
50%	5.55	1.75	1.00
20%	8.04	2.54	1.45
10%	9.66	3.04	1.74
4%	11.43	3.60	2.06
2%	13.04	4.11	2.35
1%	14.49	4.56	2.61
0.1%	19.04	6.00	3.43

Table 5-3: Peak flow estimates – Mayne tributary

AEP (%)	FSU SC (m3/s)	Growth curve
50%	0.13	1.00
20%	0.19	1.45
10%	0.22	1.74
4%	0.27	2.06
2%	0.30	2.35
1%	0.34	2.61
0.1%	0.44	3.43

To ensure that flows are applied appropriately a single point inflow at the top of the model will be used and then laterals applied. The peak flows estimated at 09_1505_1 will be used as the point source inflows for the Mayne river and the lateral flow will be the difference in flows between the 09_1505_1 and 09_1428_02 estimates. Further to this the Mayne tributary will be applied as a point inflow to the model however this catchment is included in the 09_1428_02 catchment. To ensure no double counting occurs the peak flow value for the Mayne tributary will be subtracted from the lateral flow applied. Table 5-4 shows the final flows applied to the model.

Table 5-4: Final peak flow estimates to be applied to the model

AEP (%)	09_1505_1 (point)	Mayne tributary (point)	09_1428_02 (lateral)
50%	5.55	0.13	0.74
20%	8.04	0.19	1.07
10%	9.66	0.22	1.28
4%	11.43	0.27	1.53
2%	13.04	0.30	1.75
1%	14.49	0.34	1.91
0.1%	19.04	0.44	2.54

6 Hydrograph shape and storm duration

Two methods are considered for the generation of hydrograph shape: FSU and FSR RR. Figure 6-2 and Figure 6-2 shows the hydrographs generated for the catchment considered. The FSU method hydrographs are approximately long with a steep rising limb and an elongated falling limb. In contrast the FSR RR hydrographs are much shorter (8-12 hours) and the limbs are the same shape. Although the FSU method has been used to estimate the peak flows it is thought that the hydrograph duration estimated is not appropriate for the catchment. It is therefore recommended that the FSU hydrograph shape be used but the storm duration and hydrograph length be reduced to approximately 12 hours (FSR RR length). This ensures that the correct shape is being used and that the length is appropriate for the catchment and not overestimated. To further check the appropriateness of the storm duration it is recommended that sensitivity tests be carried out using the hydraulic model where the hydrograph length is increased and decreased by 20%.

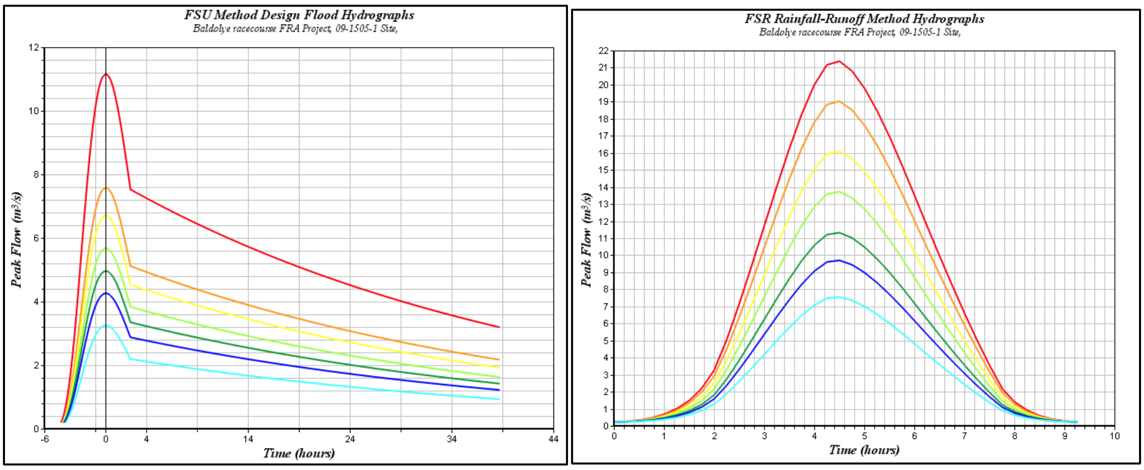


Figure 6-1: 09_1505_1 flow hydrographs – FSU (left) and FSR RR (right)

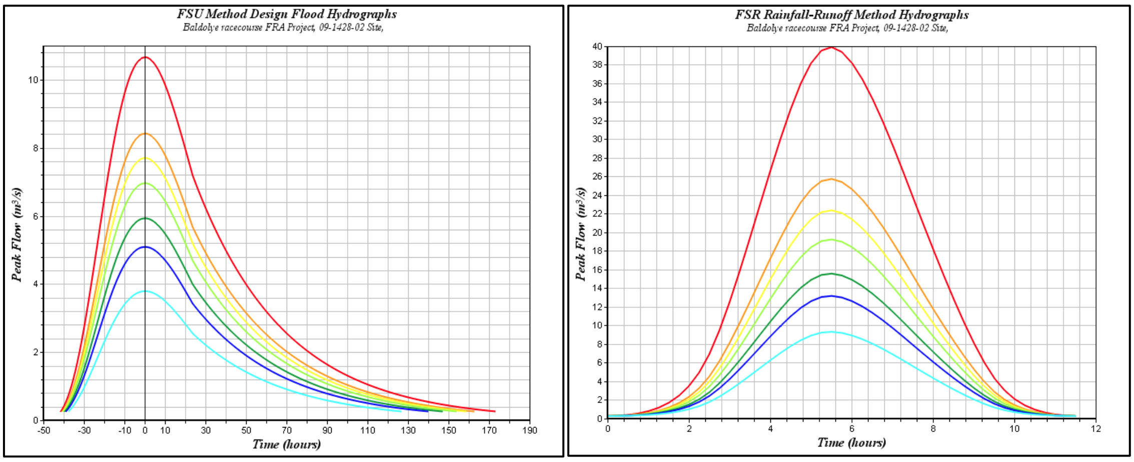


Figure 6-2: 09_1428_02 flow hydrographs – FSU (left) and FSR RR (right)

7 Downstream Boundary

The downstream boundary of the Mayne River is the Baldoyle Estuary. The watercourse considered is therefore subject to tidal influences at the downstream boundary which needs to be accounted for. It is recommended that the downstream of the Mayne River model have a HT downstream boundary to simulate the tidal influence present.

Figure 7-1 shows the FEM FRAMS tidal flood extent map for the Baldoyle estuary. The map show that downstream of section of the Mayne River is not at risk from tidal flooding for any of the return periods considered. This is due to a sluice gate present at the outflow point of the river. There is also a node label with reported levels at the mouth of the Mayne River (node 074). To simulate the potential tidal influence on the watercourse it is suggested to set a constant HT downstream boundary to the 10% AEP tidal level reported. This allows a conservative approach to be taken during the assessment.

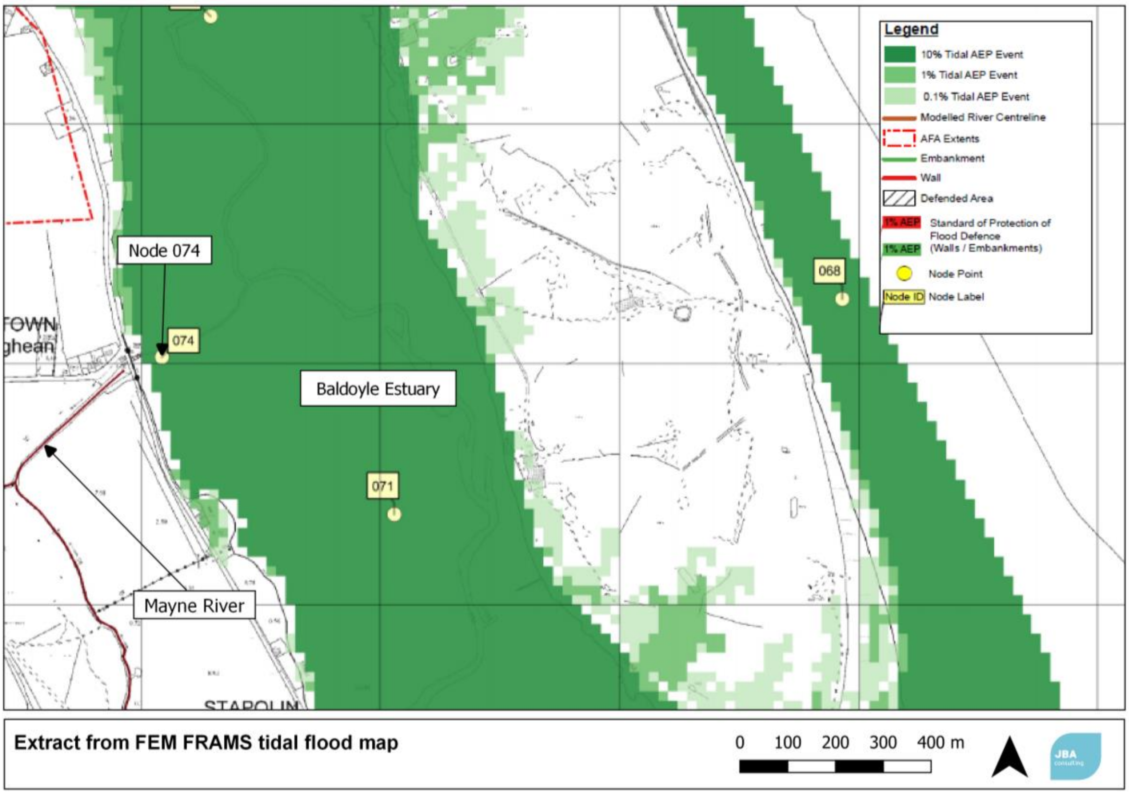


Figure 7-1: Extract from FEM FRAMS tidal flood map

Table 7-1: Water levels reported at node 074

% AEP event	Water level (mOD)
10%	2.69
1%	3.11
0.1%	3.35

8 CFRAM & other study Comparison

The Mayne River and surrounding area were modelled as part of the Fingal East Meath Flood Risk Assessment and Management Study (FEM FRAMS) which was a pilot study for the CFRAM mapping project. Table 8-1 compares the modelled FEM FRAM reported flows for the nearest node with those estimated for this check file.

From the table it is noted that the flows reported in FEM FRAMS differ to those estimated in this report. The flows estimated in this check file are higher than those estimated in FEM FRAMS apart for the 0.1% AEP event due to the difference in the growth curves applied (FEMS FRAMS has steeper curve, refer to Section 3.3.3).

Investigation into the methods used to calculate the flows applied in the FEM FRAMS model was carried out. Both the hydrology and hydraulics reports for the study were examined however there was little information provided. Only peak flows estimated at gauged locations were presented and no other record of inflows to any of the hydraulic models provided. From the documents the inflow values for the FEM FRAMS study were generated using either FSSR16 method or using the Institute of Hydrology Unit Hydrograph (UH) method. The UH method was used to generate inflows for catchments and sub catchments less than 25km2 and so was applied along the Mayne River which has a total catchment area of approximately 19km2 and has no gauge along the watercourse. It is mentioned in the text that the UH method used did not take in to account any catchment characteristics (Qbar was not calculated and applied) for the study. This method is very simplistic and does not allow any consideration of catchment variability. In light of this it is noted that the flow estimations from this check file take catchment characteristics into consideration and are therefore more representative of the catchment in question.

Given the approach taken in the FEM FRAM study and the lack of detail as to how and where the flows are applied and the inappropriate growth curve applied it is recommended that the FEM FRAMS estimated peak flows be ignored and the flows estimated for this check file be used in analysis instead. This also ensures that the most conservative flow values are used in the assessment of the flood risk to the site.

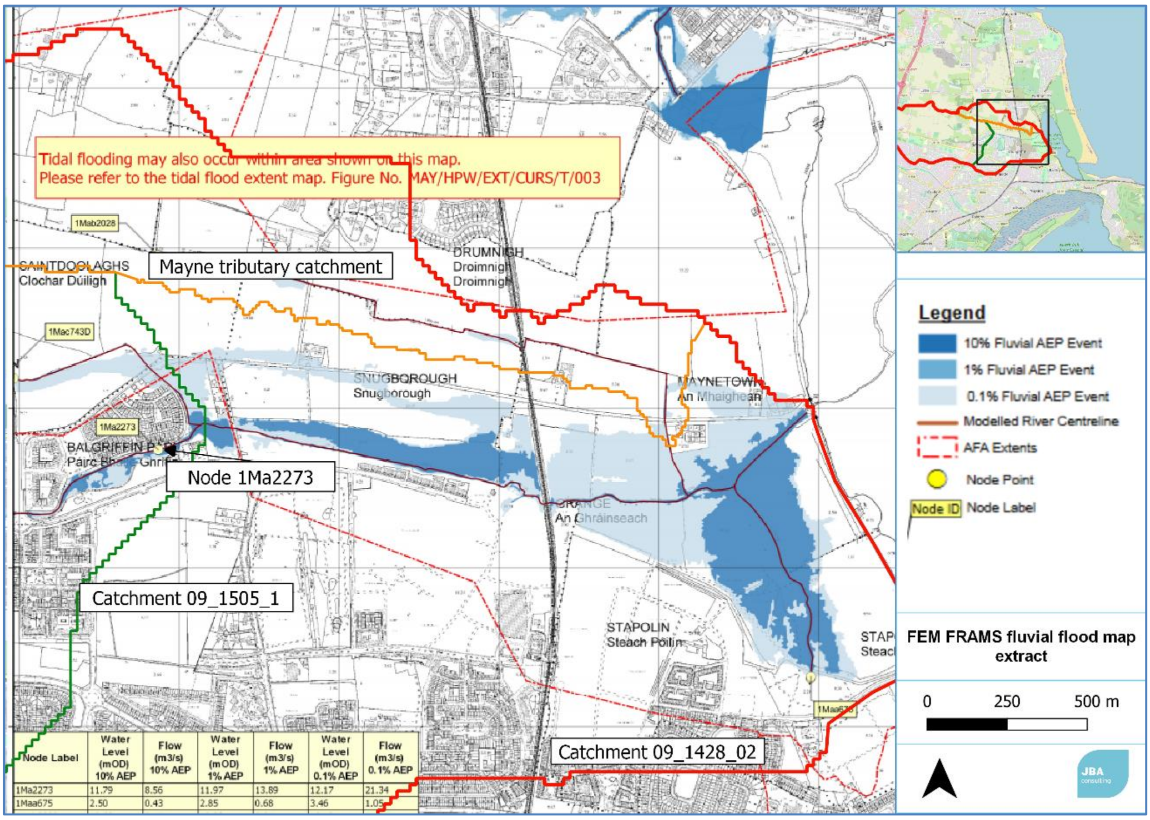


Figure 8-1: FEM FRAMS fluvial flood map extract

Table 8-1: Comparison of peak flows (m3/s)

AEP	09_1505_1	FEM FRAM 1Ma2273
10%	9.66	8.56
1%	14.46	13.89
0.1%	19.04	21.34

9 Discussion and summary of results

9.1 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	FSU method chosen as it is considered most representative and ensures a conservative approach is taken when assessing flood risk to the site
Climate change allowance	+20% flow as per OPW MRFS
How will the flows be applied to a hydraulic model? If relevant. Will model inflows be adjusted to achieve a match with lumped flow estimates, or will the model be allowed to route inflows?	Single inflow point at upstream extent of model
Recommended sensitivity tests for hydraulic model e.g. peak flow, volume, hydrograph shape, downstream boundary, bankfull	Flow routing test recommended (no structures model run) to ensure that it is appropriate to apply hydrology estimated at a downstream point upstream and examine the impact of storage and other hydrological barriers within the system.

9.2 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	Watercourse is ungauged therefore no flow checking, or validation can be carried out.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	FSU method applied outside of normal recommended range but considered more appropriate than the FSU SC method give expected catchment response.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	Appropriate for further FRA work along the watercourse but should be reviewed prior to use to see if there have been any further studies or gauges installed since the completion of this check file. Not suitable for low flow analysis.
Give any other comments on the study, e.g. suggestions for additional work.	FEM FRAMS hydrology is very uncertain due to lack of clarity and explanation within the documentation.

9.3 Checks

Are the results consistent, for example at confluences?	No confluences explicitly modelled
Has joint probability been considered?	Yes fluvial-tidal considered. Fluvial confluences downstream of site.
Have adjustments to catchment descriptor methods or gauge data been applied?	Yes pivotal gauge = Kinsaley Hall used – weighted growth curve used.
Is storm duration important?	Potentially, sensitivity tests recommended on hydrograph length.
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	Results reasonably similar to FEM FRAMS reported nodes but reporting higher flow values.
Describe any other checks on the results	Hydraulic routing test recommended and sensitivity test on hydrograph length and volume
Location of calculation sheets, data and records.	Jfes (Search for quotation number Q20-1580), project folder.
Unscaled hydrographs	L:\2020\Projects\2020s1166 - Richmond Homes - Baldoyle Racecourse Dublin FRA\1_WIP\HO\Non_Graphical_Review

9.4 Final results

AEP (%)	09_1505_1 (P)	Mayne Tributary (P)	09_1428_02 (L)
50%	5.55	0.13	0.74
20%	8.04	0.19	1.07
10%	9.66	0.22	1.28
4%	11.43	0.27	1.53
2%	13.04	0.30	1.75
1%	14.49	0.34	1.91
0.1%	19.04	0.44	2.54

Appendices

A Methods

A.1 The FSU method

The Flood Studies Update (FSU) method to estimate Qmed as described in research reports produced from FSU work packages 2.2 and 2.3, has been used. Qmed can be estimated using a regression equation based on seven different physical catchment descriptors, in conjunction with an urban adjustment, developed in FSU work package 2.3.

The multivariate regression equation was developed on the basis of data from 199 gauged catchments, linking Qmed to a set of catchment descriptors.

$$QMED = 1.237 \times 10^{-5} AREA^{0.937} BFI_{soil}^{-0.922} SAAR^{1.306} FARL^{2.217} DRAIND^{0.341} S1085^{0.185} (1 + ARTDRAIN2)^{0.408}$$

Where:

- AREA is the catchment area (km2).
- BFIsoils is the base flow index derived from soils data
- SAAR is long-term mean annual rainfall amount in mm
- FARL is the flood attenuation by reservoir and lake
- DRAIND is the drainage density
- S1085 is the slope of the main channel between 10% and 85% of its length measured from the catchment outlet (m/km).
- ARTDRAIN2 is the percentage of the catchment river network included in the Drainage

The urban extent can be taken into account using the following equation:

$$Q_{MEDfinal} = Qmed\,(1 + URBEXT)^{1.482}$$

Where URBEXT is the percentage of the catchment covered by urban land use.

Following the calculation of QMED the calculated adjustment factor and a growth curve are applied to generate the peak flows for AEP events. In this case the growth curve produced by the FSU pooling group for the ungauged catchment has been applied.

The catchment descriptors can be used to determine Qmed. In order to improve on this initial estimate of QMED, the data transfer process can be used. In the terminology of the FSU research reports, the gauging station where the adjustment factor is calculated is referred to as a donor site. An adjustment factor for QMED is calculated as the ratio of the gauged to the ungauged estimate of QMED at the gauging station. This factor is then used to adjust the initial estimate of QMED at the hydrological estimation point.

The growth factors for this site are also calculated from the FSU using pooling groups.

For pooled analysis within the FSU, gauges are chosen on the basis of their similarity with the subject catchment according to three catchment descriptors, i.e. AREA, SAAR and BFIsoil. The report on FSU WP 2.2 presents two alternative equations for calculating the similarity of catchments according to these three descriptors. For this study, equal weight was given to each of these variables, applying the similarity distance formula given as Equation 10.2 in the report on FSU WP 2.2.

Not all gauges in Ireland were considered for use in pooling, because the analysis required to fit a flood growth curve makes use of the magnitude of each annual maximum flow, and thus it is necessary that even the highest flows are reliably measured. This excludes gauges where there is significant uncertainty in the high flow rating.

Although there is some evidence from research on UK data that flood growth curves are affected by additional catchment descriptors such as FARL, the FSU research found that FARL was not a useful variable for selection of pooling groups (uncertainty was greater when FARL was included than when it was excluded) and therefore no attempt was made to allow for the presence of lakes in the composition of pooling groups. Similarly, no allowance was made for arterial drainage in selecting pooling groups.

For pooled growth curves, WP 2.2 recommends considering 3-parameter distributions, because the extra data provided by the pooling group ensures that the standard error is lower than it would be for single-site analysis. The report states that either the generalised extreme value (GEV) or generalised logistic (GL) distributions are worth considering. For this study, GEV has been fitted for the pooled analysis.

A.1.1 Pooling group details.

Station No.	Name	Watercourse	Years	Cumulative years
08002	Naul	Delvin	35	35
09002	Lucan	Griffeen	21	56
10021	Common's Road	Shanganagh	9	65
08009	Balheary	Ward	16	81
14009	Cushina	Cushina	38	119
08008	Broadmeadow	Broadmeadow	36	155
14007	Derrybrook	Stradbally	38	193
24022	Hospital	Mahore	35	228
14011	Rathangan	Slate	39	267
36031	Lisdarn	Cavan	45	312
25040	Roscrea	Bunow	35	347
09001	Leixlip	Ryewater	9	356
25023	Milltown	Little Brosna	63	419
205020	Comber	Enier	35	454
206001	Mountmill bridge	Clanrye	43	497
07001	Tremblestown	Tremblestown	42	539

Statistic	Value
Number of station-years pooled	539
Number of stations	16
Mean length of AMAX records pooled	34
Shape	0.315
Scale	0.035
Distribution	GEV

A.2 The FSU Small Catchments Method

The FSU small catchments method was created as part of FSU working package 4 and is discussed in 'Work Package 4.2 - Flood Estimation in Small and Urbanised Catchments'.

The FSU small catchment equation is a 5 variable regression equation that was developed after the examination of multiple small catchments equations and regression analysis of multiple catchment descriptors. The FSU small catchment equation for QMED is:

$$Qmed = (2.0951*10^{-5})*(AREA^{0.9245})*(SAAR^{1.2695})*(BFI^{-0.9030})*(FARL^{2.3163})*(S1085^{0.2513})$$

Where:

- AREA is the catchment area (km2)
- SAAR is long-term mean annual rainfall amount in mm
- BFISoil is the base flow within the catchment soil
- FARL is the percentage of the catchment covered by lakes or reservoirs
- S1085 is the slope of the main channel between 10% and 85% of its length measured from the catchment outlet (m/km)

The urban extent can be taken into account using the same method as above for the FSU standard method.

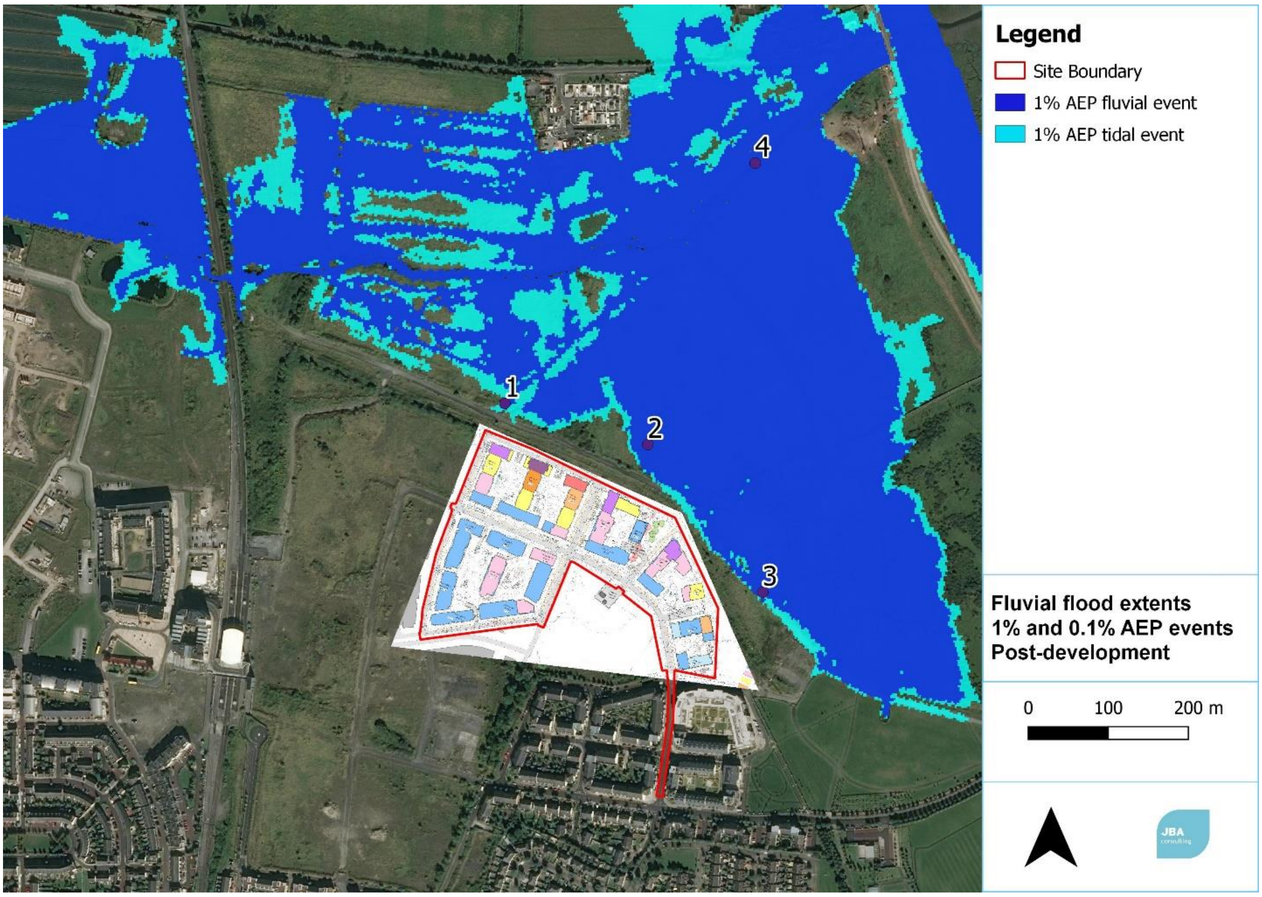
B CFRAM report extracts

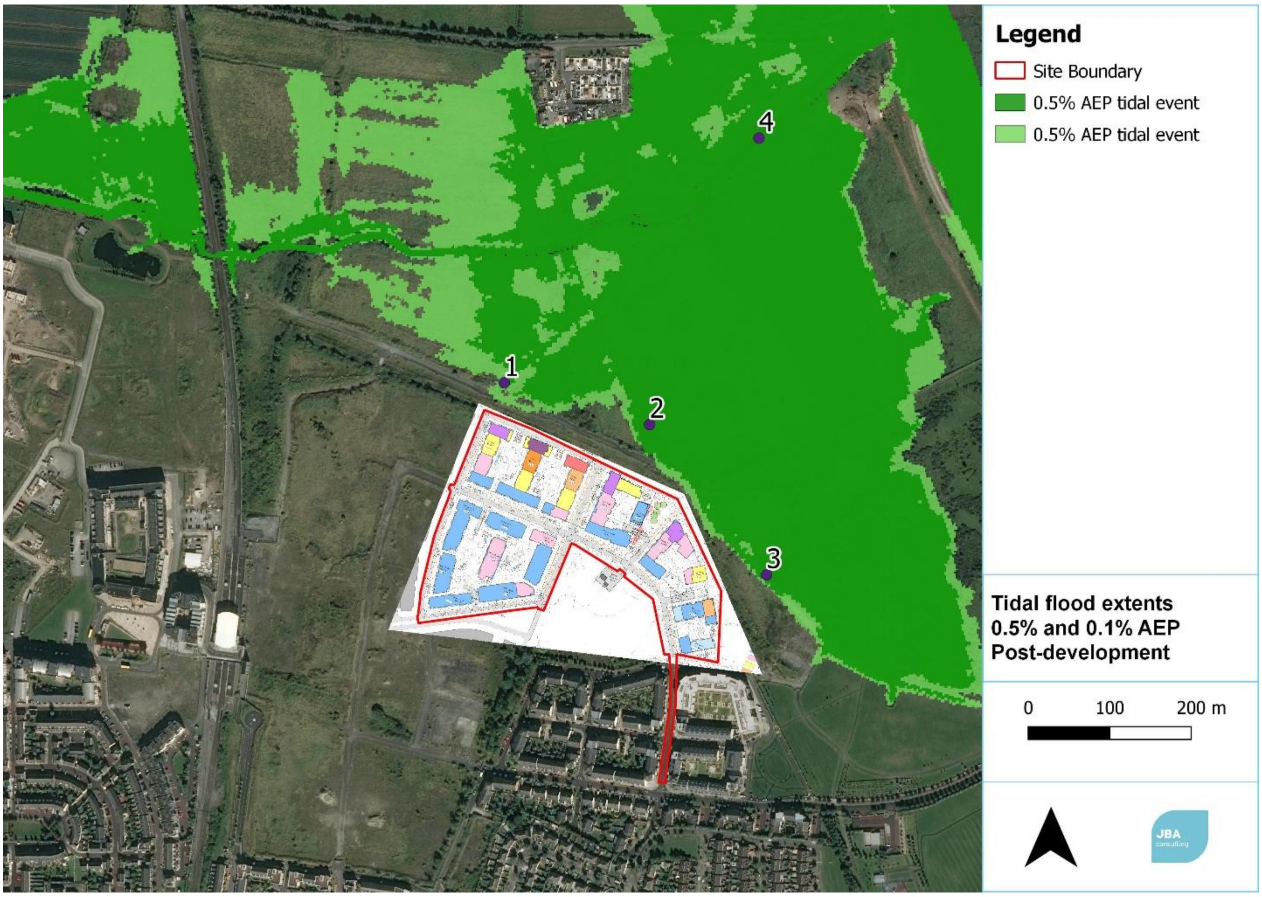
For FEM FRAMS documents see link below:

"\\IRE-RDC03\General\Reference\CFRAM\FEMFRAMS"

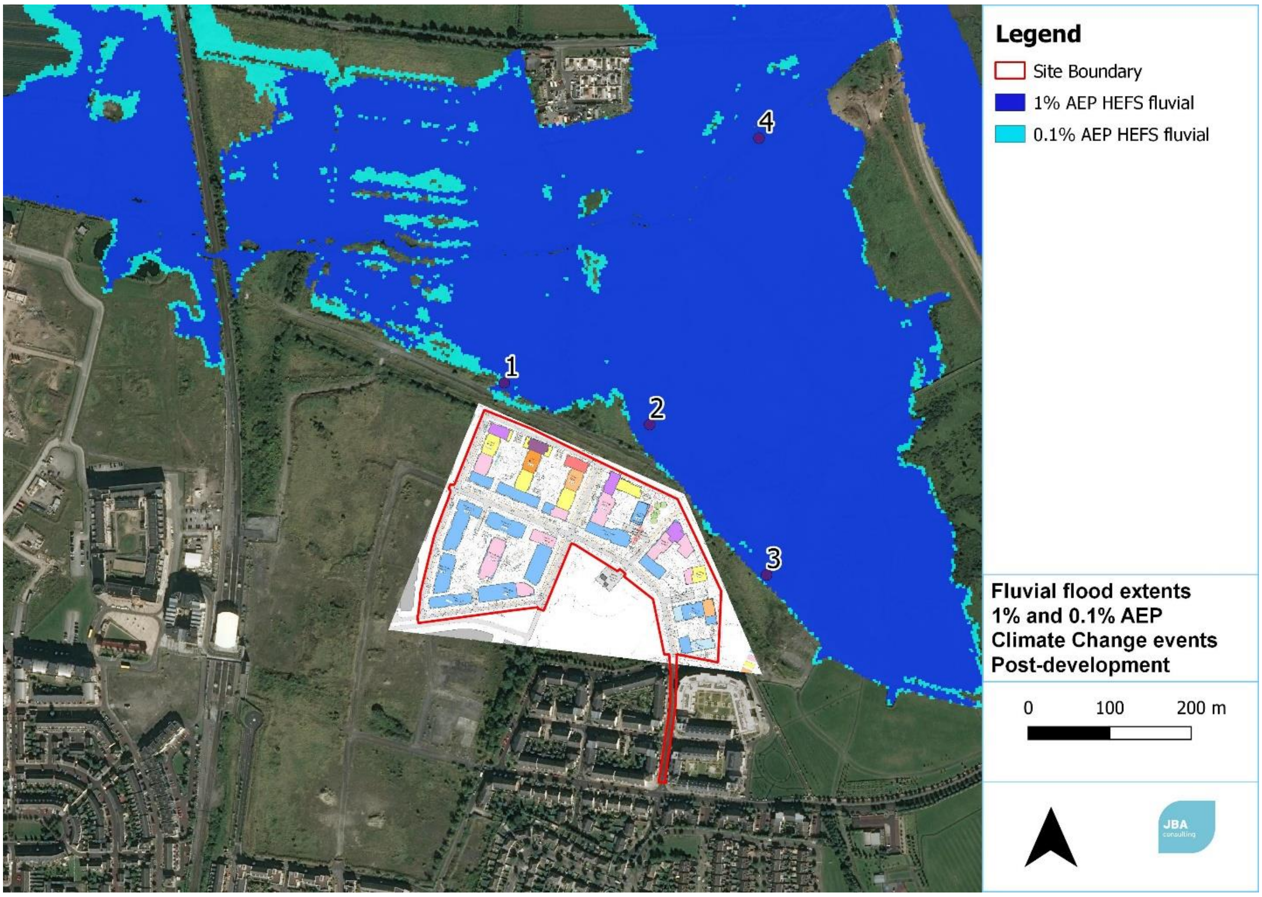
C Appendix - Flood Maps

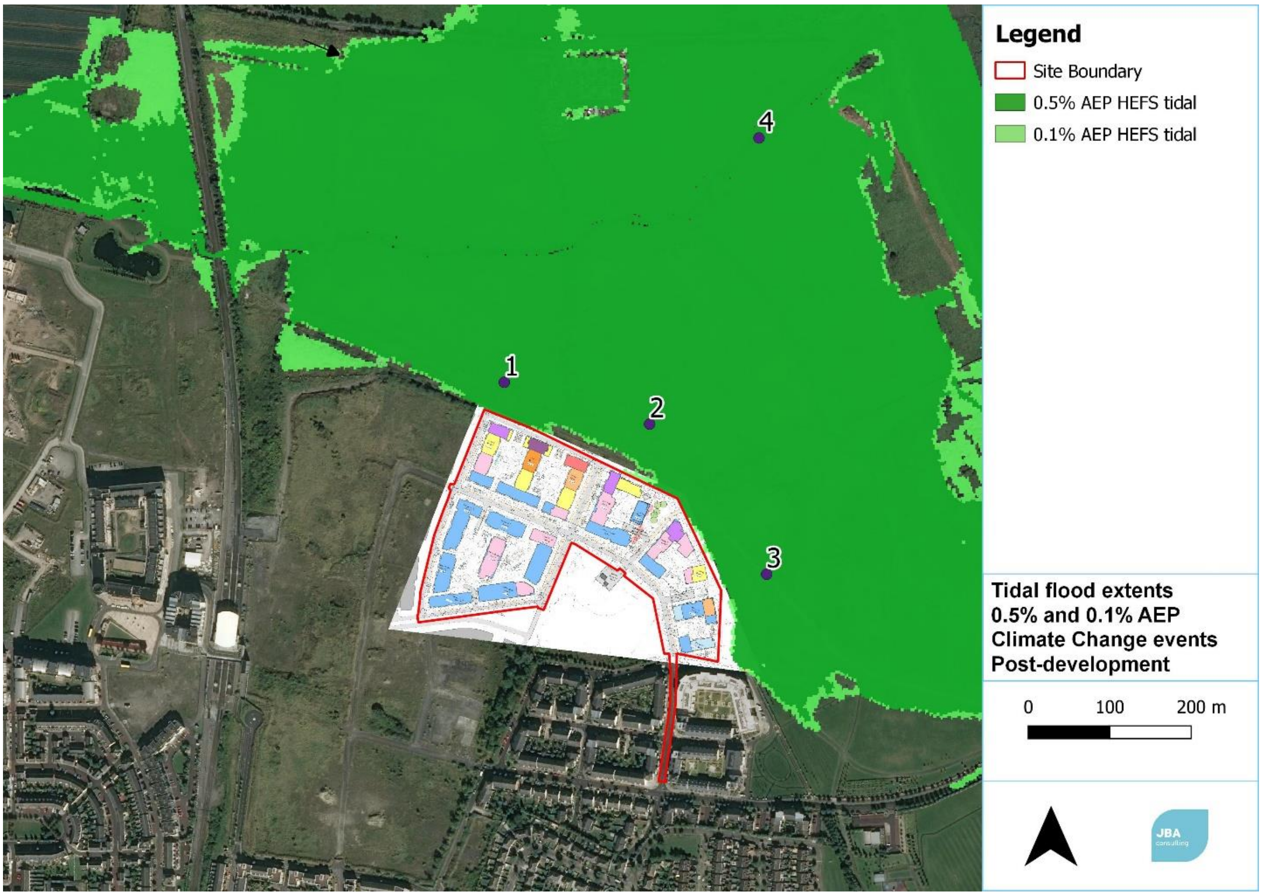
C.1 Flood Map





C.2 Climate Change Flood Map





1
2
3
4
Legend
Site Boundary
0.5% AEP HEFS tidal
0.1% AEP HEFS tidal
Tidal flood extents
0.5% and 0.1% AEP
Climate Change events
Post-development
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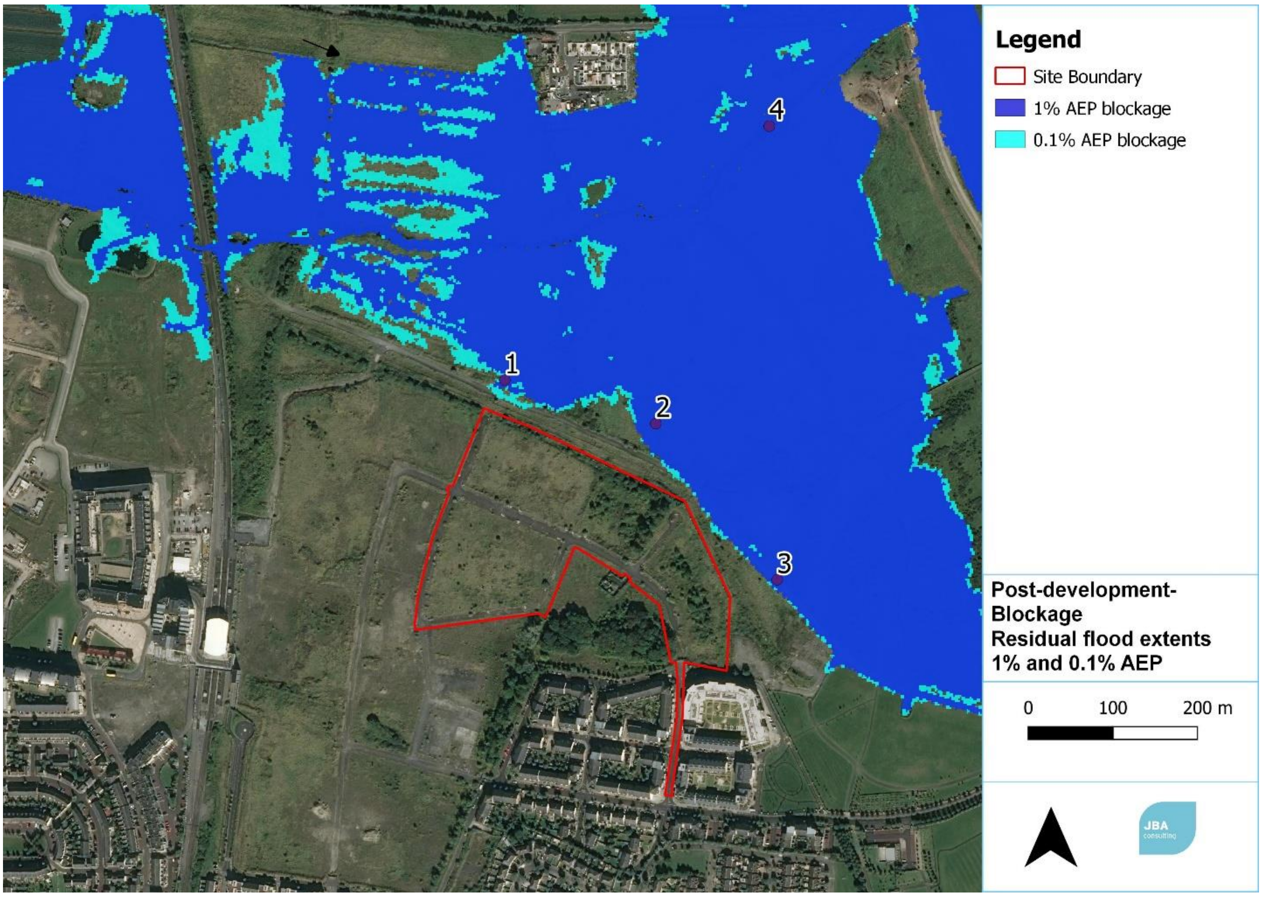
100
200 m

D Appendix -Residual Risk



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