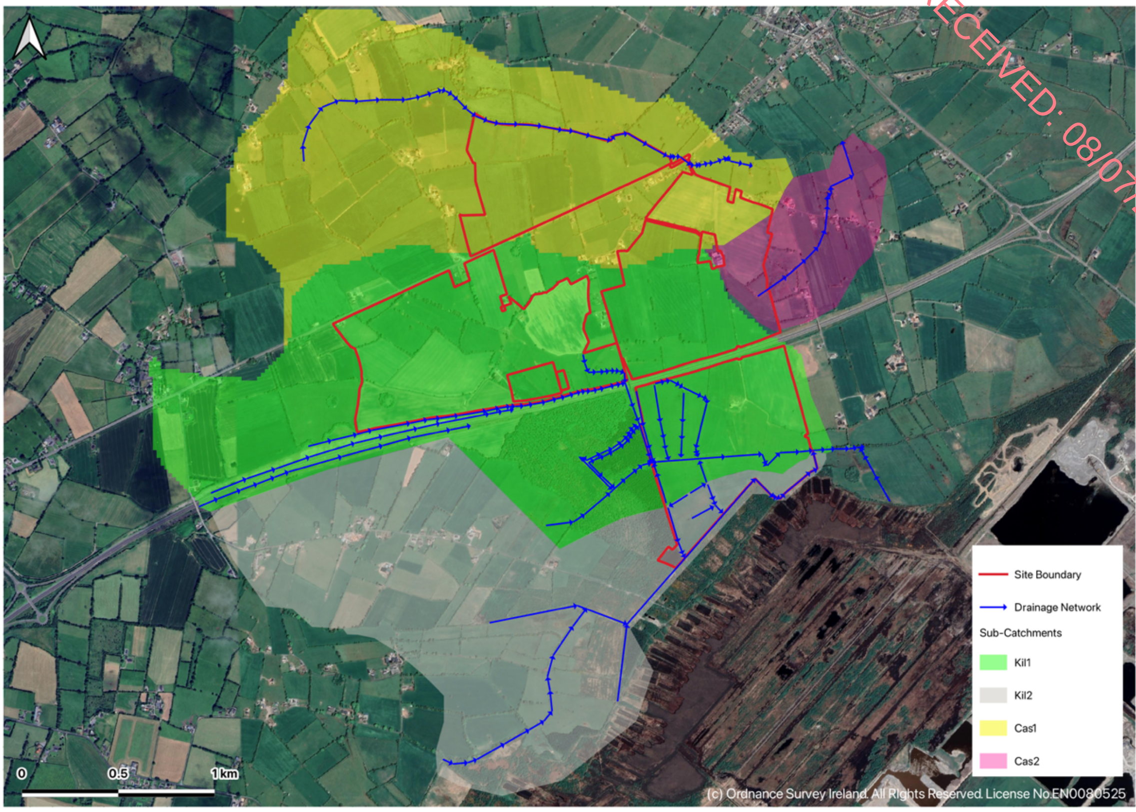
Figure 8 – Sub-catchments associated with the site boundary



2.5.2 Sub-catchment description: Kil1

Kil1 is characterised by a relatively dense network of field drains from agricultural lands and culverts. Crucially, the main channel is considered to be that which directs water under the M6. This sub-catchment has an area of 3.47 km^2. A detailed description of the flow network as surveyed is illustrated in Figure 9. The main channel, Kil1, rises in the centre of the catchment as a small field drain with an invert elevation of 110 mOD. It was noted across multiple site visits in May 2025 that the channel was dry at this elevation. Kil1 flows eastwards before being culverted southwards beneath the M6 motorway (Kil1_01). Water was observed in the channel at an elevation of 92.73 mOD and a small flow was noted to be entering the culvert (approx. 0.5 l/s). A field drain which joins Kil1 at the inlet of the M6 culvert Kil1_01 was noted as being dry for its entirety. A 450 mm culvert connects FD01 to Kil1_01 where it enters the TII culvert network.

Two open drainage channels are present alongside the M6 (M6 North & M6 South), to the west of Kil1_01, with 450 mm culverts connecting road runoff to the TII drainage network. The 450 mm culvert serving the M6 North channel was noted to be orientated in a south-east direction as it passes underneath the M6. The 450 mm culvert servicing the M6 South channel was oriented due east. Following an extensive walkover no outfall for either of these two culverts was identified in the forestry and agricultural lands south of the M6. A short salt tracing exercise was attempted to confirm the presence or otherwise of hydraulic connections between the M6 North and M6 South culvert inlets and the Kil1_01 culvert outlet. This test yielded no detectable results but it was observed that water entering the M6 North and South culverts outfall to a sedimentation tank which would significantly dilute the salt introduced. This also confirms that these culverts are part of a constructed drainage network. Without additional drainage network maps it has been assumed that these culvert inlets connect at subsurface junctions and outfall to Kil1_01 culvert outlet (900 mm). In addition French drains track along both sides of the M6 (Figure 10) and slope towards Kil1_01 culvert outlet.

Downstream of the M6 motorway, the Kil1 channel is fed by multiple field drains. These drains are not hydraulically connected to any sources upgradient (north) of the M6. It has been assumed that these were installed during raising of lands during motorway construction. The presence of standing water observed in FD02, FD03, FD04 and FD05 reinforces this. Surveyed water elevations confirm a general flow direction south towards Kil1. The channels would benefit from drainage maintenance works to remove vegetation and silt that has accumulated in places. Similarly FD06, FD07, FD08 and FD09 contained standing water, but surveyed water elevations implied an easterly flow direction towards Kil1.

Figure 9 – Kil1 detailed drainage network

2.5.3 Sub-catchment description: Kil2

Kil2 is comprised of three channels maintained by the OPW as part of the Boyne East Arterial Drainage Scheme (C1/64/1, C1/64/1/16 and C1/64/1/18). This sub-catchment has an area of 2.59 km^2 and acts as a tributary to the main Kil1 channel. The confluence of these two watercourses is at the southeast corner of the site boundary. The main channel is known as the Kiltotan and Collinstown (EPA code: 07K04) and is characterised by steep banks as a result of regular OPW maintenance. Contrary to the mapped EPA River Network and OPW Drainage Network databases, the walkover confirmed that this channel runs alongside the southern site boundary (Figure 8) and does not cut across the south east corner as is mapped in Figure 2. No major inflows to the channel were noted during site visits.

Figure 10 – French drains and their flow direction along the M6 towards Kil1

2.5.4 Sub-catchment description: Cas1

Cas1 is the northernmost catchment that interacts with the application site, flowing alongside the northern site boundary. The channel is named the Castlejordan Stream (EPA code: 07C04) and has an area of 2.59 km^2. It is characterised by steep banks following regular drainage maintenance (C1/64/1/13/4). There are multiple field drains that direct surface water into the main channel, but none contained water during multiple site visits through May 2025. There were no other major inflows to the channel as it passes through the site boundary. The channel is culverted under the R446, where it continues downstream before joining the Rochfortbridge Stream, approximately 1.4 km east of the site boundary.

2.5.5 Sub-catchment description: Cas2

Cas2 is the easternmost catchment and only interacts with a very small part of the application site. It has an area of 0.52 km^2, of which only 0.1 km^2 lies within the site boundary. It is essentially a field drain within the eastern portion of the site which directs surface water north towards the Castlejordan stream. The catchment is within agricultural lands. In a manner consistent with Kil2 and Cas1, the channel banks are steep following drainage works aimed at containing water within the channel.

2.5.6 Designated Areas

Designated areas within the area are presented in Table 1. The River Boyne and River Blackwater SPA and SAC are hydraulically connected to the site via downstream drainage 24 km to the east. A number of other ecological designated areas are proximal to the site boundary

Table 1 – Summary of Designated Sites Within a 15 km Radius of the Site

Ecological Designated Sites	Site Code	Location at Closest Point to the Proposed Project
Cloncrow Bog NHA	000677	3 km west
Lough Ennell SAC & pNHA	000685	6 km north west
Raheenmore Bog SAC & pNHA	000582	6 km south
Milltownpass Bog NHA	002323	7 km north east
Black Castle Bog NHA	000570	12 km south east
River Boyne and River Blackwater SPA & SAC	004232	24 km east

2.5.7 Flooding History

2.5.7.1 Historical OSI Maps

The historical 6" OSI maps (1830 - 1930) show no evidence of historical flooding at the application site (Plate 1). It is noted from the historical 6" maps that field drainage networks have since been disrupted by infrastructure projects such as the M6 motorway. Channels associated with the Kil1, Kil2 and Cas1 catchments are largely shown as being present on historical maps.

2.5.7.2 OPW Flood Hazard Mapping

Consultation of the OPW flood hazard mapping tool shows that one flood event was recorded within 5 km of the site boundary (Plate 2). This flood event was recorded in 2005 and refers to recurring flooding in low-lying spots on the roads in the area of Piercetown. No previous flooding events have been recorded with respect to the watercourses that flow through the site boundary.

Plate 1 - Historical 6" OSI maps (1830 – 1930)

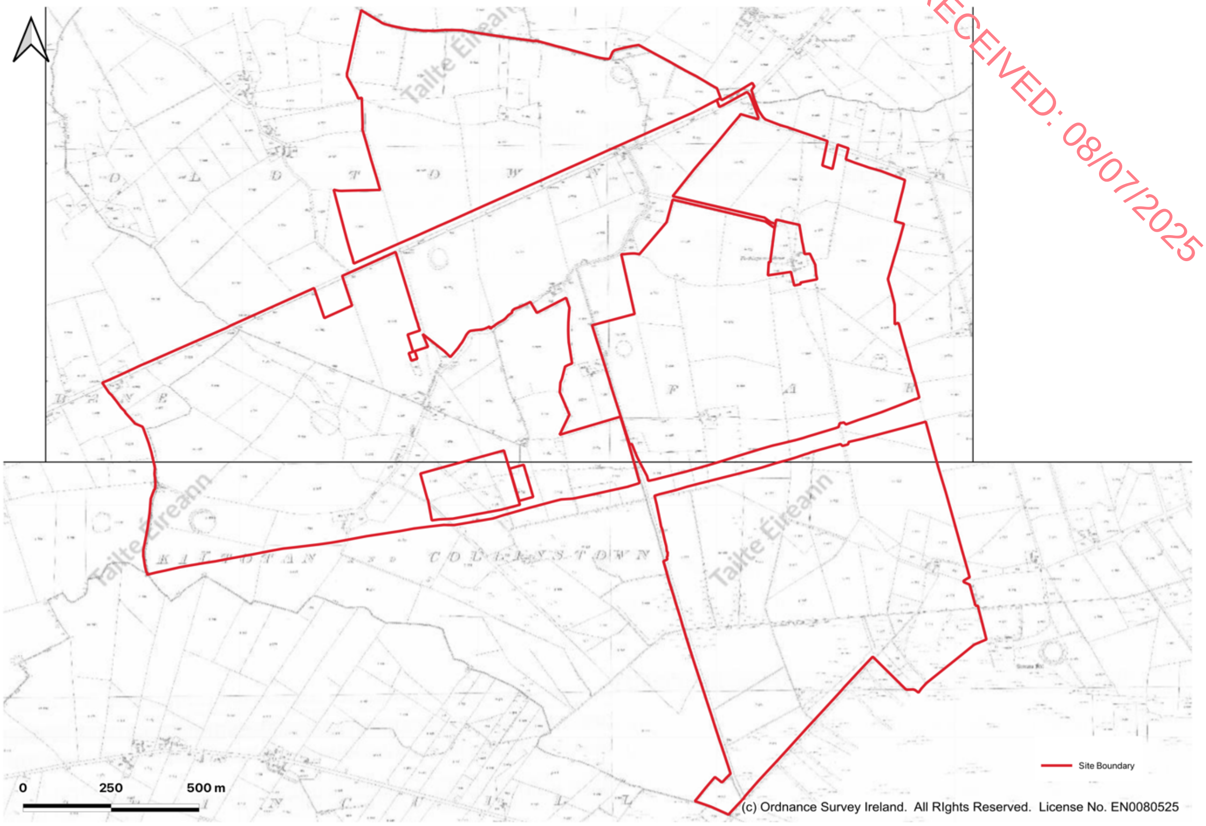


Plate 2 – OPW Historical Flood Events Map

2.5.8 Flood Risk Indicators

2.5.8.1 National Indicative Fluvial Mapping (NIFM)

The margins flanking the Kiltotan and Collinstown stream are covered by OPW National Indicative Fluvial Mapping (NIFM), which infers flood risk on the margins of the cutaway bog south of the site boundary (Plate 3). Predicted flood waters appear to encroach only marginally on these lands at the southern site boundary. No other channels associated with the application site exhibit flooding according to the NIFM.

Plate 3 – OPW National Indicative Fluvial Mapping flood extents

2.5.9 CFRAM

The OPW FloodInfo resource shows that the channels within the site boundary have not been covered by detailed CFRAM hydraulic modelling or CFRAM Indicative flood mapping.

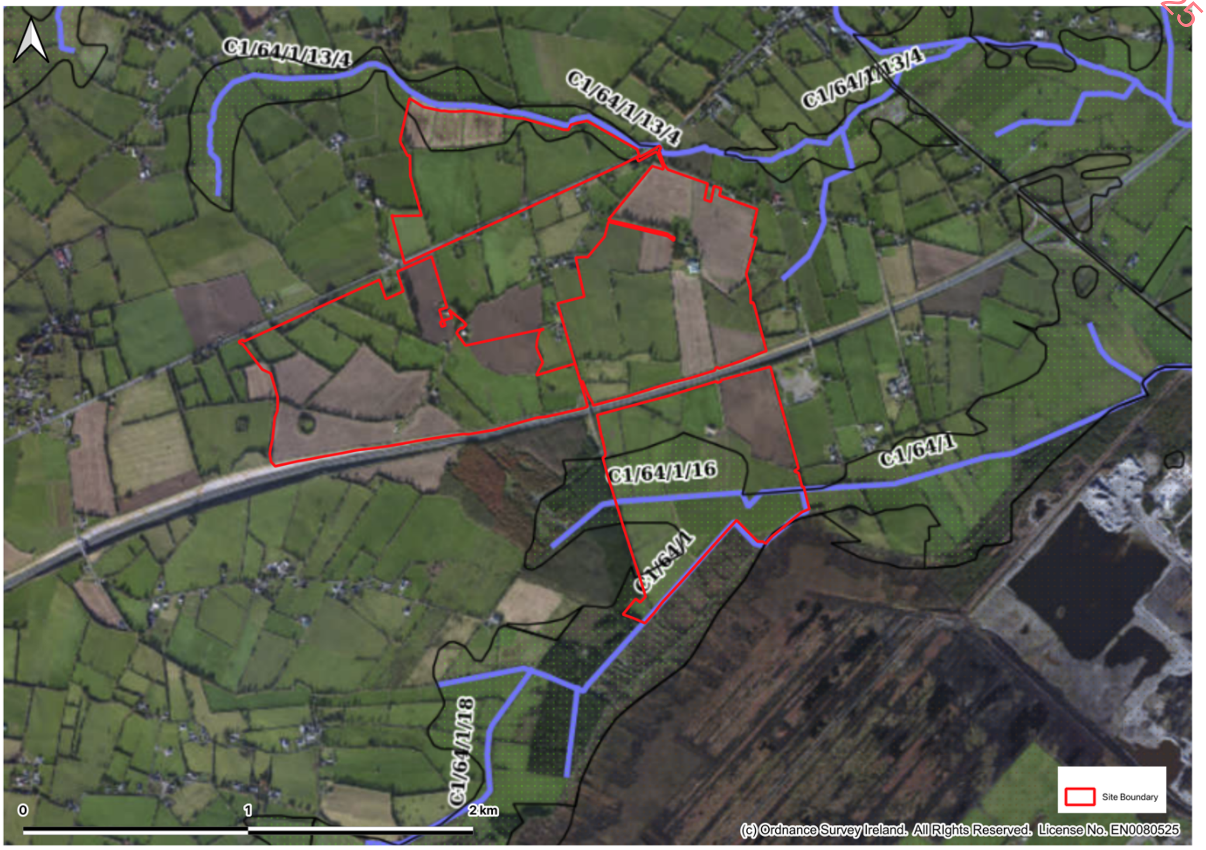
2.5.10 Benefitting Lands

Plate 4 shows that a large portion of the site boundary lies within benefitting lands, tracking along the watercourses associated with the Kil1, Kil2 and Cas1 catchments. These maps were prepared to identify areas that would benefit from land drainage schemes and typically indicate low lying land near watercourses that would be prone to flooding.

The emphasis of these schemes was the improvement of agricultural land. With respect to the site boundary, Plate 4 confirms that there are multiple channels which are maintained as part of the Boyne Arterial Drainage Scheme.

It is noted that the OPW Drainage Map also corresponds with the drainage network layout that was groundtruthed as part of the site walkover, with respect to the Kil2 channel. This is further evidence that the EPA river network map is incorrect in the southern portion of the application site.

Plate 4 - Drainage Channels and Benefitting lands



3 SEQUENTIAL TEST & VULNERABILITY MATRIX

3.1 SEQUENTIAL APPROACH

The 'Planning System and Flood Risk Management Guidelines for Planning Authorities (2009)' require the planning system at national, regional, and local levels to:

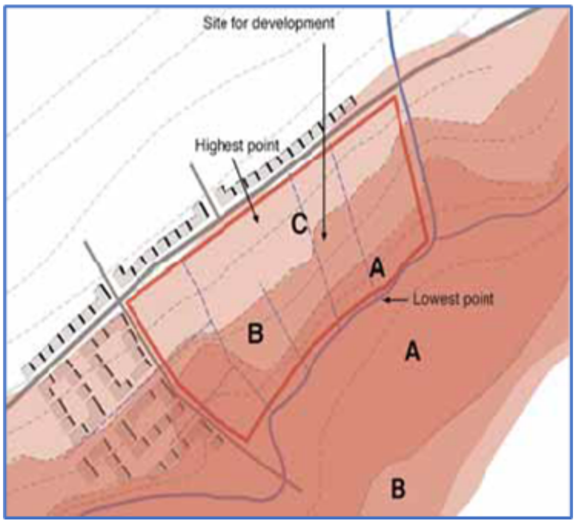
- Avoid development in areas at risk of flooding by not permitting development in flood risk areas, particularly floodplains, unless where it is fully justified that there are wider sustainability grounds for appropriate development and unless the flood risk can be managed to an acceptable level without increasing flood risk elsewhere and where possible, reducing flood risk overall.
- Adopt a sequential approach to flood risk management based on avoidance, reduction and then mitigation of flood risk as the overall framework for assessing the location of new development in the development planning processes; and

- Incorporate flood risk assessment into the process of making decisions on planning applications and planning appeals.

The sequential approach is used to assess flood risk at the site and, where there is variability, to assign appropriate zones in accordance with the Guidelines (DoEHLG, 2009). As shown in Plate 5, Zone A, applied to areas with a high probability of flooding, defines areas with the highest risk of flooding from rivers (i.e. more than 1% probability or more than 1 in 100). Development in this zone should be avoided and/or only considered in exceptional circumstances. Development should only be permitted in areas at risk of flooding when there are no alternative, reasonable sites available in areas at lower risk that also meet the objectives of proper planning and sustainable development. Zone B is applied to areas with a moderate probability of flooding from rivers. (i.e. a 0.1% to 1% probability or between 1 in 1000 and 1 in 100), with Zone C having a low probability of flooding.

With respect to coastal flooding Zone A is applied to areas with the highest risk of coastal flooding (i.e. more than 0.5% probability or more than 1 in 200 year return period). Development in this zone should be avoided and/or only considered in specified circumstances. Zone B is applied to areas with a moderate probability of coastal flooding (between 1 in 200 and 1 in 1000), with Zone C having a low probability of coastal flooding (less than 0.1% or 1 in 1000). The Flood Risk Assessment will clarify within which zone the site lies.

Plate 5 – Schematic map showing use of the Sequential Approach to assign Flood Risk Zones (DoEHLG, 2009)



3.2 VULNERABILITY MATRIX

Clause 2.16 of the Flood Management Guidelines (OPW, 2009) states: 'The classification of different land uses and types of development as highly vulnerable, less vulnerable and water-compatible is influenced primarily by the ability to manage the safety of people in flood events and the long-term implications for recovery of the function and structure of buildings.'

The Planning System and Flood Risk Management guidelines provide three vulnerability categories based on the development type. The proposed works fall into the following vulnerability categories as follows:

- **Highly vulnerable** = residential, hospitals, schools, **essential infrastructure**, emergency service facilities.

- **Less vulnerable** = buildings used for retail, warehousing, commercial, **industrial** and non-residential institutions.
- Water-compatible development = amenity open space, outdoor sport and recreation.

Different types of development are appropriate in each of the Flood Zones, based on their vulnerability to flood risk. Hence:

- **Highly vulnerable: requires Justification test in Flood Zone A and Flood Zone B, appropriate in Flood Zone C;**
- **Less vulnerable: requires Justification test in Flood Zone A; appropriate in Flood Zone B and Flood Zone C;**
- Water-compatible: appropriate in Flood Zones A, B and C.

Highly vulnerable development should only be considered in zones A and B if adequate lands or sites are not available in Zone C and subject to a flood risk assessment to the appropriate level of detail to demonstrate that flood risk to and from the development can or will adequately be managed at the site.

The development works proposed in the central portion of the site are considered to be 'essential infrastructure' and therefore comes under 'highly vulnerable development'. The solar farm has been designed to be a water compatible land use, due to all solar panels being raised above maximum predicted flood level, hence the solar panels are deemed appropriate to progress in Flood Zones A, B and C.

Based on desktop information collected to this point the majority of the site is deemed to be within Flood Zone C. Based on the NIFM database a small area in the southern portion of the application site may be in Flood Zone A. The hydraulic capacity of the proposed bridges will also be investigated as part of the modelling exercise.

A conservative approach is being applied and the assessment will proceed to quantitative determination of flood levels in watercourses adjacent to the site. Unless the quantitative assessment shows the site to be in Flood Zone A or Flood Zone B then a Justification Test is not required.

3.3 S-P-R MODEL

The flood risk assessment is carried out using the source-pathway-receptor (S-P-R) model, as outlined below. The S-P-R model is used to identify the sources of flood water, the people and assets affected by potential flooding, and the pathways by which the flood water reaches those receptors.

Consideration will be given to the predominant sources, pathways and receptors in terms of the influence they have on site flooding, or the manner in which they may be impacted. The primary water sources on site are as follows:

Sources	Pathways	Receptors
Extreme rainfall event (1 in 100 year)	Pluvial Flooding	Proposed Site
Channels within site boundary	Fluvial Flooding	Proposed Site Infrastructure
Runoff from upgradient lands	Road Runoff	Local Road & M6
Drainage/throughflow from upgradient lands	Field Drains	Third Party Lands and Property

The risk of pluvial flooding is considered to be low. No significant enclosed topographical depressions were noted on the site topographical survey. The topographical gradients and the dense surface water drainage network means that there is low probability of rainfall accumulating within the application site.

Based on the findings of the desktop assessment fluvial flooding is considered to be the primary flood mechanism. Fluvial flooding mechanisms will be looked at in more detail to quantify flood risk from the various catchments within the site boundary. Quantification of this risk will be achieved by firstly determining flood flows in the watercourses as they flow through/past the site.

A hydraulic model will then be compiled to facilitate estimation of flood levels within, and adjacent to, the site when these peak flows are passed through a series of surveyed cross sections. Mitigation measures will then be applied as appropriate.

4 SUBJECT SITE FLUVIAL FLOOD FLOW CALCULATIONS

4.1 OPW ADVICE

In selecting appropriate formulae reference has been made to an advisory response from OPW Hydrology Section and Work Package 4.2:

- For catchments between 5 km^2 and 25 km^2 the preferred equation is the ‘FSU small catchments’ equation. When using the small catchment equation, we generally advocate not using a pivotal site adjustment seeing as there is a very small pool of other small catchments from which to source a pivotal site.
- For catchments less than 25 km^2 we would always say that at least three methods should be explored and that the choice of the flow to be used is up to the practitioner.
- The WP4.2 report is intended to provide a further methodology for small catchment flood estimation. As far as we are concerned, it is the preferred method.
- For catchments less than 5 km^2 there is no FSU method applicable. For such ’small’ catchments we would suggest that maybe the rational method or modified rational method could be used.

The OPW FSU method alone may therefore be deemed unsuitable for the calculation of potential flood flows in this instance.

Flood flow calculations for each sub-catchment are presented below.

4.2 FLOOD FLOW CALCULATIONS: KIL1

4.2.1 OPW FSU - 7 Variable Equation

The ungauged method can be used to determine flood flows at the site using catchment characteristics, which are then corrected using a correlation against descriptors for gauged catchments. The median annual maximum flood magnitude (QMED), as outlined in the Flood Studies Update (FSU) (Nicholson & Bree 2013) is now preferred over the mean annual flood flow rate (Q_{bar}) parameter described in the Flood Studies Report (FSR) (NERC 1975). The preferred median method is less sensitive to large extreme floods and to flood measurement error in general. The estimation method for ungauged locations is based on a regression analysis relating observed QMED to physical catchment descriptors (PCDs) at gauged locations in Ireland, given by the following equation:

$$QMED_{rural} = 1.237\text{x}10^{-5} \,.\, AREA^{0.937} \,.\, BFI_{soil}^{-0.922} \,.\, SAAR^{1.306} \,.\, FARL^{2.217} \,.\, DRAIND^{0.341} \,.\, S^{0.185} \,.\, (1 + ARTDRAIN2)^{0.408}$$

The PCDs applicable to the Kil1 catchment are shown in Table 2.

Table 2 - Physical Catchment Descriptors Applicable to the Kil1 catchment

PCD	Description	Units	Value
AREA	Catchment area	km^2	3.47
SAAR	Average annual rainfall	mm	901.14
BFIsoil	Baseflow index derived from soils data		0.727
FARL	Flood attenuation from reservoirs and lakes		1
DRAIND	Ratio of river network to catchment area	no./km^2	0.507
S_{1085}	Slope of the main stream between the 10 and 85 percentiles	m/km^2	5.559
ARTDRAIN2	Proportion of river network included in drainage schemes		0.802
URBEXT			0
$QMED_{rural}$		m^3/s	0.534
$QMED_{urban}$		m^3/s	0.534

A principal of the FSU is the concept of a pivotal site, however no pivotal sites were considered suitable for application to such a small catchment. The return-period flood flow (Q_T) is determined by an index flood method, whereby a growth factor as determined from an EV1 distribution plot is applied. In this case:

$$Q_t = QMED \text{ x } 2.55$$

$$Q_{100} = 0.534 \text{ m}^3/\text{s x } 2.55$$

$$Q_{100} = 1.36 \text{ m}^3/\text{s}$$

Finally, a climate change growth factor of 20 % is applied:

$$Q_{100} = 1.36 \text{ x } 1.2$$

$$\mathbf{Q_{100} = 1.63 \text{ m}^3/\text{s}}$$

Using the standard OPW FSU approach the climate adjusted Q_{1000} flow in the watercourse as it passes the site is equal to:

$$Q_{1000} = QMED \text{ x } 3.33$$

$$Q_{1000} = 0.534 \text{ m}^3/\text{s x } 3.33$$

$$\mathbf{Q_{1000} = 1.81 \text{ m}^3/\text{s}}$$

4.2.2 OPW FSU – Small Catchments

The updated Flood Studies Update (Nicholson and Bree, 2013) presents the formula suited to catchments less than 25 km^2:

$$QMED_{rural} = 2.0951x10^{-5} . AREA^{0.9245} . BFIsoil^{-0.9030} . SAAR^{1.2695} . FARL^{2.3163} . S^{0.2513}$$

The same PCDs shown in Table 2 are again applied. This equation yields a Q_{MED} value of 0.32 m^3/s. As per the OPW Guidelines a pivotal site adjustment factor is not being applied to the outcome of the small catchments equation.

In this case the Q_{100} flood flow is determined as follows:

$$QT = QMED \text{ x growth factor}$$

$$Q_{100} = 0.324 \text{ m}^3/\text{s x } 2.55$$

$$Q_{100} = 0.825 \text{ m}^3/\text{s}$$

Finally, a climate change growth factor of 20% is applied:

$$Q_{100} = 0.825 \text{ x } 1.2$$

$$\mathbf{Q_{100} = 0.99 \text{ m}^3/\text{s}}$$

In this case the Q_{1000} flood flow is determined as follows:

$$Q_{1000} = QMED \text{ x } 3.33$$

$$Q_{1000} = 0.324 \text{ m}^3/\text{s x } 3.33$$

$$\mathbf{Q_{1000} = 1.1 \text{ m}^3/\text{s}}$$

4.2.3 OPW FSU – 3 Variable Method

The FSU 3-variable equation was developed as part of the FSU. It was developed as a 'short cut' equation for the estimation of flow in ungauged catchments:

$$QMED = 0.000302.AREA^{0.829} . SAAR^{0.898} . BFI^{1.539}$$

$$QMED = 0.23 \text{ m}^3/\text{s}$$

Application of the relevant growth factors as per above results in:

$$\mathbf{Q_{100+cc} = 0.715 \text{ m}^3/\text{s}}$$

$$\mathbf{Q_{1000} = 0.794 \text{ m}^3/\text{s}}$$

4.2.4 Flood Studies Report, FSR (NERC 1974)

This is the original FSR method, with the regression coefficient for Ireland. Estimates from this equation should be treated with extreme caution. Growth factor of 1.96 was applied to determine Q_{100}. It is recommended that these equations should be used only for preliminary flood estimates.

$$QBAR = 0.0172 . AREA^{0.94} . STMFRQ^{0.27} . S1085^{0.16} . SOIL^{1.23} . RSMD^{1.03} . (1 + LAKE)^{-0.85}$$

Table 3 - Calculations of Q_{100} – FSR Ungauged Catchments

Area, km²	STMFRQ, jn/km²	S_{1085}, m/km	SOIL	RSMD	LAKE	Q_{BAR} m³/s	Q_{BAR} x 1.96 gf m³/s	Q_{100} x 1.47 sfe m³/s	Q_{100} x x cc (1.2), m³/s
3.47	0.287	5.559	0.35	34.44	0	0.548	1.075	1.581	**1.90**

Using a growth factor of 2.6 to convert from Q_{BAR} to Q_{1000}, the resulting Q_{1000} flow is estimated as **2.09** m³/s.

4.2.5 Institute of Hydrology Report (IH)124 (1994)

Report No. 124 derives an equation to estimate flood flows for small rural catchments (less than 25 km²). The equation has a standard factorial error (SFE) of 1.65.

$$Qbar_{rural} = 0.00108\ (AREA^{0.89} \times SAAR^{1.17} \times SOIL^{2.17})$$

Table 4 - Calculations of Q_{100} – IH124

Area, km²	SAAR	SOIL	Q_{BAR} m³/s	Q_{BAR} x 1.96 gf m³/s	Q_{100} x 1.65 sfe m³/s	Q_{100} x x cc (1.2), m³/s
3.47	901.14	0.35	0.96	1.88	3.11	**3.72**

Without implementing the SFE (1.65), the Q_{100} rate plus 20% climate change factor was:

$$Q_{100} = 1.88\ m^3/s \times 1.2 = 2.25\ m^3/s$$

Using a growth factor of 2.59 to convert from Q_{BAR} to Q_{1000}, the resulting Q_{1000} flow is estimated as **4.1** m³/s.

This method was developed for small catchments (< 25 km²) in the UK. Its derivation did not include any Irish catchments. The equation tends to overestimate QBAR for the smallest of the UK catchments used. This value is not comparable to results derived from other formulae.

4.2.6 Modified IH 124 (Cawley & Cunnane 2003)

Irish researchers at NUIG (Cawley & Cunnane 2003) developed a Modified Institute of Hydrology 124 methodology and formula as follows:

$$Qbar_{rural} = 0.000036\ (AREA^{0.94} \times SAAR^{1.58} \times SOIL^{1.87})$$

Table 5 - Calculations of Q_{100} – Modified IH124

Area, km^2	SAAR	SOIL	Q_{BAR} m^3/s	Q_{BAR} x 1.96 gf m^3/s	Q_{100} x 1.65 sfe m^3/s	Q_{100} x x cc (1.2), m^3/s
3.47	901.14	0.35	0.759	1.488	2.456	**2.94**

Using a growth factor of 2.59 to convert from Q_{BAR} to Q_{1000}, the resulting Q_{1000} flow is estimated as **3.24** m^3/s.

4.2.7 Modified Rational Method

FSU Work Package 4.2 shows that the UK only apply the Rational Method to catchments from 2 to 4 km^2. In Ireland this method is more commonly used to determine stormwater attenuation requirements. It is calculated using the formula:

$$QT = 2.78 \times C_v \times C_r \times I \times A$$

where:

Q_T = design peak flow, l s^{-1}

T = return period in years = 21.2 mm/hr

C_v = runoff coefficient = 0.84 (winter)

C_r = peaking/routing factor = 1.3 (arbitrary value)

A = 3.47 km^2

Hence:

$$Q_{100} = 2.78 \times 0.84 \times 1.3 \times 0.0212 \times 3.473$$

$$Q_{100} = 0.223\ m^3/s$$

$$Q_{100} + 20\%\ cc = 0.525\ m^3/s$$

$$Q_{1000} = \mathbf{0.578\ m^3/s}$$

4.2.8 Summary of Flood Flow Calculations

Results from the various flood estimation methods are summarised below in Table 6. In taking a conservative approach, the flood flow values selected for use in the hydraulic model were those calculated using the Modified IH124 method, as this method was developed using Irish catchment characteristics. The values derived using this method are 65% greater than average taken across all formulae. The respective Q_{100+cc} and Q_{1000} values being equal to 2.94 m^3/s and 3.24 m^3/s, respectively.

Table 6 - Summary of Calculated Flood Flows for the Kil1 catchment

Methodology	Q_{100} + 20% cc (m^3/s)	Q_{1000} (m^3/s)
FSU Standard	1.63	1.81
FSU small catchments	0.99	1.10
FSU – 3 variable	0.72	0.79
FSR 6 – including SFE	1.90	2.09
IH124 – including SFE	3.72	4.10
Modified IH124 – including SFE	**2.94**	**3.24**
Modified rational method	0.53	0.58
Minimum	0.53	0.58
Maximum	3.72	4.10
Average (n = 7)	1.78	1.96

4.3 FLOOD FLOW CALCULATIONS: KIL2

The physical catchment descriptors applicable to the Kil2 catchment are shown in Table 7.

Table 7 - Physical Catchment Descriptors Applicable to the Kil2 catchment

PCD	Description	Units	Value
AREA	Catchment area	km^2	2.59
SAAR	Average annual rainfall	mm	902
BFIsoil	Baseflow index derived from soils data		0.726
FARL	Flood attenuation from reservoirs and lakes		1
DRAIND	Ratio of river network to catchment area	no./km^2	0.736
S_{1085}	Slope of the main stream between the 10 and 85 percentiles	m/km^2	9.0587
ARTDRAIN2	Proportion of river network included in drainage schemes		0.6847
URBEXT			0
$QMED_{rural}$		m^3/s	0.492
$QMED_{urban}$		m^3/s	0.492

Results from the various flood estimation methods are summarised below in Table 8. In taking a conservative approach, the flood flow values selected for use in the hydraulic model were those calculated using the Modified IH124 method, as this method was developed using Irish catchment characteristics. The values derived using this method are 58% greater than average taken across all formulae. The respective Q_{100+cc} and Q_{1000} values being equal to 2.24 m^3/s and 2.47 m^3/s, respectively.

Table 8 - Summary of Calculated Flood Flows for the Kil2 catchment

Methodology	Q_{100} + 20% cc (m^3/s)	Q_{1000} (m^3/s)
FSU Standard	1.51	1.67
FSU small catchments	0.67	0.75
FSU – 3 variable	0.56	0.62
FSR 6 – including SFE	1.68	1.87
IH124 – including SFE	2.87	3.16
Modified IH124 – including SFE	**2.24**	**2.47**
Modified rational method	0.39	0.43
Minimum	0.39	0.43
Maximum	2.87	3.16
Average (n = 7)	1.42	1.51

4.4 FLOOD FLOW CALCULATIONS: CAS1

The physical catchment descriptors applicable to the Cas1 catchment are shown in Table 9.

Table 9 - Physical Catchment Descriptors Applicable to the Cas1 catchment

PCD	Description	Units	Value
AREA	Catchment area	km^2	2.59
SAAR	Average annual rainfall	mm	907.14
BFIsoil	Baseflow index derived from soils data		0.714
FARL	Flood attenuation from reservoirs and lakes		1
DRAIND	Ratio of river network to catchment area	no./km^2	1.069
S_{1085}	Slope of the main stream between the 10 and 85 percentiles	m/km^2	5.47
ARTDRAIN2	Proportion of river network included in drainage schemes		1
URBEXT			0.0138
$QMED_{rural}$		m^3/s	0.559
$QMED_{urban}$		m^3/s	0.559

Results from the various flood estimation methods are summarised below in Table 10. In taking a conservative approach, the flood flow values selected for use in the hydraulic model were those calculated using the Modified IH124 method, as this method was developed using Irish catchment characteristics. The values derived using this method are 56% greater than average taken across all formulae. The respective Q_{100+cc} and Q_{1000} values being equal to 2.26 m^3/s and 2.99 m^3/s, respectively.

Table 10 - Summary of Calculated Flood Flows for the Cas1 catchment

Methodology	Q_{100} + 20% cc (m^3/s)	Q_{1000} (m^3/s)
FSU Standard	1.71	1.90
FSU small catchments	0.78	0.87
FSU – 3 variable	0.55	0.61
FSR 6 – including SFE	1.57	1.73
IH124 – including SFE	2.89	3.82
Modified IH124 – including SFE	**2.26**	**2.99**
Modified rational method	0.39	0.43
Minimum	0.39	0.43
Maximum	2.89	3.82
Average (n = 7)	1.45	1.76

4.5 FLOOD FLOW CALCULATIONS: CAS2

The physical catchment descriptors applicable to the Cas2 catchment are shown in Table 11.

Table 11 - Physical Catchment Descriptors Applicable to the Cas1 catchment

PCD	Description	Units	Value
AREA	Catchment area	km^2	0.52
SAAR	Average annual rainfall	mm	907.1
BFIsoil	Baseflow index derived from soils data		0.714
FARL	Flood attenuation from reservoirs and lakes		1
DRAIND	Ratio of river network to catchment area	no./km^2	1.069
S_{1085}	Slope of the main stream between the 10 and 85 percentiles	m/km^2	5.47
ARTDRAIN2	Proportion of river network included in drainage schemes		1
URBEXT			0.0138
$QMED_{rural}$		m^3/s	0.124
$QMED_{urban}$		m^3/s	0.124

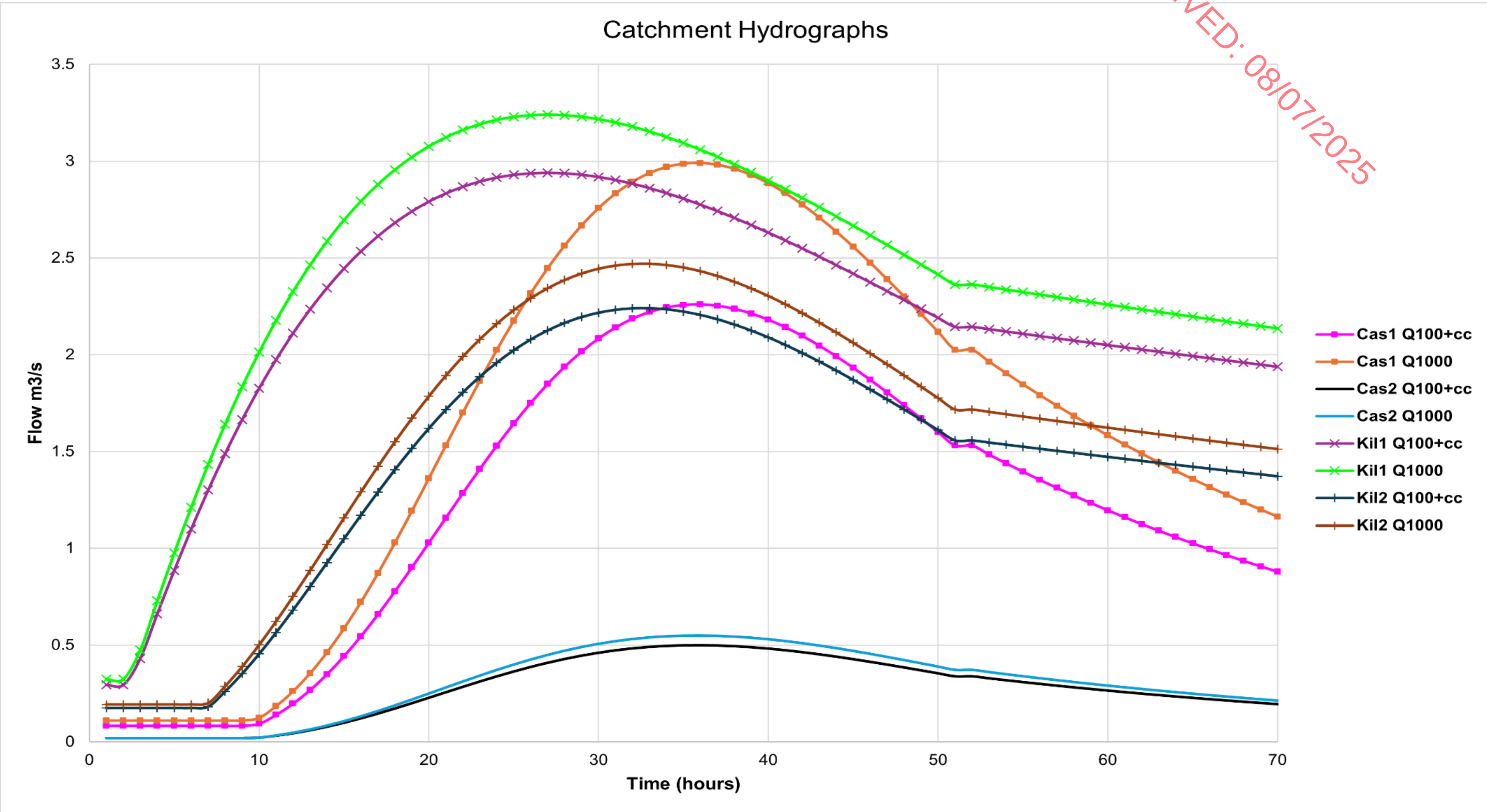
Results from the various flood estimation methods are summarised below in Table 12. In taking a conservative approach, the flood flow values selected for use in the hydraulic model were those calculated using the Modified IH124 method, as this method was developed using Irish catchment characteristics. The values derived using this method are 39% greater than average taken across all formulae. The respective Q_{100+cc} and Q_{1000} values being equal to 0.50 m^3/s and 0.55 m^3/s, respectively.

Table 12 - Summary of Calculated Flood Flows for the Cas2 catchment

Methodology	Q_{100} + 20% cc (m^3/s)	Q_{1000} (m^3/s)
FSU Standard	0.38	0.42
FSU small catchments	0.18	0.20
FSU – 3 variable	0.15	0.19
FSR 6 – including SFE	0.56	0.59
IH124 – including SFE	0.69	0.76
Modified IH124 – including SFE	**0.50**	**0.55**
Modified rational method	0.07	0.08
Minimum	0.07	0.08
Maximum	0.69	0.76
Average (n = 7)	0.36	0.40

Seventy hour hydrographs for each catchment and flood flow scenario are shown in Graph 1. Time to peak characteristics have been derived from the FSU portal and are representative of how ‘flashy’ the rainfall-runoff response is in each catchment.

Graph 1 – Hydrographs for each catchment and flood flow scenario



5 HYDRAULIC MODEL

5.1 MODEL CONCEPT

A site-specific hydraulic model was constructed using Flood Modeller (version 6.1), an industry standard hydraulic modelling software package for which Envirologic maintains a full license. This software package is designed to perform one dimensional (1D) hydraulic simulations for networks of natural or constructed water channels. In addition to the one-dimensional hydraulic solver the software also utilises a two-dimensional solver (2D) which models water flow and depth in situations where flood levels overtop the bank-full capacity of the surveyed channels and spill onto the adjoining floodplain. Construction of the 1D–2D linked model relies on four primary inputs summarised as follows:

- Geometric Data: Surveyed cross-sectional data of the main channel through the site boundary;
- Geometric Data: A georeferenced digital elevation model of the site and surrounding landscape to cover potential adjoining flood plain upstream and downstream of the site location;
- Upstream Boundary Conditions - Q_{100} & Q_{1000} flood flow volumes for the upstream catchment of the site;
- Inclusion of Manning Roughness Coefficient values, used to calculate frictional forces within the flood model.

5.2 MODEL BUILD – EXISTING DRAINAGE REGIME

5.2.1 Cross Sections

The 1D model was compiled using evenly spaced cross sections along watercourses within the site boundary. These sections were surveyed manually using Trimble RTK VRS technique. Cross section locations for each channel are shown in Figure 11 and Figure 12. Sixty five cross sections were surveyed across four separate channels (see Table 13). In each catchment the cross sections extended beyond the downstream end of the site boundary.

Table 13 – Survey Details

Channel	Number of Cross Sections	Modelled Reach Length
Kil1	36	1,830 m
Kil2	11	1,515 m
Cas1	15	1,750 m
Cas2	3	600 m