- **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.

Based on desktop information collected to this point the site is deemed to be within Flood Zone C. 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 quantitiative 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
Storm rainfall event (1 in 100 year)	Pluvial Flooding	Proposed Site
Kilcrow River Tributaries	Fluvial Flooding	Proposed Site Infrastructure
Runoff from upgradient lands	Road Runoff	Local Road
Drainage/throughflow from upgradient lands		Third Party Lands and Property
Gortaha River Tributaries		

Flooding mechanisms will be looked at in more detail to quantify flood risk from the Kilcrow River catchment. 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 catchment associated with the furthest downstream point of the site boundary has an area of 2.00 km^2. The OPW FSU method alone may therefore be deemed unsuitable for the calculation of potential flood flows in this instance.

4.1.1 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 subject site are shown in Table 2.

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Table 2 - Physical Catchment Descriptors Applicable to the Subject Site

PCD	Description	Units	Value
AREA	Catchment area	km^2	2.00
SAAR	Average annual rainfall	mm	938.91
BFIsoil	Baseflow index derived from soils data		0.6908
FARL	Flood attenuation from reservoirs and lakes		1
DRAIND	Ratio of river network to catchment area	no./km^2	0.212
S_{1085}	Slope of the main stream between the 10 and 85 percentiles	m/km^2	1.034
ARTDRAIN2	Proportion of river network included in drainage schemes		0.9404
URBEXT			0
$QMED_{rural}$		m^3/s	0.198
$QMED_{urban}$		m^3/s	0.198

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:

$$Q_t = QMED \times 2.51$$

$$Q_{100} = 0.198\ m^3/s \times 2.51$$

$$Q_{100} = 0.496\ m^3/s$$

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

$$Q_{100} = 0.496 \times 1.2$$

$$\mathbf{Q_{100} = 0.596\ m^3/s}$$

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

$$Q_{1000} = QMED \times 3.33$$

$$Q_{1000} = 0.198\ m^3/s \times 3.33$$

$$Q_{1000} = 0.658\ m^3/s$$

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

$$Q_{1000} = 0.658 \times 1.2$$

$$\mathbf{Q_{1000} = 0.790\ m^3/s}$$

4.1.2 OPW FSU – Small Catchments

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

$$QMED_{rural} = 2.0951\text{x}10^{-5} \;.\; AREA^{0.9245} \;.\; BFIsoil^{-0.9030} \;.\; SAAR^{1.2695} \;.\; FARL^{2.3163} \;.\; S^{0.2513}$$

The same PCDs shown in Table 2 are again applied. This equation yields a Q_{MED} value of 0.328 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:

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

$$Q_{100} = 0.328 \text{ m}^3 \text{ s}^{-1} \text{ x } 2.51$$

$$Q_{100} = 0.823 \text{ m}^3 \text{ s}^{-1}$$

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

$$Q_{100} = 0.823 \text{ x } 1.2$$

$$\mathbf{Q_{100} = 0.987 \text{ m}^3 \text{ s}^{-1}}$$

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

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

$$Q_{1000} = 0.328 \text{ m}^3\text{/s x } 3.33$$

$$Q_{1000} = 1.091 \text{ m}^3\text{/s}$$

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

$$Q_{1000} = 1.091 \text{ x } 1.2$$

$$\mathbf{Q_{1000} = 1.309 \text{ m}^3\text{/s}}$$

4.1.3 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:

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

$$QMED = 0.14 \text{ m}^3\text{/s}$$

Application of the relevant growth factors as per above and 20% climate change adjustment factor results in:

$$\mathbf{Q_{100} = 0.428 \text{ m}^3\text{/s}}$$

$$\mathbf{Q_{1000} = 0.568 \text{ m}^3\text{/s}}$$

4.1.4 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, km^2	STMFRQ, jn/km^2	S_{1085}, m/km	SOIL	RSMD	LAKE	Q_{BAR} m^3/s	Q_{BAR} x 1.96 gf m^3/s	Q_{100} x 1.47 sfe m^3/s	Q_{100} x x cc (1.2), m^3/s
2.004	0.499	1.034	0.35	35.991	0	0.303	0.594	0.8745	**1.049**

Using a growth factor of 2.6 to convert from Q_{BAR} to Q_{1000}, the resulting Q_{1000} flow which includes a 20% climate change factor is estimated as **1.392** m^3/s.

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

Report No. 124 derives an equation to estimate flood flows for small rural catchments (less than 25 km^2). 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, 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
2.004	938.91	0.35	0.617	1.210	1.997	**2.396**

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

$$Q_{100} = 1.211 \text{ m}^3/\text{s} \times 1.2 = 1.45 \text{ m}^3/\text{s}.$$

Using a growth factor of 2.59 to convert from Q_{BAR} to Q_{1000}, the resulting Q_{1000} flow which includes a 20% climate change factor is estimated as **3.167** m^3/s.

This method was developed for small catchments (< 25 km^2) 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.

4.1.6 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, 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
2.00	938.9	0.35	0.483	0.947	1.563	**1.875**

Using a growth factor of 2.59 to convert from Q_{BAR} to Q_{1000}, the resulting Q_{1000} flow which includes a 20% climate change factor is estimated as **2.47** m³/s.

4.1.7 Modified Rational Method

FSU Work Package 4.2 shows that the UK only apply the Rational Method to catchments from 2 to 4 km². 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 = 100

C_v = runoff coefficient = 0.84 (winter)

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

A = 2.004 km²

$I_{tc,\,T}$ = hourly rainfall intensity for design duration of tc (hours) and return period T (years) = 29.2 mm *1.36 = 39.712 mm

t_c= time of concentration defined as the travel time from the furthest point on the catchment to the outlet (mins):

$$t_c = 0.0195 \times L^{0.77} \times S^{-0.385}$$

L = length of stream = 1600 m

S = catchment gradient, m m^{-1} = 0.001

tc = 81.6 minutes = 1.36 hours

Hence:

$$Q_{100} = 2.78 \times 0.84 \times 1.3 \times 0.0292 \times 2.004$$

$$Q_{100} = 0.348\ m^3\ s^{-1}$$

$$Q_{100} + 20\%\ cc = \mathbf{0.417}\ m^3\ s^{-1}$$

$$Q_{1000} + 20\%\ cc = \mathbf{0.552}\ m^3\ s^{-1}$$

4.1.8 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 IH124 method, as these were the maximum values. The respective Q_{100} and Q_{1000} values being equal to 2.40 m^3/s and 3.16 m^3/s, respectively. These values include a 20% factor for climate change.

Table 6 - Summary of Calculated Flood Flows (includes 20% Climate Change Factor)

Methodology	Q_{100} + 20% cc (m^3/s)	Q_{1000} + 20% cc (m^3/s)
FSU Standard	0.60	0.79
FSU small catchments	0.99	1.09
FSU – 3 variable	0.43	0.57
FSR 6 – including SFE	1.04	1.39
IH124 – including SFE	**2.40**	**3.16**
Modified IH124 – including SFE	1.88	2.48
Modified rational method	0.42	0.55
Minimum	0.42	0.55
Maximum	2.40	3.16
Average (n = 7)	1.11	1.43

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.

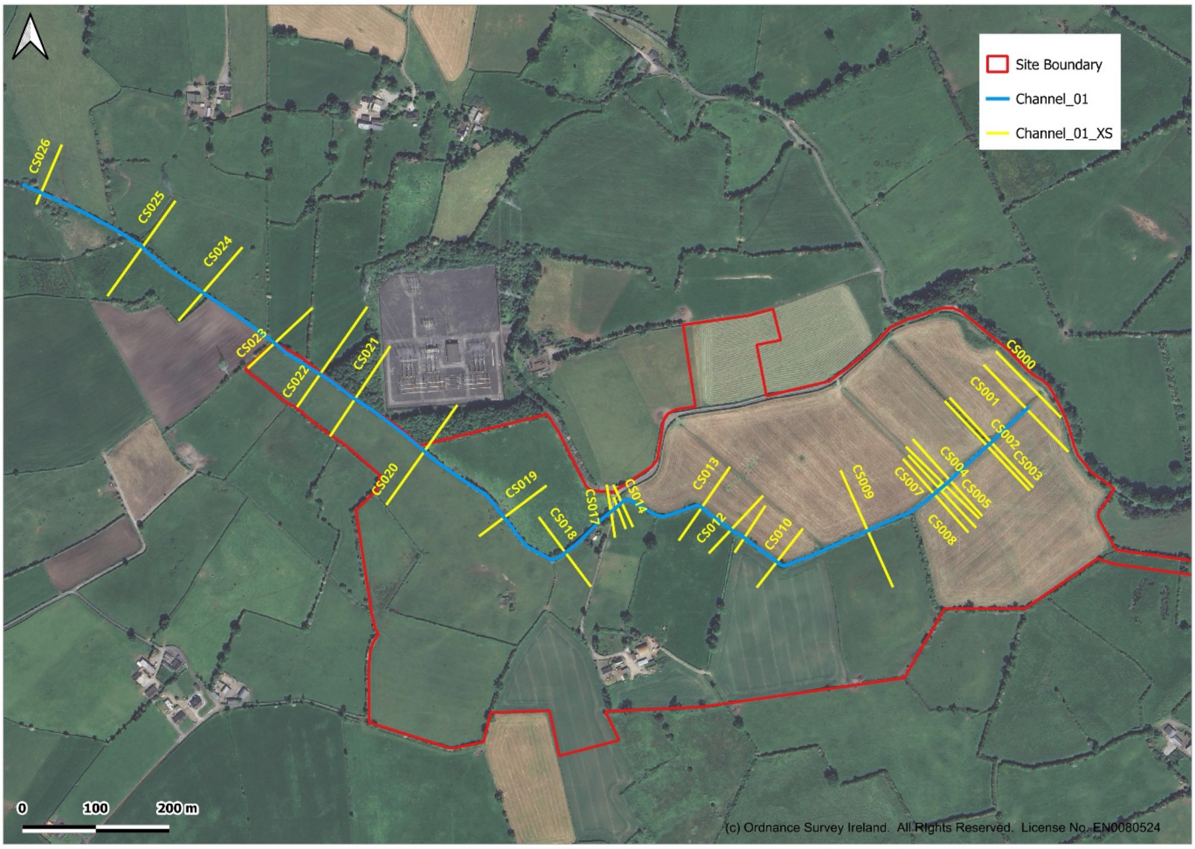
5.2 MODEL BUILD – EXISTING DRAINAGE REGIME

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 on the central channel are shown in Figure 7. Twenty six sections were surveyed along the central channel. As stated previously the surface water catchment to this central channel as it passes the downgradient site boundary is 2.00 km^2.

A further 19 cross sections were surveyed across drainage ditches that outfall to the central channel within the site. Only one of these was considered as contributing flows high enough that it should be included in the flood model; this being a drainage tributary that extends 950 m south. Nine cross sections were surveyed along this southern drainage tributary. It has a catchment of approximately 0.68 km^2. Accordingly, 34% of the Q_{100} and Q_{1000} flow values were attributed to this southern drainage tributary, based on its proportional area within the overall site catchment.

Figure 7 - Cross Section Locations



5.2.2 Flow Boundaries

The IH124 $Q_{1000+cc}$ flow value of 3.16 m^3/s was selected as the design flood flow through the entire site. By areal proportion an upstream flow value of 2.09 m^3/s was introduced to the central channel (Channel 01) upstream of cross section CS001 and 1.06 m^3/s (34% of 3.16 m^3/s) was introduced to the southern tributary (Channel 02) upstream of cross section CS100. The combined flow of 3.16 m^3/s is then routed through all remaining downstream cross sections. The same modelling concept approach was applied in relation to the catchment Q_{100} flow value of 2.94 m^3/s.

5.2.3 Roughness Coefficients & Gradients

A Manning's roughness coefficient of 0.03 was applied to open river channel bed sections (noted as silty/gravelly) and a value of 0.045 applied to riverbanks. The central channel (Channel 01) is noted on the OPW drainage network database as being maintained as part of the Killimor arterial drainage district. It was observed during the site visit that the channel profiles generally have steep banks and flat channel beds. Throughout the existing central channel (Channel 01) the hydraulic gradient was generally 0.02%. This steepened to a maximum gradient of 1.18% in the western part of the site.

5.2.4 Existing Structures

There are four culverts in place along the modelled reaches. Culvert specifications are noted as follows:

- CS006 = Culvert field crossing along Channel 01:
    - 1 no. circular concrete culvert with an opening of 900 mm
    - Length = 6.0 m
    - Pipe crown elevation = 52.05 mOD
    - Pipe invert elevation = 51.15 mOD
    - Upstream top of wall elevation = 53.32 mOD
    - Culvert deck level = 53.21 mOD
- CS016 = Culvert crossing on Channel 01 for access road to existing dwelling:
    - 1 no. concrete culvert with an opening of 950 mm
    - Length = 7.5 m
    - Pipe crown elevation = 51.18 mOD
    - Pipe invert elevation = 50.18 mOD
    - Upstream top of wall elevation = 51.70 mOD
    - Culvert deck level = 51.87 mOD
- CS102 = Culvert crossing on Channel 02 for access between fields:

- 1 no. concrete culvert with an opening of 650 mm
- Length = 4.0 m
- Pipe crown elevation = 52.95 mOD
- Pipe invert elevation = 52.30 mOD
- Upstream top of wall elevation = 53.31 mOD
- Culvert deck level = 53.40 mOD

- CS110 = Culvert on Channel 02 immediately upstream of outfall to Channel 01:
  - 1 no. concrete culvert with an opening of 500 mm
  - Length = 0.5 m
  - Pipe crown elevation = 51.95 mOD
  - Pipe invert elevation = 51.45 mOD
  - Upstream top of wall elevation = 52.72 mOD
  - Culvert deck level = 52.72 mOD

5.2.5 Existing Drainage Regime: Simulations

This step of the assessment focussed on the following scenarios:

- Validation of the model build using observed vs modelled water levels
- 1 in 100-year fluvial flood event
- 1 in 1000-year fluvial flood event

5.2.5.1 Simulation: Validation

Surface water levels were recorded on 1st and 2nd May 2024 as part of the topographical survey. These surveyed water levels were compared with water levels modelled by the hydraulic simulation, with results shown in Table 7. A flow of 0.2 m^3/s provided the least amount of error between the surveyed and modelled water levels and were deemed representative of flows observed on the day.

Validation results showed that the model was extremely accurate throughout the modelled reach of the central channel, with the difference generally below 60 mm. There was a slight increase in divergence of up to 200 mm at CS022 and CS023 with this being attributed to the sharp increase in hydraulic gradient towards the end of the model. Another slightly higher difference between observed and predicted water levels of 120 mm occurred immediately upstream of culvert CS016. During surveying it was noted that there was a large amount of silt and vegetation at the culvert inlet which was not accounted for in the model.

The results of the validation exercise confirm that the model is valid and accurate and is appropriate for predicting flood flows through the application site.

Table 7 - Surface Water Levels Validation

Cross Section	Surveyed Surface Water Level (mOD)	Modelled Water Level at 0.2 m^3/s (mOD)	Difference (m)
CS002	51.62	51.64	-0.02
CS003	51.60	51.63	-0.04
CS004	51.58	51.61	-0.03
CS005	51.58	51.61	-0.03
CS007	51.58	51.60	-0.02
CS008	51.58	51.60	-0.02
CS009	51.52	51.54	-0.02
CS010	51.17	51.24	-0.07
CS011	50.81	50.80	0.02
CS012	50.76	50.73	0.03
CS013	50.70	50.66	0.03
CS014	50.40	50.50	-0.12
CS015	50.37	50.48	-0.12
CS017	50.1	50.18	-0.08
CS018	49.78	49.70	0.09
CS019	48.39	48.28	0.11
CS020	45.84	45.90	-0.06
CS021	43.78	43.84	-0.06
CS022	43.18	42.96	0.22
CS023	42.82	42.63	0.19
CS024	42.45	42.45	0.00
CS025	42.31	42.38	-0.08
CS026	42.25	42.26	0.00

5.2.6 Simulation: Flood Flows

The conveyance capacity of all surveyed cross sections along the existing stream were assessed for suitability to transmit Q_{100} and Q_{1000} flood flows, with a 20% allowance included for climate change. The design flows are as follows:

- Central channel (Channel 01) Q_{100} = 1.59 m^3/s
- Central channel (Channel 01) Q_{1000} = 2.10 m^3/s
- Southern tributary (Channel 02) Q_{100} = 0.80 m^3/s
- Southern tributary (Channel 02) Q_{1000} = 1.06 m^3/s

The predicted surface water elevations from the Flood Modeller 1D simulation under steady-state conditions are presented in Table 8.

The results showed that under flood conditions waters are maintained within the central channel profile. There is surcharging upstream of the culvert at CS016 but these upstream waters remain confined within the channel profile.

Full surcharging occurs at the inlets of both culverts on the southern tributary under Q_{100} flows, these being positioned at CS102 and CS110. As proposed works involve realignment of this channel it was not deemed necessary to construct a full 1D-2D flood simulation to assess of the fate of waters that spill onto the floodplain. The southern tributary (Channel 02) was capable of safely transmitting 0.6 m^3/s with the existing culverts in place.

Table 8 - Hydraulic Model Flow Simulation Outputs for existing hydraulic regime for Central Channel

Cross Section	Channel 01			
	Q_{100} Flow (m^3/s)	Q_{100} fluvial flood levels (mOD)	Q_{1000} Flow (m^3/s)	Q_{1000} fluvial flood levels (mOD)
CS001	1.59	52.57	2.10	52.72
CS002	1.59	52.38	2.10	52.56
CS003	1.59	52.39	2.10	52.58
CS004	1.59	52.37	2.10	52.55
CS005	1.59	52.36	2.10	52.55
CS006UP	1.59	52.28	2.10	52.43
CS006DN	1.59	52.29	2.10	52.44
CS007	1.59	52.29	2.10	52.44
CS008	1.59	52.29	2.10	52.44
CS009	1.59	52.20	2.10	52.34
CS010	1.59	51.73	2.10	51.84
CS011	1.59	51.40	2.10	51.56
CS012	2.40	51.64	3.16	51.85
CS013	2.40	51.58	3.16	51.79
CS014	2.40	51.41	3.16	51.64
CS015	2.40	51.40	3.16	51.63
CS016UP	2.40	50.69	3.16	50.81
CS016DN	2.40	50.66	3.16	50.77
CS017	2.40	50.66	3.16	50.77
CS018	2.40	50.18	3.16	50.28
CS019	2.40	48.67	3.16	48.74
CS020	2.40	46.37	3.16	46.47
CS021	2.40	44.32	3.16	44.42
CS022	2.40	43.55	3.16	43.71
CS023	2.40	43.33	3.16	43.49
CS024	2.40	43.14	3.16	43.28

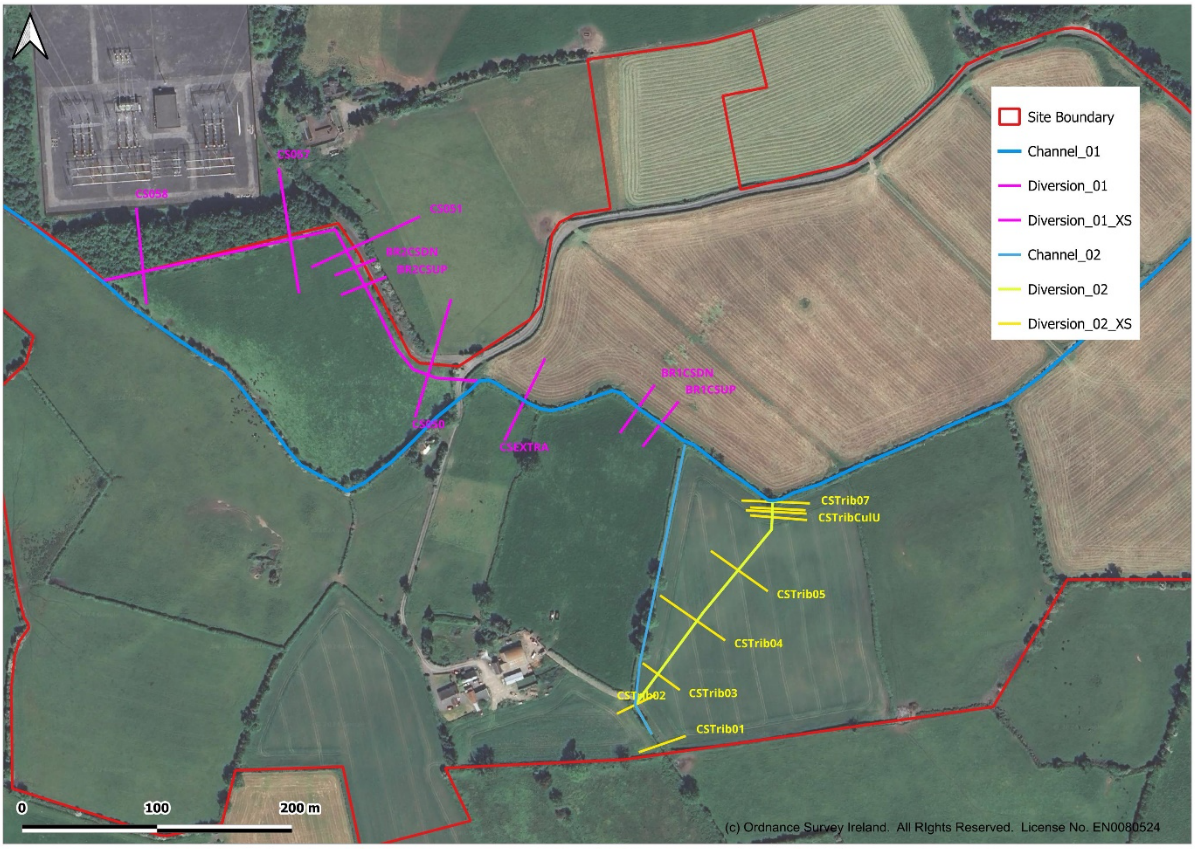
Cross Section	Channel 01			
	Q_{100} Flow (m^3/s)	Q_{100} fluvial flood levels (mOD)	Q_{1000} Flow (m^3/s)	Q_{1000} fluvial flood levels (mOD)
CS025	2.40	42.99	3.16	43.10
CS026	2.40	42.48	3.16	42.88

5.3 MODEL BUILD – REALIGNED DRAINAGE REGIME

In order to facilitate efficient site layout design the proposed development works include for the realignment of the local drainage network at two separate channel reaches, as indicated in Figure 8:

1. Realignment 01 – Channel 01. The reach between CS016 and CS020 will be diverted north and then west for 350 m. The culvert currently in place at CS016 shall be decommissioned.
2. Realignment 02 – Channel 02. The southern drainage tributary will be diverted northeastwards from where it currently flows past the on-site dwelling. The culverts currently in place at CS102 and CS110 shall be decommissioned. A new culvert will be installed to facilitate a proposed access road just before the southern tributary outfalls to the central channel.
3. Invert levels along the realigned drainage channels have been derived at the cross sections shown in Figure 8, based on a uniform bed gradient between the start and end of each realigned channel reach.

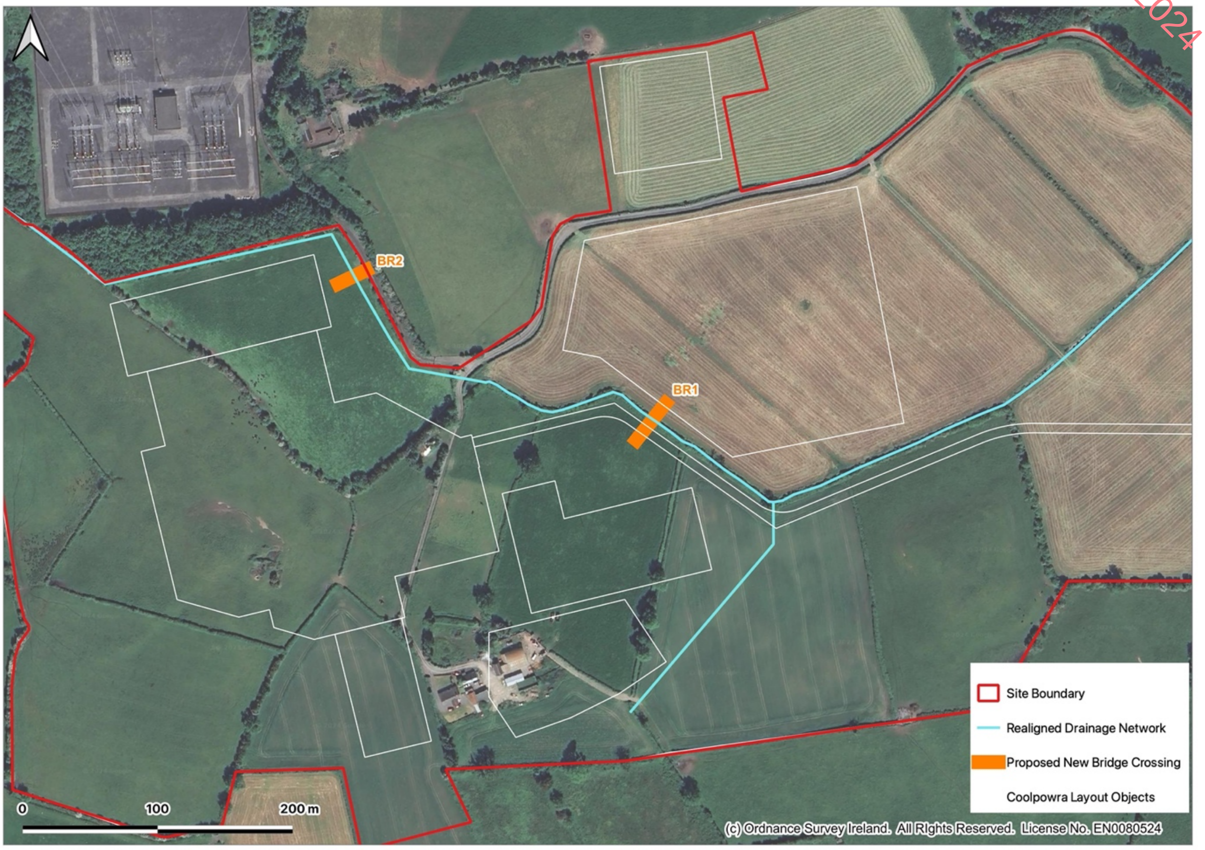
Figure 8 - Location of diverted channels and cross sections



5.3.1 Proposed Structures

In addition to the above, two new bridges are proposed to facilitate new internal access roads, these will be installed (i) on the central channel between CS012 and CS013, and (ii) on the northern limb of Realignment 01. Locations of the proposed bridges are shown in Figure 9.

Figure 9 - Location of Proposed Bridges



The proposed replacement culvert structure will be located on Realigned Channel 02, just upstream of its confluence with Channel 01. It will have the following specifications:

- CSTribCul = New culvert upstream of confluence of Realignment 02 and Channel 01:
    - 1 no. circular concrete culvert with an opening of 1,200 mm
    - Width = 6 m
    - Pipe crown elevation = 52.45 mOD
    - Pipe invert elevation = 51.25 mOD
    - Culvert deck level = new access road elevation

The design specifications for the two new proposed bridges require a freeboard of 300 mm for the water level corresponding to the Q_{1000} + climate change flow. The bridge structure consists of a precast concrete deck. Stone gabions will act as a foundation to the concrete base of the deck level, which will be set back approximately 1m from the top of the channel bank. There will be a minimum clearance of 400mm from the top of the channel bank to the bridge soffit.

- BR1 = Proposed bridge along Channel 01 between CS012 and CS013:
  - Precast concrete bridge deck
  - Length = 6 m
  - Soffit elevation = 53.0 mOD
  - Spring elevation = Ground elevation
  - Bridge deck level = 53.5 mOD
- BR2 = Proposed bridge on northern limb of Realignment 01
  - Precast concrete bridge deck
  - Width = 6 m
  - Soffit elevation = 51.0 mOD
  - Spring elevation = Ground elevation
  - Bridge deck level = 51.5 mOD

5.3.2 Proposed Drainage Regime Flood Scenarios

The conveyance capacity of all surveyed and realigned cross sections along the existing stream and realigned channel reaches were assessed for suitability to transmit Q_{100} and Q_{1000} flood flows, with a 20% allowance included for climate change. The design flows are as before:

- Central channel (Channel 01) Q_{100} = 1.59 m^3/s
- Central channel (Channel 01) Q_{1000} = 2.10 m^3/s
- Southern tributary (Channel 02) Q_{100} = 0.80 m^3/s
- Southern tributary (Channel 02) Q_{1000} = 1.10 m^3/s

The predicted surface water elevations from the Flood Modeller 1D-model under steady-state conditions are presented in Table 9.

Table 9 - Hydraulic Model Flow Simulation Outputs for Channel 01 with diversions 01 and 02 incorporated

Cross Section	Channel 01 & Channel 02			
	Q_{100} Flow (m^3/s)	Q_{100} fluvial flood levels (mOD)	Q_{1000} Flow (m^3/s)	Q_{1000} fluvial flood levels (mOD)
CS001	1.59	52.57	2.10	52.72
CS002	1.59	52.38	2.10	52.56
CS003	1.59	52.39	2.10	52.58
CS004	1.59	52.37	2.10	52.55
CS005	1.59	52.37	2.10	52.55
CS006UP	1.59	52.28	2.10	52.43
CS006DN	1.59	52.29	2.10	52.44
CS007	1.59	52.29	2.10	52.44
CS008	1.59	52.29	2.10	52.44
CS009	1.59	52.20	2.10	52.34
CS010	2.40	51.93	3.16	52.08
CS011	2.40	51.74	3.16	51.90
CS012	2.40	51.75	3.16	51.92
BR1CSUP	2.40	51.70	3.16	51.87
BR1CSDN	2.40	51.69	3.16	51.86
CS013	2.40	51.68	3.16	51.85
CSEXTRA	2.40	51.40	3.16	51.53
CS014	2.40	50.87	3.16	50.98
CS050	2.40	50.80	3.16	50.92
BR2CSUP	2.40	49.66	3.16	49.63
BR2CSDN	2.40	49.81	3.16	49.89
CS051	2.40	49.07	3.16	49.12
CS057	2.40	48.09	3.16	48.19
CS058	2.40	46.89	3.16	46.99
CS020	2.40	46.37	3.16	46.47
CS021	2.40	44.32	3.16	44.42
CS022	2.40	43.55	3.16	43.71
CS023	2.40	43.33	3.16	43.49
CS024	2.40	43.14	3.16	43.28
CS025	2.40	42.99	3.16	43.10
CS026	2.40	42.48	3.16	42.88
CSTrib01	0.80	53.18	1.06	53.24
CSTrib02	0.80	52.85	1.06	52.91
CSTrib03	0.80	52.46	1.06	52.52
CSTrib04	0.80	52.09	1.06	52.26
CSTrib05	0.80	52.04	1.06	52.23
CSTribCulUp	0.80	51.94	1.06	52.09
CSTribCulDn	0.80	51.93	1.06	52.08

Cross Section	Channel 01 & Channel 02			
	Q_{100} Flow (m^3/s)	Q_{100} fluvial flood levels (mOD)	Q_{1000} Flow (m^3/s)	Q_{1000} fluvial flood levels (mOD)
CSTrib06	0.80	51.93	1.06	52.08
CSTrib07	0.80	51.93	1.06	52.08

The results showed that under flood conditions waters are maintained within the central channel and the realigned tributary to the south. There is no surcharging upstream of any of the new structures. As the floodwaters were contained within the 1D model it was not necessary to develop a 1D-2D linked hydraulic model.

The longitudinal profiles of Channel 01, including the realignments and proposed bridges, are shown for the Q_{100} and Q_{1000} scenarios in Plate 4 and Plate 5, respectively.

The longitudinal profiles of Channel 02, including the upgraded culvert, are shown for the Q_{100} and Q_{1000} scenarios in Plate 6 and Plate 7, respectively.

Plate 4 – Longitudinal Profile of Channel 01 with Realigned Channel under Q_{100} scenario

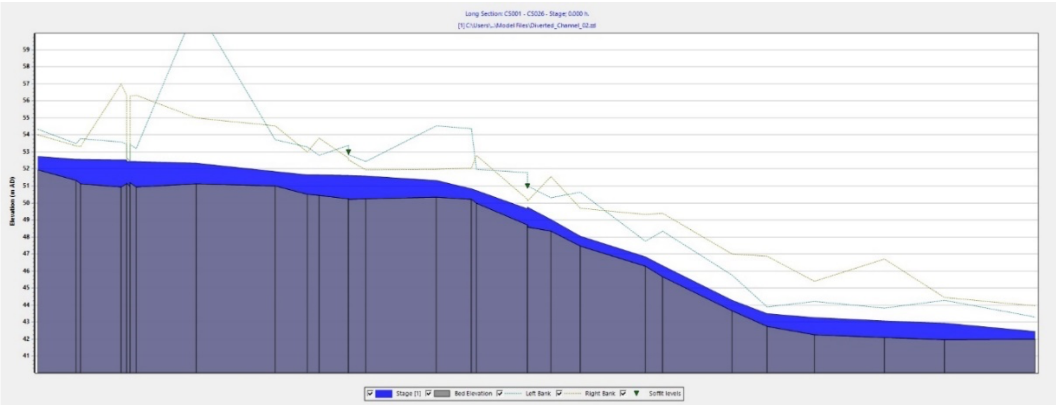


Plate 5 – Longitudinal Profile of Channel 01 with Realigned Channel under Q_{1000} scenario

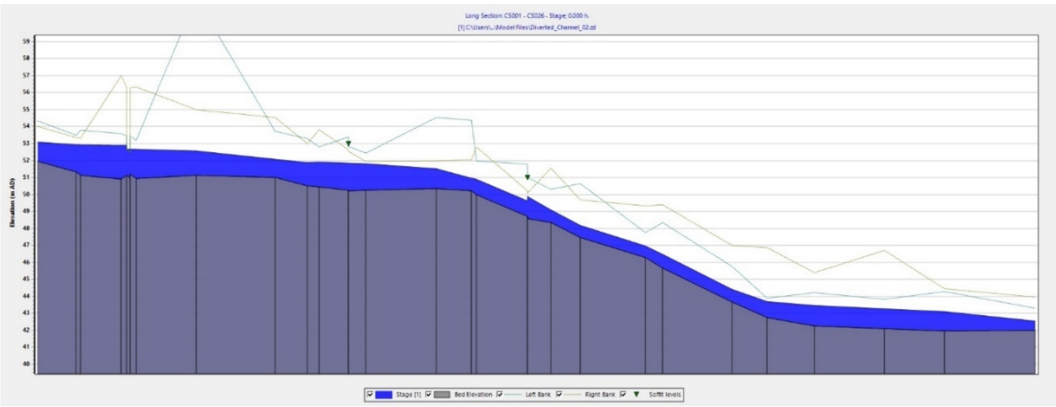


Plate 6 – Longitudinal Profile of Channel 02 with Realigned Channel under Q_{100} scenario

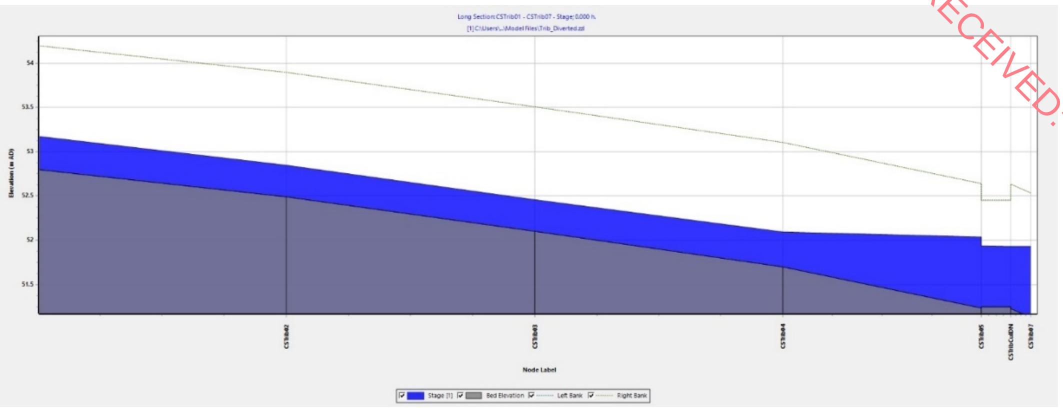
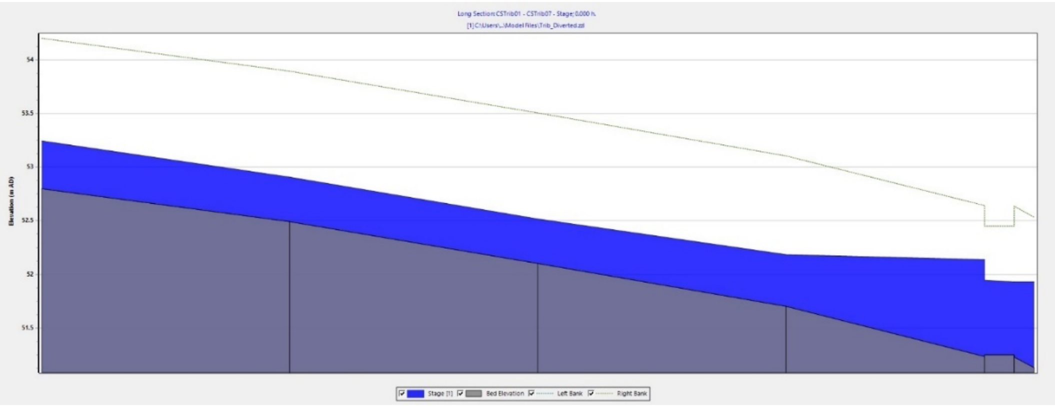


Plate 7 – Longitudinal Profile of Channel 02 with Realigned Channel under Q_{1000} scenario



6 MITIGATION

6.1 OPW SECTION 50

As the two proposed bridges cross a channel that is maintained as part of an arterial drainage scheme permission must be sought from the OPW by way of a Section 50 application. This is typically implied as a Condition of Planning. The proposed bridges have been designed to meet OPW criteria, i.e. that a where a channel is maintained as part of an arterial drainage scheme the opening must be capable of transmitting the Q_{100} with a 1.6 drainage factor applied, plus climate change.

The proposed 1,200 mm diameter culvert along Realignment 02 achieves the required standard of obtaining a 300 mm freeboard under the Q_{100} x 1.6 drainage factor.

6.2 FINISHED FLOOR LEVELS

In order to minimise potential flood risk at the development minimum finished floor level of any new building shall satisfy the 300 mm freeboard requirement above Q_{1000} flood levels, which have been adjusted for climate change.

Finished floor levels of specified proposed structures were assessed to see if this criteria was satisfied, through a comparison with the $Q_{1000 + cc}$ at the nearest adjacent cross section. This analysis is presented in

Table 10 and shows that:

- proposed FFL at structures numbered 3, 4, 5 and 6 needs to be raised 70 mm, from 51.15 mOD to 51.22 mOD;
- proposed FFL at structure numbered 22 needs to be raised 220 mm, from 51.00 mOD to 51.22 mOD

Proposed FFL at all other structures are appropriate and satisfy the requirements of the Flood Risk Guidelines (2009).

Table 10 – Analysis of Proposed Finished Floor Levels

Item Number	Building/Item	Proposed FFL, mOD	Adjacent Cross Section	Q_{1000} + cc Flood Level	Amend Proposed FFL, mOD
1	400 kV Substation	49.65	CS057	48.19	
2	AIS 400 kV	50.25/53.00	Br2CSUp	49.63	
3	Transformers (OCGT)	51.15	CS050	50.92	51.22
4	House Transformers	51.15	CS050	50.92	51.22
5	OCGT Building	51.15	CS050	50.92	51.22
6	Admin./Control Building	51.15	CS050	50.92	51.22
9	Emergency Generators	51.50	CS050	50.92	
10	Firewater Pumphouse	51.50	CS050	50.92	
11	Fire Water Tanks	51.50	CS050	50.92	
12	Workshop & Storage	51.50	CS050	50.92	
13	Fuel Polishing Unit	51.50	CS050	50.92	
14	Fuel Storage Tanks	51.50	CS050	50.92	
15	Fuel Unloading	51.50	CS050	50.92	
19	IPP Building	53.15	Br1CSDn	51.86	
20	Transformer	53.00	Br1CSDn	51.86	
21	Temporary Construction Compound	53.50	Br1CSUp	51.87	
22	Gas Heater Compound	51.00	CS050	50.92	51.22
24	AGI Compound	54.50	Br1CSDn	51.86	
26	ESB Rural Supply	53.15	CS010	52.08	

6.3 STREAM REALIGNMENT METHOD STATEMENT

6.3.1 Introduction

The following method statement shall be made available to Galway County Council, National Parks and Wildlife Service, and Inland Fisheries Ireland for review prior to works commencing.

The method statement intends to describe programme of works relating to two drainage channel diversions and the subsequent infilling of existing drainage channels, outlining in broad terms the manner in which the different aspects of the work will be undertaken. These works are required to accommodate development works as part of Project Coolpowra.

The aim of this programme of works are as follows:

a. Excavate proposed realignment channels;

b. Decommission redundant stretches and structures;

c. Construction of two bridges along Channel 01

d. Installation of a new culvert on Channel 02;

e. Maximise potential for development of ecological habitat in the recommissioned channels. This will include suitability for fish passage, and provision of areas suitable for spawning;

f. Minimise the amount of damage to existing habitat when diverting flow from channel currently in use to new channel reach.

6.3.2 Cleaning Original Channels

The banks and bed of the original channel are heavily overgrown and require cleaning. This is necessary to ensure the cross-sectional area provides adequate conveyance capacity to transmit flood flows. All vegetation and excess silt in the original channel will be removed using an excavator.

It is acknowledged that there will be a temporary adverse impact to habitat associated with the removal of this vegetation. Once new vegetation is established, the longer-term impact will be positive.

6.3.3 Channel 01 Realigned Section Invert Levels

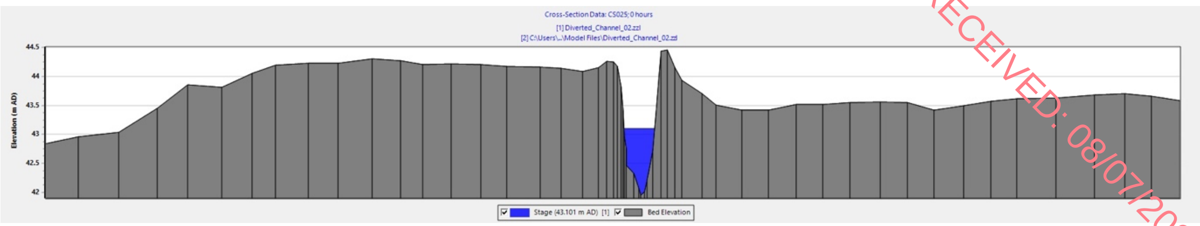
The gradient for the realigned channel in Channel 01 is 1.4%. Proposed inverts for each cross section along this reach are shown in Table 11.

Table 11 – Proposed Invert Levels on Specified Sections on Channel 01 Realigned Reach

Cross Section	Proposed Invert Elevation (mOD)
CS014	53.18
CS050	52.85
BRCSUP	52.46
BR2CSDN	52.09
CS051	52.04
CS057	51.94
CS058	51.93
CS020	51.93

The realigned Channel 01 will have a general cross section profile as shown in Plate 9.

Plate 8 – Proposed cross section dimensions in realigned section of Channel 01



6.3.4 Channel 02 Realigned Section Invert Levels

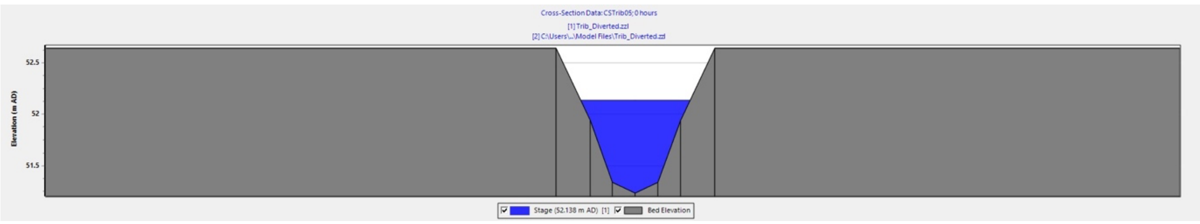
Proposed inverts for each cross section along Channel 02 reach are shown in Table 12.

Table 12 – Proposed Invert Levels on Specified Sections on Channel 01 Realigned Reach

Cross Section	Proposed Invert Elevation (mOD)
CSTrib01	52.80
CSTrib02	52.49
CSTrib03	52.10
CSTrib04	51.70
CSTrib05	51.25
CSTribCulUP	51.25
CSTribCulDN	51.25
CSTrib07	51.24

The realigned Channel 02 will have a general cross section profile as shown in Plate 9.

Plate 9 – Proposed cross section dimensions in realigned section of Channel 02.



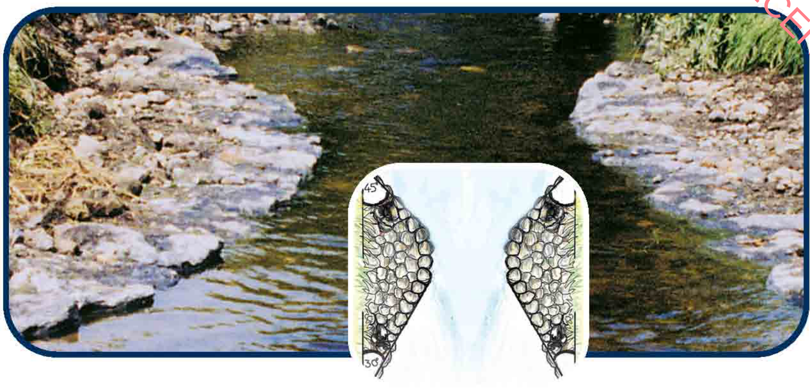
6.3.4.1 General Channel Modifications

The gradient across the Channel 01 route is moderate to high which means there is potential for introducing oxygen to the stream by way of cascades and turbulent zones. Velocity, and turbulence, can be increased slightly at minor narrowed sections in a low flow channel, as per Plate 10.

Rows of larger stones/boulders will be placed on the stream bed in flatter sections to create riffles. Where possible, the channel will be deepened on the outer side of any bends to create pools.

ENVIROLOGIC

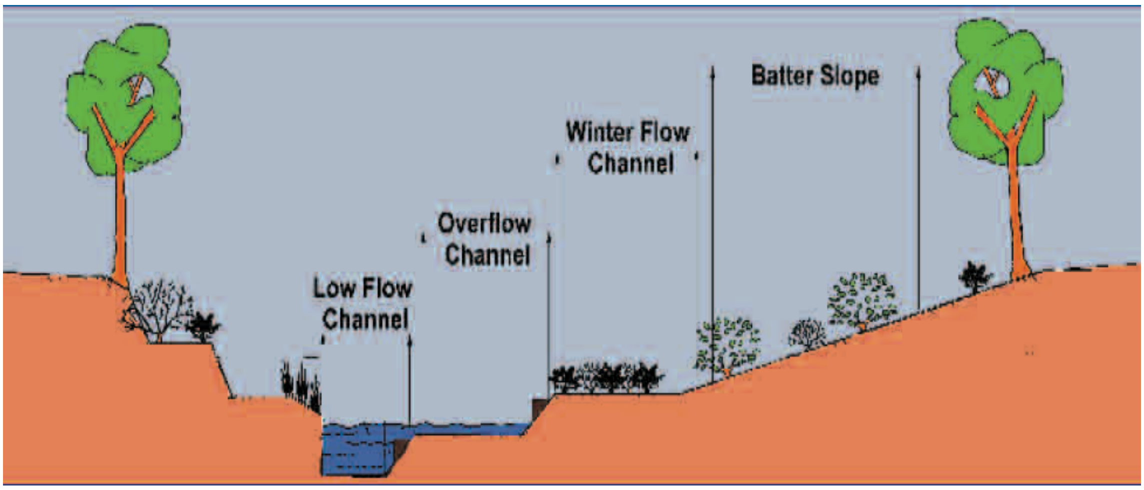
Plate 10 – Narrow river channel in low flow (IFI & OPW, 2010)



6.3.5 Channel Cross Sections

The width of the river channel will be reduced from the river bed to a height of 300 mm. This reduced width will be around 0.5 – 1.0 m. This has the effect of maintaining higher velocities in the wetted channel during normal and low flow regimes. The upper section of the profile will be wider, to provide a conveyance capacity capable of transmitting flood flows. A schematic is presented in Plate 11.

Plate 11 – Schematic of stream cross sectional profile (ERFB, 2011)



The inside of any channel bends will be landscaped with sloping marginal benches, as shown in Plate 12.

Plate 12 – Example of stepped bend of river bend

6.3.6 Channel Bank Vegetation

Any excavated soils will be stockpiled temporarily and used to cap the banks of the rehabilitated channel. This will promote establishment of vegetation.

The rehabilitated channel bank will be planted with native species that can be controlled/maintained to ensure conveyance capacity of channel is not significantly reduced by overgrowth in future. Grass and juvenile, native trees are deemed suitable. Trees will provide cover to pooled sections of the river channel.

Bank gradients should be such that no bank failure or slippages will occur in future.

6.3.7 Channel Opening

Works on the diverted channels will commence from the downstream end. Once the diverted channels and structures are fully complete, the existing channels can then be diverted and sealed off from any flow and infilled. Upon flow entering the diverted channels, a cofferdam should be placed at the downstream end of each diverted channel to trap excess sediment and prevent it entering the watercourses downstream of the site. Straw bales can be placed at increments along each diverted channel to trap sediment. Sediment removal can occur periodically over the first number of weeks following flow entering the diverted channels.

6.3.8 Hydrocarbons

Hydrocarbon spill kits will be on-site during works. Any fuels and lubricants will be stored in bunded compounds. Refuelling will be carried out safely and securely away from the river environs. Machinery will be fully inspected prior to, and during, the course of works for suitability. Support vehicles will remain on the tarmac / hard-core roadway.

6.3.9 Timing of Works

All works within the river channel shall be carried out between the months of August to September, to coincide with low stream flows and to avoid interference with spawning runs.

Bank maintenance works on existing sections, primarily involving the removal of scrub, should take place between October and March.

Following opening of the diverted channels, water flow will be maintained in the existing channels for a minimum period of 24 hours, to facilitate downstream migration of any insects/fish.

6.3.10 Invasive Species

Standard precautionary measures to be practiced for protection against risk of invasive species. Any machinery, including excavator and dumper will be cleaned with a pressure washer prior to arriving on site, and upon leaving site.

7 SUMMARY

Development works are proposed at a site in Coolpowra, Portumna, Co.Galway. The development consists of an upgrade and replacement of the existing 500kV AIS substation with a 400kV GIS substation, a reserve Gas-Fired Generator comprised of three OCGT Units and various alternative technology infrastructure.

Following groundtruthing it was confirmed that the proposed development site lies within a catchment that drains westwards to the Kilcrow River. A central channel runs through the site from the eastern to the western boundary. This channel is maintained as part of the Killimor Arterial Drainage Scheme with the result that many of the cross sections are deep and narrow. The surface water catchment to the downstream site boundary has an area of 2.0 km^2. Multiple field boundary drainage channels are present throughout the site, with one in particular noted as having a significant flow contribution to the overall site run-off.

A thorough desktop study confirmed that there are no indicators of historical flooding at the site nor is the site deemed to be within an area at risk of fluvial, pluvial or groundwater flooding.

Given the small catchment size the IH124 method was selected to estimate flood flows in the central channel as it flows through the site. Suitable adjustment factors, growth factors and climate change factors (+20%) were applied and the resultant Q_{100} and Q_{1000} flows at the downstream site boundary were calculated as 2.4 m^3/s and 3.16 m^3/s respectively.

A 1D-hydraulic model was compiled using site-specific data. Evenly spaced cross sections were surveyed along the central channel throughout the site and a tributary which extends to the south. The surveyed cross sections extended approximately 400 m downstream of the application site boundary.

The conveyance capacity of all surveyed cross sections along the central stream (Channel 01) and southerly drainage tributary (Channel 02) were assessed for suitability to transmit Q_{100} and Q_{1000} flood flows, with a 20% allowance included for climate change. The simulation output showed that under Q_{1000} conditions the existing culverts at CS006 and CS016 are vulnerable to surcharge, but floodwaters are maintained within the upstream bank profile. Under the proposed development works, the culvert at CS016 is to be decommissioned following the proposed channel diversion upstream of the CS016 culvert.

Two culverts on the southern tributary surcharged, resulting in bank overtopping. The more southerly culvert is to be decommissioned while the culvert at the northern end of Channel 02 shall be upgraded.

The modelled reaches are to be re-aligned in two locations to facilitate efficient site layout. Two new bridge crossings are also proposed. Detailed design specifications are included for new bridge structures and the cross sections and longitudinal profiles of the realigned channel reaches. Additional mitigation measures are outlined to enhance habitat quality and biodiversity in the new channel reaches.

Following incorporation of the culvert upgrade, two channel realignments, and two new bridge structures modelling showed that that there will be no surcharge of flood water outside of the stream channel under Q_{1000} conditions, with a climate change factor included. Therefore, it can be confirmed that the application site is currently in Flood Zone C and will remain in Flood Zone C following proposed works (i.e. not at risk of flooding). The proposed works will not result in an increased flood risk within the site or downstream.

Subject to the proposed works being carried out in accordance with the specifications presented in this assessment, it can be concluded that the proposed development will not have a negative impact, in terms of flood risk, on the local drainage network, on local private property, or to the surrounding environment and human health.

Permission for the proposed bridges shall be sought from the OPW by way of Section 50 license applications.

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