Oifig na nOibreacha Poiblí
Office of Public Works

Flood Map Update

MR037 Mohill

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2.0	Final	KM	DW	CG	09/12/25

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Glossary

AEP – Annual Exceedance Probability

AFA - Area for Further Assessment

AMAX – Annual Maxima

CFRAM - Catchment Flood Risk Assessment & Management Study

FSU - Flood Studies Update

HEPs - Hydrological Estimation Points

HEFS – High-end Future Scenario

ISIS-TUFLOW - Hydraulic Modelling Software

LA – Local Authority

MRFS – Mid-range Future Scenario

PCDs – Physical Catchment Descriptors

QMED – Median Flow

1 Map Review Programme

The Map Review Programme is the process that the OPW follows to update predictive flood mapping to continue to provide the best available flood risk information to as wide an audience as possible. The Flood Maps have been developed from detailed engineering analysis and modelling. There is always some uncertainty with regard to the accuracy of predictive flood models; however, the detailed models used have been developed using the best available modelling techniques, tools and data at the time of production.

Updates and revisions to the Flood Maps will be prepared as appropriate. Updates to the Flood Maps are considered when one of the below criteria are met:

- A change in the physical conditions since the Flood Map was produced. Examples of potential changes include new infrastructure, a new development, a culvert or bridge upgrade, land raising, channel realignment, etc.
- An error has been identified in the survey. Errors in the survey may include a channel missing or a channel misaligned, or an error in the surveyed levels used.
- Completion of an OPW-funded Flood Relief Scheme or Minor Works Scheme.
- Evidence presented by a recent flood event that calls into question the published Flood Map.
- The completion of a Strategic Flood Risk Assessment, supported by hydraulic modelling, which produces flood maps that are materially different to the OPW published Flood Map.

The Flood Map Review Programme covers Flood Maps produced by the National Catchment Flood Risk Assessment and Management Programme (CFRAM) and other projects that produce detailed productive flood mapping as published as Flood Maps on www.floodinfo.ie. The CFRAM Programme was the principle vehicle to deliver on Ireland's commitments under the EU Floods Directive (2007/60/EC). The EU Floods Directive also requires that the Member States review and if necessary update the flood maps on a six-yearly cycle; the Map Review Programme is the process that satisfies this requirement.

The review of indicative national mapping datasets such as the outputs of the National Indicative Fluvial Mapping study and the National Coastal Flood Hazard Mapping is not considered as part of the Map Review Programme.

2 Preliminary Assessment

2.1 Introduction

A Preliminary Assessment of the perceived deficiencies in the flood mapping for the Mohill Area for Further Assessment (AFA) has been carried out. Details of this Preliminary Assessment are included in this section.

Note that this Preliminary Assessment should not be considered conclusive and further investigation, and analysis will be required to ensure that the revised flood mapping represents the existing situation as closely as possible.

The Preliminary Assessment considers the following:

- Discussions with Stakeholders of the issues;
- Identification and preliminary review of CFRAM data, CFRAM mapping, hydrology and hydraulics methodology
- A preliminary review of key hydraulic structures within the AFA.

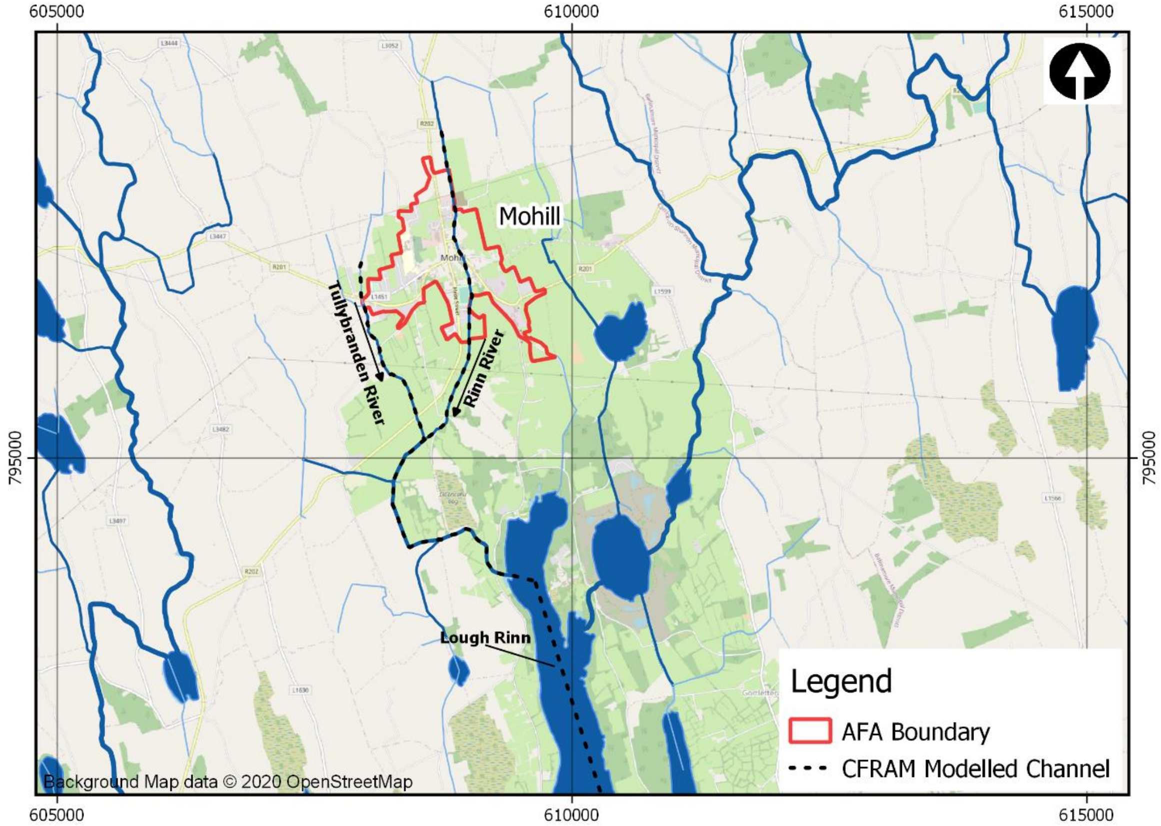

Figure 2-1 - Overview of Mohill

2.2 Stakeholders

A Map Review was requested by Leitrim County Council, the Local Authority (LA) for Mohill. A summary of their reasoning is listed below:

- The LA noted that a 1D only model was used to produce the flood extents for the CFRAM Study. The LA noted that this may not be suitable for complex urban flow paths and does not reflect conditions on the ground.
- The Flood Maps appear pixelated and show inconsistencies.
- The LA noted that they were unaware of property flooding in either 2009 or 2015 flood events.
- The LA flagged that the culvert within the town has a history of blockage but no property flooding was associated with this.
- Concerns were raised by the LA that the model for Mohill was not calibrated. At the time of the CFRAM no gauge that was available for calibration. The Shannon CFRAM also noted that some of the hydrologically predicted flows at Hydrological Estimation Points (HEPs) could not be reflected in the hydraulic model.

2.3 Shannon CFRAM Study

2.3.1 Hydraulic Model - Schematisation

The Shannon CFRAM study model for Mohill (N02) is available. The model is a 1D-2D ISIS – TUFLOW model. The model is of catchment scale and the 2D area refers to a different urban area on the reach. Mohill is represented using extended 1D cross-sections, see Figure 2-2.

A review of the model schematisation indicated that the concerns raised by the local authority are valid. The model makes use of extended cross-section across an urban floodplain. For mapping purposes, the water level is projected across this extended line – ignoring whether the flow is contained in the river channel. Therefore, a 1D-2D model is required in the urban area to accurately assess the flood risk.

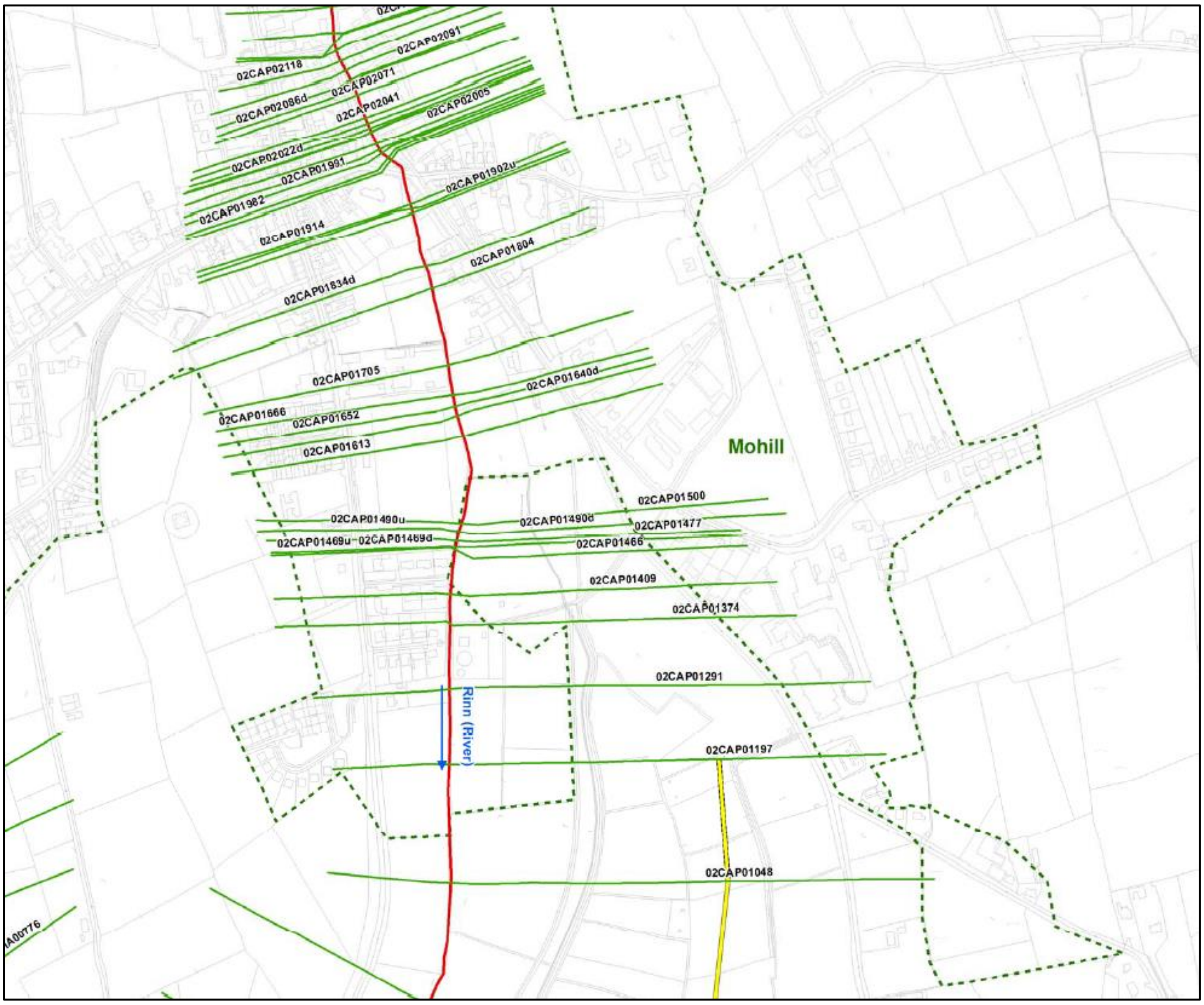

Figure 2-2 - Mohill AFA - CFRAM Model Schematisation - Extracted from Shannon CFRAM 25/26 N02 Hydraulic Report

The Shannon CFRAM hydraulics report did not flag any model assumptions and limitations associated with Mohill. The CFRAM Study also did not flag any deficiencies in the available survey data.

2.3.2 **CFRAM Design Flows**

The hydrology developed for Mohill by the CFRAM Study is based on Flood Studies Update (FSU) ungauged site methods. No gauge data is available for the Mohill AFA. The Shannon CFRAM used the seven variable equation developed in FSU Work Package 2.3 to estimate QMED flows at Mohill. This method is typically recommended for use in catchments with an area greater than 25km^2 which is not the case at the Mohill AFA (10 km^2 approx.). For catchments less than 25km^2 the recommended equation is the FSU five factor equation (Work Package 4.2a) – this will be examined and updated if required in this study.

The design flows were developed using an ungauged assessment and pooling group. The peak flows will be reviewed and reassessed as part of this Map Update. If required, the flows will be updated based on the latest datasets available.

2.3.3 CFRAM Hydrograph Shape

The CFRAM developed a flood hydrograph width from a gauge downstream in the catchment – 26008 Johnston's Bridge, see Figure 2-3. This is known as a pivotal site – where the shape of the flood hydrograph at a gauged location is transposed to an ungauged site. A comparison between key physical catchment descriptors at the pivotal site (26008 Johnston's Bridge) and just downstream of the Mohill AFA is shown in Table 2.1 and Figure 2-3. For comparison, a typical HEP located just downstream of Mohill was selected.

Table 2.1 – Comparison of Key Physical Catchment Descriptors

PCDs	**26008 – Johnston's Bridge**	**26_1894_2 – D/S Mohill**
Area (km^2)	280	10.5
BFIsoil	0.611	0.472
SAAR (mm)	1035	1036
FARL	0.855	1
S1085 (m/km)	1.106	4.163

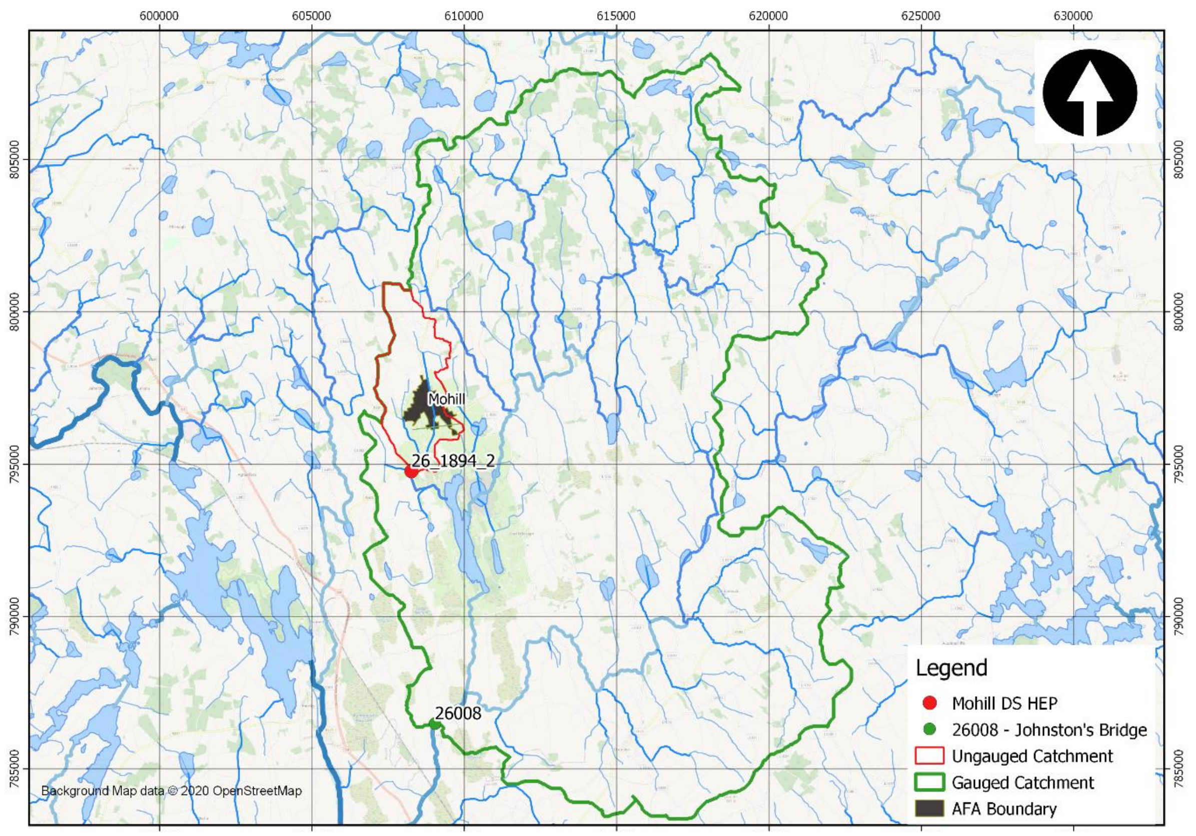

Figure 2-3 - Mohill Catchment & Gauged Catchment (Pivotal Site)

As can be observed from both Table 2.1 and Figure 2-3 the catchment size of the pivotal site is significantly bigger than at Mohill (by a factor of 28). There is also a larger number of lakes upstream of the pivotal site which would attenuate flows as can be seen from the relatively low FARL value - a measure of reservoirs and lakes within a catchment. The hydrograph shape used in the CFRAM study (see 21/11/2009) is shown in Figure 2-4.

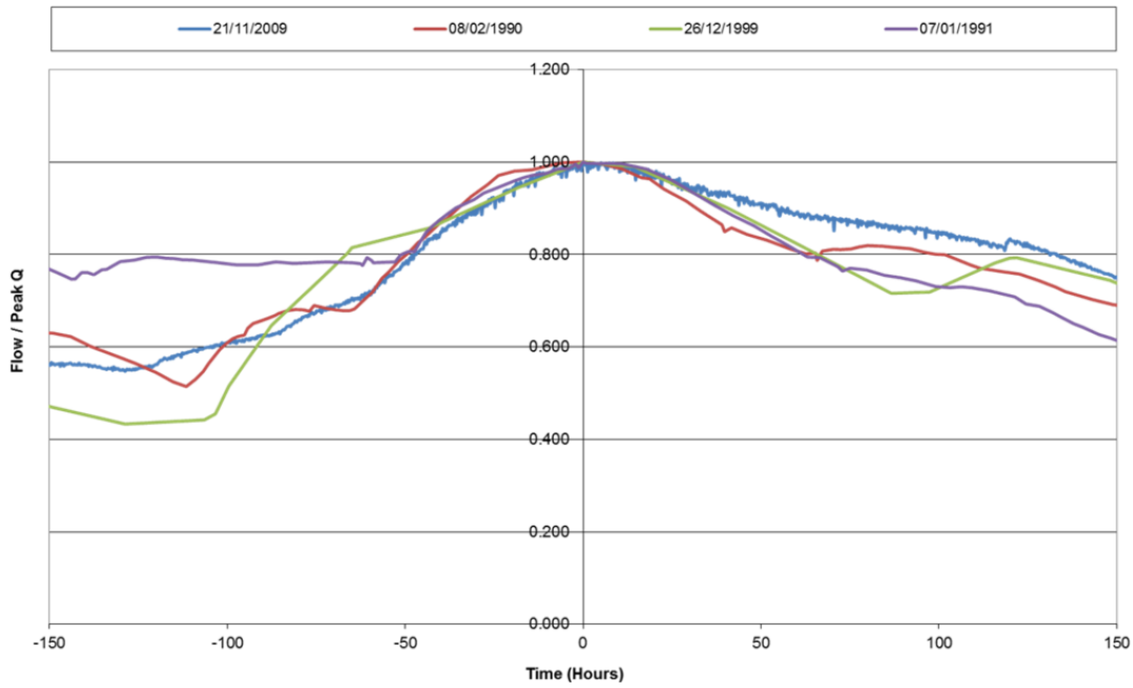

Figure 2-4 – Mohill AFA Hydrograph Shape – Figure A1.10 Extracted from Shannon CFRAM 25/26 N02 Hydraulic Report

The hydrograph is considerable in its length with a time to peak of 150 hours. The catchment at Mohill is small, without any lakes or reservoirs; it is unlikely that the catchment of the River Rinn at Mohill would have a similar hydrograph shape to the chosen pivotal gauge. The catchment at Mohill would be significantly flashier than the selected gauge. Therefore, it is likely that the hydrograph shape used here is not suitable. While the peak flows may not be altered the time to peak is overestimated. This may influence flood extents in areas where out-of-bank flows occur.

The Shannon CFRAM hydrology report notes that the hydrograph shape for this reach may be “more suitable” for other reaches than for the River Rinn. A sensitivity test undertaken with a realistic hydrograph for the area concluded that the reduction in “flood depths was negligible in and around the Mohill AFA which confirms that flooding is dominated by the flood peak, not the volume”. This conclusion was based on the outputs of a 1D only model. In a 1D-2D model where the floodplain storage is explicitly accounted for, the flood volume may impact flood extents. This will be reviewed further in this Map Update study.

2.3.4 CFRAM Calibration

As noted previously the no flows gauge is located within the AFA to undertake a calibration or verification exercise. No alternative sources of data were identified to validate the model during the CFRAM study.

Concerns were raised by the LA that hydrology for the River Rinn was not calibrated. Overland flow paths from the floodplain of the River Rinn bypass the lower reaches of the River Rinn and join directly into Lough Rinn. The theoretical flows did not match the modelled flows as did not account for this bypassing of flow. Although the model did not “calibrate” to the theoretical peak flow this does not necessarily indicate an issue with the hydrology; to force the model to match the theoretical flow can add flow unnecessarily. The appropriateness of the flow rates in the channel will be examined in this Map Update.

2.4 Key Hydraulic Structures

A review of the CFRAM survey and model indicated one key structure which is likely to be a significant hydraulic control within Mohill, see Table 2.2 - Key Structure. A site visit will be undertaken to help discern the most appropriate representation of the structures in the model. The site visit will also identify any other key structures or additional survey required.

Discussion with the LA have indicated that there have been no changes to the culverts or channels in and around Mohill. A site visit will be undertaken to confirm this, and confirm if any additional survey is required.

Table 2.2 - Key Structure

<table>
<tr><th>Location</th><th>Upstream Face</th><th>Downstream Face</th></tr>
<tr><td rowspan="2">Main Street Culvert</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">Larger diameter pipe behind upstream arch. Significant reduction in channel size entering structure.

Development in channel downstream of culvert. Steel girders in channel may cause blockage risk at downstream face. Critical structure for model.</td></tr>
</table>

2.5 Summary of Preliminary Assessment

The outcomes from the Preliminary Assessment can be summarised as follows:

- The 1D extended cross-sections that were used to model Mohill in the CFRAM study was not appropriate – a 1D-2D model will be developed and the mapping updated;
- The peak flows developed will be updated and combined with a more realistic hydrograph shape. A review of the methods undertaken to estimate QMED will also be completed;
- Two key hydraulic control structures were identified. A site visit to Mohill will be used to confirm if any additional structures or changes to the watercourse through the Mohill AFA have occurred since the CFRAM survey.

The above issues identified satisfy the requirements for a Map Update.

3 Hydrology

3.1 Catchment Overview

The focus of this Map Update is the AFA of Mohill. The catchment of the Rinn River which flows north to south through the centre of the town ranges from 4.5-5.5 km^2. Roughly 1 km downstream of the AFA, the Tullybraden River joins the Rinn River increasing the catchment size to 9.9km^2. The River Rinn continues southwards before entering Lough Rinn 3.5 km

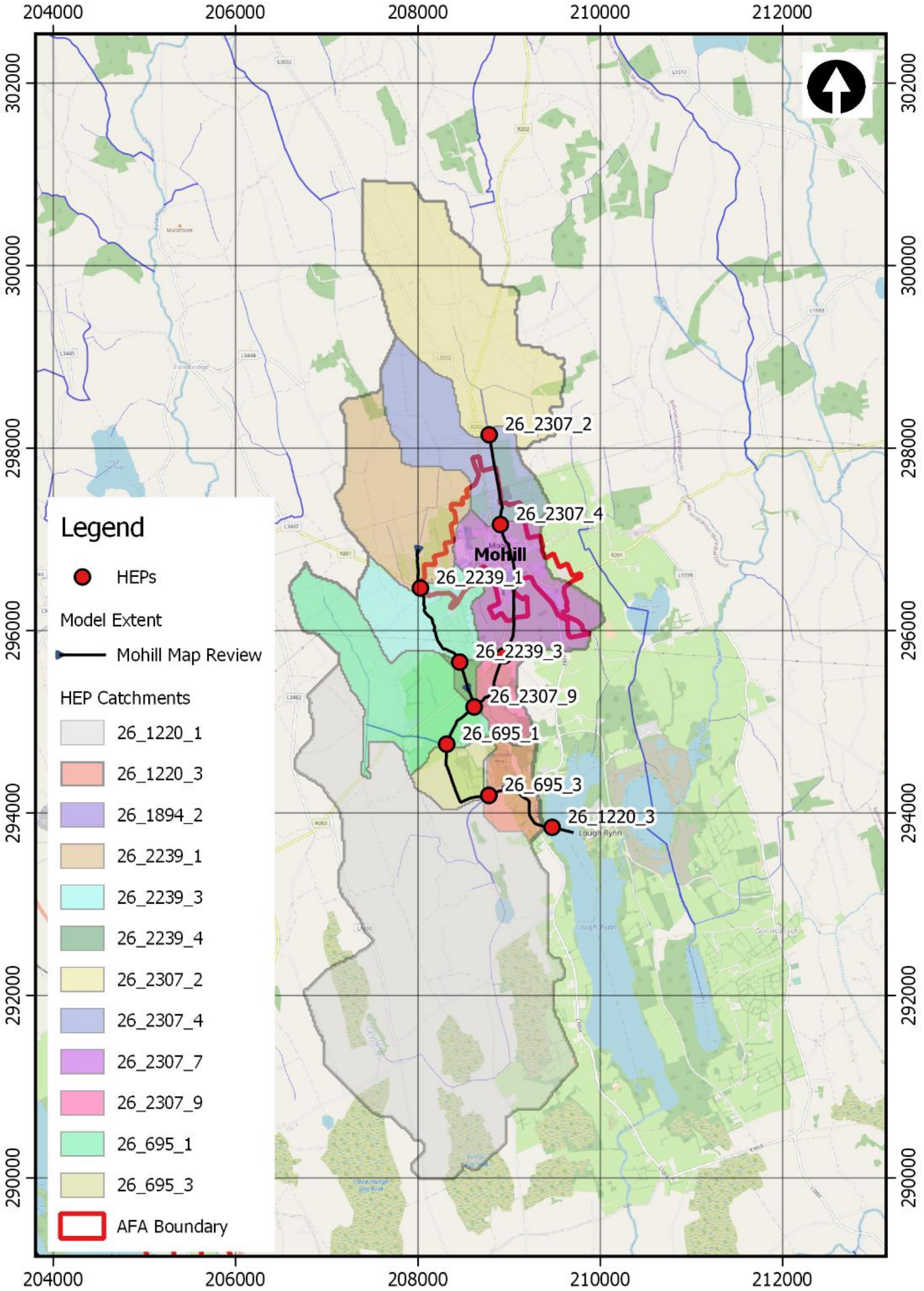

Figure 3-1 - Proposed HEPs and Catchments downstream of the AFA. The catchment is small in hydrological terms, and unusually for the region has no lakes or reservoirs upstream of Mohill.

This Map Update includes the updating of peak flow estimates for the HEPs used on the Shannon CFRAM study from the modelled watercourse upstream of Mohill to the confluence with Lough Rinn, see Figure 3-1.

The confluence has been selected as the downstream extent of the model as it is a natural hydraulic break and remote from the AFA to minimise uncertainty. The HEPs selected previously are considered appropriate for use in this study. A summary of key physical Catchment Descriptors (PCDs) of the HEPs is shown in Table 3.1.

Table 3.1 – Summary of HEP PCDs

HEP	AREA (km^2)	FARL	S1085 (m/km)	BFISOIL	SAAR (mm)
26_2307_2	3.2	1.00	8.4	0.45	1049
26_2307_4	4.8	1.00	5.7	0.45	1049
26_2307_7	6.4	1.00	5.8	0.48	1041
26_2307_9	6.8	1.00	4.4	0.45	1039
26_1894_2	10.5	1.00	4.2	0.47	1036
26_695_1	11.8	1.00	4.2	0.47	1034
26_695_3	12.2	1.00	3.5	0.47	1034
26_1220_1	21.6	0.97	3.5	0.48	1022
26_1220_3	22.2	0.97	2.7	0.48	1021
26_2239_1	1.9	1.00	3.3	0.47	1041
26_2239_3	2.9	1.00	8.0	0.47	1033
26_2239_4	3.0	1.00	8.7	0.47	1033

3.2 Index Flood (QMED) Estimation

As no gauge is available within the study area the calculation of the index flood at each of the HEPs can only be based on their PCDs. There are several potential methods to estimate QMED:

- The FSU seven variable equation - typically recommended for use in catchments with an area greater than $25km^2$. This method was used on the CFRAM study;
- The FSU five variable (Work Package 4.2a) - recommended for catchments less than $25km^2$;
- The FEH Statistical with revised equation for QMED method is applicable to catchments greater than $0.5km^2$ although based off rural catchments in the UK;
- The Institute of Hydrology (IoH) Report 124 method provides an estimate of QBAR and is applicable to catchments less than $25km^2$.

Table 3.2 – Rural QMED Estimates

	FSU: 7-Variable	FSU: Work Package 4.2a	FEH	IoH 124
HEP	QMED			QBAR
	m^3/s	m^3/s	m^3/s	m^3/s
26_2307_2	0.9	1.5	2.1	2.3
26_2307_4	1.2	2.0	2.9	3.3
26_2307_7	1.5	2.4	3.3	4.2
26_2307_9	1.7	2.5	3.8	4.5
26_1894_2	2.5	3.5	5.1	6.4
26_695_1	2.9	3.9	5.6	7.1
26_695_3	2.9	3.8	5.8	7.3
26_1220_1	4.2	5.8	7.8	11.0
26_1220_3	4.1	5.5	8.0	11.2
26_2239_1	0.5	0.7	1.2	1.4
26_2239_3	0.9	1.3	1.7	2.1
26_2239_4	1.0	1.3	1.8	2.2

The IoH 124 provides the largest estimates of QMED for all HEPs. The estimates are more than double both FSU methods at the most downstream HEP (26_1223_3). As part of FSU Work Package 4.2, the IoH124 method was assessed and found to "overestimate by 509% and underestimate by up to 90%" when compared to gauged values. Due to this known tendency to overestimate, the method has been excluded from further consideration in this study.

The FEH statistical method provides the next largest estimates and has been found to provide reasonable estimates for small catchments (FSU Work Package 4.2) in Ireland but is not based on any Irish data. Therefore, the FEH statistical method has not been considered further.

The FSU seven variable equation provides the smallest estimates of QMED of all those considered; this equation is not recommended for use in catchments less than $25km^2$. The QMED estimates may be lower as larger catchments would tend to be less flashy and have some attenuation which reduces peak flows.

As a general rule (but by no means absolute), the Work Package 4.2a equation is recommended by the OPW Hydrology section for use on catchments between $5km^2$ to 25 km^2. Following comparison with other available methods no justification has been identified which would contradict this advice in this case. Therefore, Work Package 4.2a has been selected as the method for estimation QMED for this study.

The majority of the HEPs, lie within the $5km^2$ to 25 km^2 range. For consistency and to avoid a discontinuity in the flow predictions, the HEPs which are below $5km^2$ have also made use of this method.

Table 3.3 – Final QMED values & Comparison CFRAM QMED values

	FSU: Work Package 4.2a - Rural	FSU: Work Package 4.2a - Urban	CFRAM QMED Values
		Selected for use	
HEP	**m^3/s**	**m^3/s**	**m^3/s**
26_2307_2	1.5	1.5	2.2
26_2307_4	2.0	2.0	2.2
26_2307_7	2.4	2.7	3.0
26_2307_9	2.5	2.8	3.3
26_1894_2	3.5	3.8	4.7
26_695_1	3.9	4.2	5.4
26_695_3	3.8	4.2	5.9
26_1220_1	5.8	6.1	7.6
26_1220_3	5.5	5.8	7.6
26_2239_1	0.7	0.7	0.9
26_2239_3	1.3	1.3	1.6
26_2239_4	1.3	1.4	1.8

Table 3.3 – Final QMED values & Comparison CFRAM QMED values, shows the final QMED values selected for use in this project. In comparison to the CFRAM study, the QMED values selected are slightly lower than previously used on the CFRAM study. Although the FSU seven variable equation (used on the CFRAM study) initially predicts lower estimates than the FSU Work Package 4.2 the final CFRAM values are slightly larger; this is due to a pivotal adjustment of 1.71.

No adjustment has been made to the QMED derived from Work Package 4.2a. The OPW hydrology section recommends no pivotal adjustment as there is insufficient gauges within the source data available to justify this.

3.3 Hydrograph Shape Analysis

As discussed in the Preliminary Assessment (Section 2.3.3) the hydrograph shape used in the Shannon CFRAM was based on the 2009 flood event at a gauge downstream 26008 gauge. This event was significant in length which is unlikely to be replicated at Mohill.

FSU Work Package 3.1 was used to estimate an alternative hydrograph shape at Mohill. The method makes use of gauged data and selects a pivotal site based on the hydrological similarity. In Table 3.4 the suggested pivotal site by FSU Work Package 3.1 and the gauge used on the CFRAM study is shown is compared to a sample HEP from the environs of Mohill.

Table 3.4 – Pivotal Gauge Selection

PCDs	26_695_1	08008 - Broadmeadow	26008 – Johnston's Bridge
	Mohill Hep	FSU: WP 3.1	Shannon CFRAM Study
Area (km2)	12	108	280
BFIsoil	0.47	0.49	0.61
SAAR (mm)	1035	811	1035
FARL	1	1	0.9
S1085 (m/km)	4.2	3.9	1.1

The selected pivotal gauge by the FSU shows good agreement across a number of key PCDs including S1085 and FARL with the Broadmeadow gauge. The catchment at the Johnston's Bridge gauge is significantly flatter than at Mohill (see S1085 values) and is influenced by lakes upstream of the gauge – both of which would cause a longer hydrograph duration than that would be expected at Mohill. While the catchment of Broadmeadow is less than half the size of the catchment at Johnston's Bridge, it is still significantly larger than the catchment at Mohill. There are limited small catchments included in the FSU WP 3.1 database of pivotal sites. A sensitivity analysis will be undertaken to ascertain how sensitive the model is to changes in hydrograph duration. The dimensionless hydrograph used in the CFRAM study and the proposed hydrograph for use is shown in Figure 3-2.

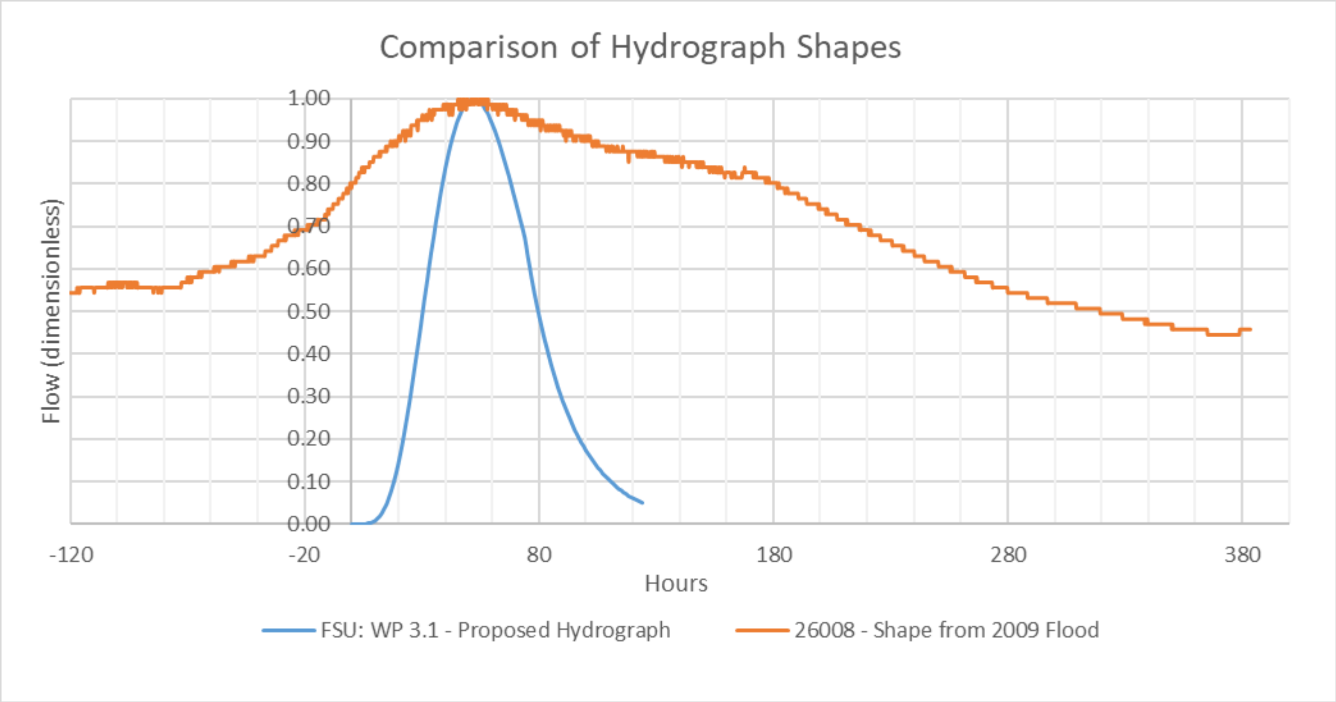

Figure 3-2 – Comparison of Hydrograph Shapes

3.4 Growth Curve & Pooling Group Development

In the absence of any gauge in the Map Update area, to update peak flood flows for Mohill a pooling group is required. Considerable additional data is now available to develop a pooling group since the CFRAM study; not only are additional annual maxima (AMAX) years available but notably, gauges located in Northern Ireland are now available for inclusion. As such it was considered appropriate to update the growth curve developed on the CFRAM study for the required events; those events with an annual exceedance probability of (AEP) of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1%.

The HEP 26_695_1 was used as the representative node for the study area, see Table 3.4 for a summary of its physical catchment descriptors. This growth curve was used to derive peak flows at all other HEPs within the study area. A list of hydrologically similar gauges were identified for inclusion in the pooling group. Each gauge was reviewed individually to ensure that the AMAX series was sufficiently reliable. For example, if a rating could not be substantiated by high flow gaugings or had an insufficiently high reliable limit the gauge was removed from the pooling group. The PCDs of each gauge were also compared to the subject site to ensure that they were not discordant. A summary of this analysis is shown in Table 3.5.

Table 3.5 - Pooling Group Summary – HEP 26_695_1

Gauge	Similarity	Location	Included?	AMAX Years	Cumulative AMAX Years
25040	0.8	Roscrea - Bunow	*Reject – Rating inconsistent with gaugings*	-	-
25034	0.8	Rochfort - L. Ennell Trib	Include	42	42
14031	1.2	Japanese Gardens - Tully	Include	25	67
30020	1.2	Ballyhaunis - Dalgan	Include	30	97
33010	1.3	Glencastle - Glencastle	Include - Gauged at QMED	17	114
10021	1.4	Common's road -	Include	24	138
13001	1.5	Goffs Br. - Mulmontry	*Reject - No high flow gaugings*	-	-
6033	1.6	Coneyburrow Br. -	*Reject – ARTDRAIN discordant*	-	-
24022	1.7	Hospital - Mahore	*Reject - No high flow gaugings available*	-	-
205020	1.7	Comber - Enler	Include	36	174
26010	1.7	Riverstown - Cloone	Include	50	224
8002	1.7	Naul - Delvin	*Reject - No high flow gaugings since rating change*	-	-
30021	1.9	Christina's Bridge - Robe	*Reject - No high flow gaugings since rating change*	-	-
203028	1.9	Whitehill - Agivey	Include	47	271
25044	1.9	Coole - Kilmastulla	*Reject - No high flow gaugings available*	-	-
16005	2.0	Aughnagross - Multeen	*Reject - URBEXT value discordant*	-	-
29001	2.0	Rathgorgin - Raford	Include	55	326
205005	2.0	Ravarnet - Ravernet	*Reject – ARTDRAIN value discordant*	-	-
19001	2.0	Ballea - Owenboy	Include	44	370
34024	2.0	Kiltimagh - Pollagh	Include	43	413
35072	2.0	Trasgarve - L. Easky	*Reject - FARL value discordant*	-	-
7023	2.0	Athboy - Athboy	*Reject - URBEXT value discordant*	-	-
14104	2.1	Greesemount - Greese	*Reject - URBEXT value discordant*	-	-
203019	2.1	Glenone Br. - Claudy	Include	48	461
14014	2.1	Portlaoise - Triogue	*Reject – ARTDRAIN value discordant*	-	-
14009	2.1	Cushina - Cushina	*Reject – ARTDRAIN value discordant*	-	-
1041	2.2	SANDY MILLS - Deele	Include	46	507

The Target period considered for this study is the 1% AEP or 1 in 100 year return period. In pooling groups, it is recommended to follow the 5T rule; for 1% AEP this would equate to 500 years of annual maxima data included in the pooling group. However, care needs to be taken when using the 5T rule as adding additional gauges to reach the target 500 years may introduce gauges that are too dissimilar to the subject site.

FSU Work Package 2.2 indicates that 3 parameter distributions are more appropriate for pooled analysis such as this; it is also noted that the Generalized Extreme Value (GEV) and Generalized Logistic (GLO) are the most suitable for Irish catchments. Figure 3-3, displays the L-moment Ratio Diagram for the target 500 years of data. The Pooled L-moments appear to lie between GEV and GLO plots (although slightly closer to GEV). As a sensitivity analysis 375 years, (T=1.33% AEP or one in 75 year) was set as the target number, to see if the additional years (from 370 to 500) altered the chosen distribution. As can been from Figure 3-4, the pooled L-moments lies slightly closer to the GEV distribution. As the GEV is chosen in both sample, it has been selected for use here.

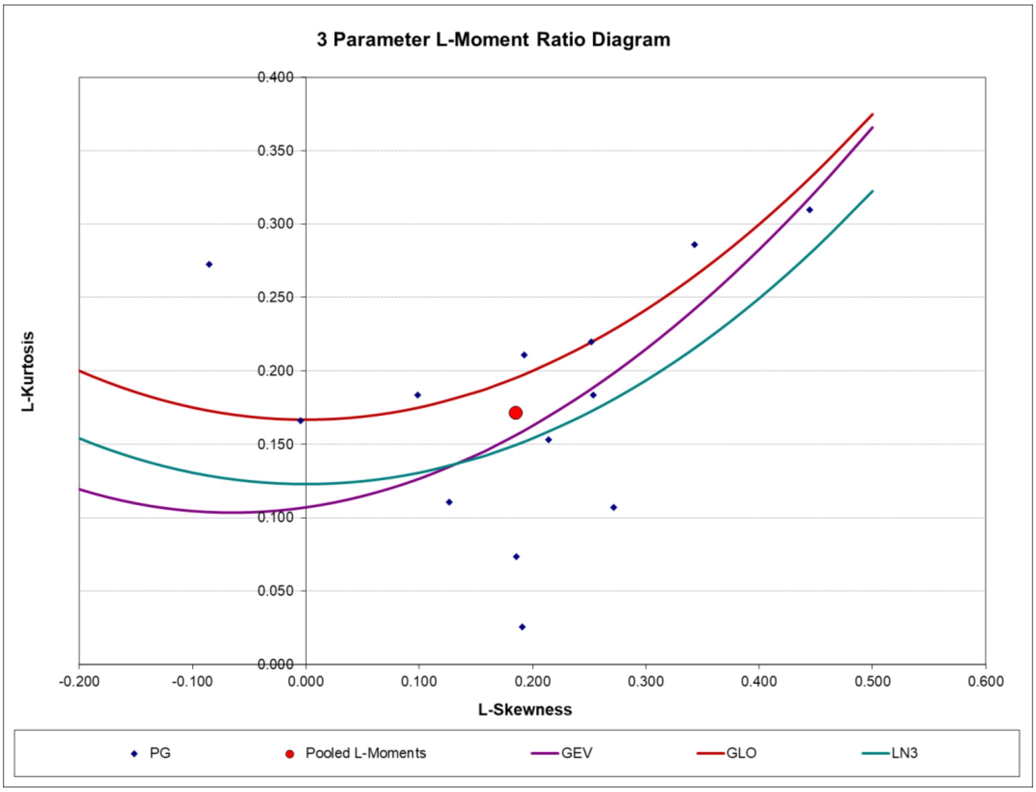

Figure 3-3 – L-moment ratio diagram for T=1% AEP Pooling Group HEP 26_695_1

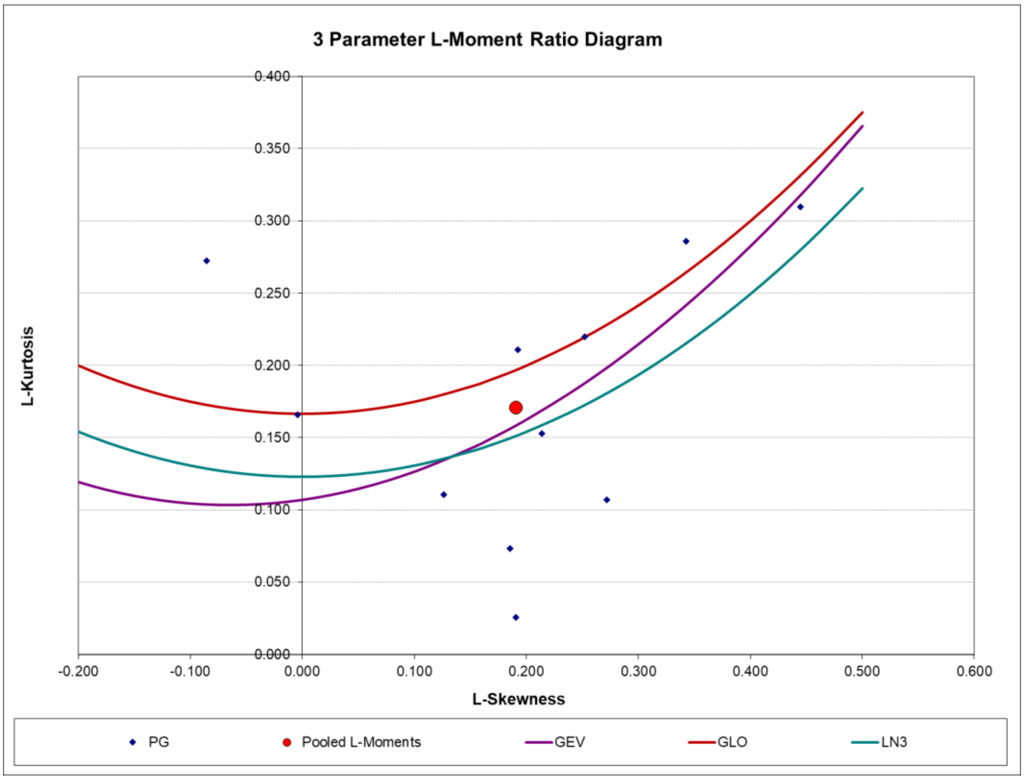

Figure 3-4 – L-moment ratio diagram for T=1.33% AEP Pooling Group HEP 26_695_1

Further analysis of pooling group outputs was undertaken by varying the 5T requirement from 100 to 500 years. A summary of the growth factors produced (GEV distribution) for the HEP 26_695_1 is shown in *Figure 3-5.* There is a reasonable spread in peak values in the estimates for 0.1% AEP event. There is no pattern in the estimates as the smallest pooling group produces the lowest values and the second smallest provides the largest estimates. This indicates that reducing the pooling group size to ensure homogeneity of the gauges is not justified. The 1% AEP is a key estimate for this study and as can been from *Figure 3-5*

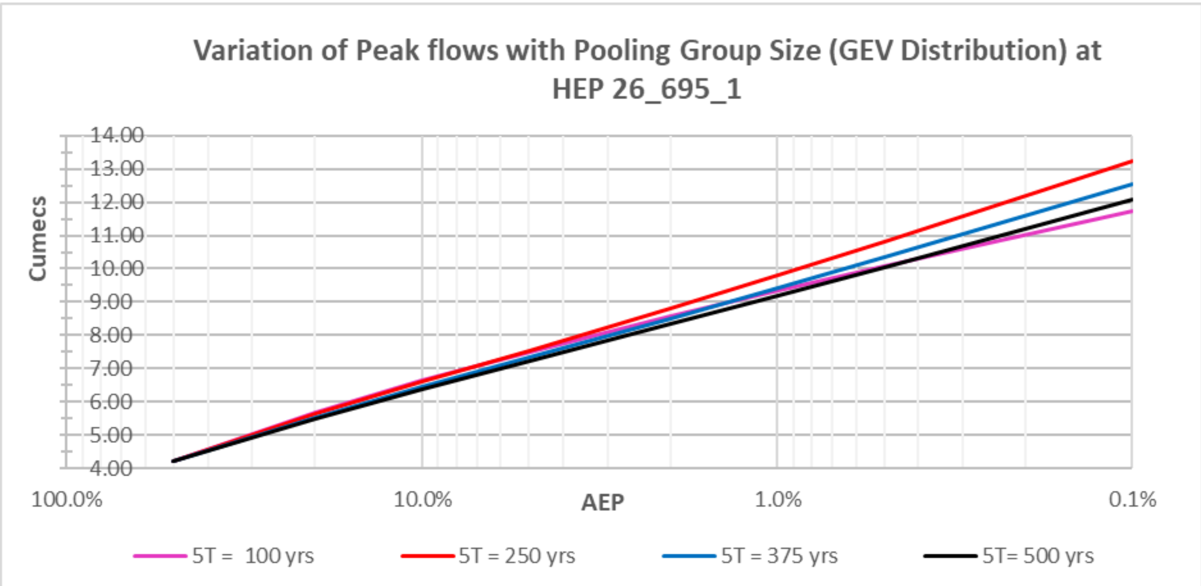

Figure 3-5 – Peak flows variation with pooling group size there is little spread in the values. All estimates lie between 9.2 and 9.8 m^3/s for the 1% AEP. The spread of values is considered small and provides confidence to 1% AEP estimates.

A comparison was also completed with the CFRAM values at the selected representative node (26_695_1). Figure 3-6, compares both growth curves produced and the resultant flows at the sample HEP. The growth curves are broadly similar with the CFRAM indicating slightly higher factors (e.g. 0.1% growth factors are 2.86 and 3.12 for the Map Update and CFRAM respectively). The CFRAM flows are approximately 40% higher than the Map Update ones. This is mostly driven by the use of a 30% higher median flow by the CFRAM study; the discrepancies in median flow selection has previously been discussed in Section 3.2.

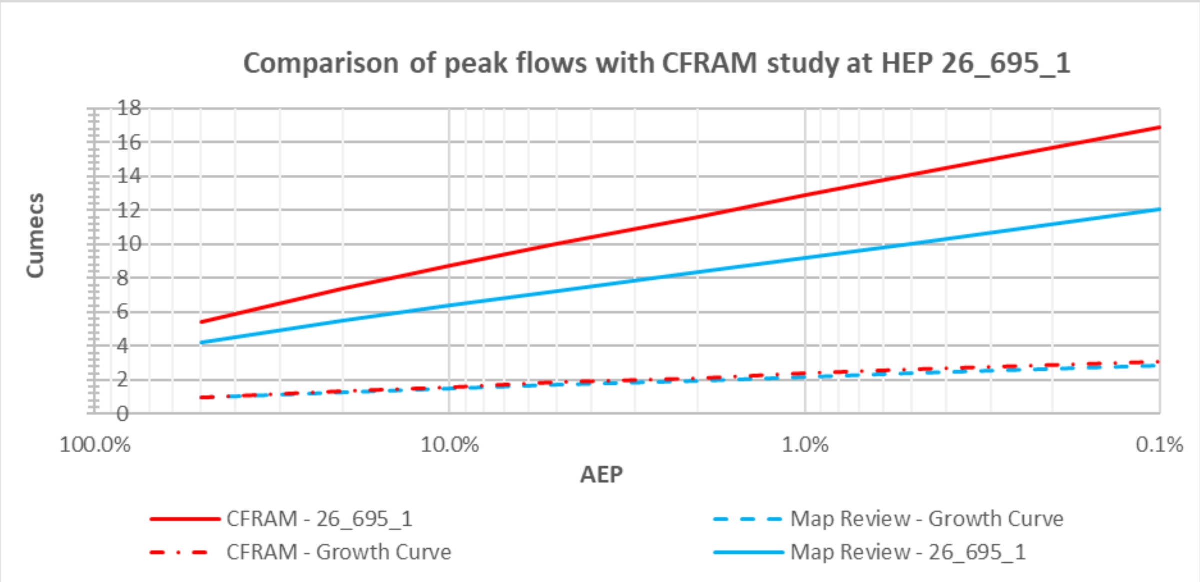

Figure 3-6 – Comparison with CFRAM flow values

3.5 Target Flows

The preliminary target flows are shown in Table 3.6. The flows are derived from the multiplication of the growth curve developed in Section 3.4 and the median flows developed in Section 3.2. Direct flow inputs and lateral inflows will be applied to the hydraulic model to replicate these peak flow values. The CFRAM study noted overland flow paths from the floodplain where part of the Rinn River was bypassed by overland flow paths. If such flow paths are replicated in this study, the flows will not be altered to meet the preliminary target.

The modelled flows will be compared to the peak flows for each return period and reported on in the Hydraulic Chapter of this report. Any variance from flows in Table 3.6 will be documented and justified.

Table 3.6 - Preliminary Target Flows – Current Scenario

Return Period (AEP)	50%	20%	10%	5%	2%	1%	0.5%	0.1%
GEV growth factor	1.00	1.30	1.51	1.71	1.97	2.17	2.37	2.86
26_2307_2	1.5	2.0	2.3	2.6	3.0	3.3	3.6	4.3
26_2307_4	2.0	2.7	3.1	3.5	4.0	4.4	4.9	5.8
26_2307_7	2.7	3.5	4.1	4.6	5.4	5.9	6.5	7.8
26_2307_9	2.8	3.7	4.3	4.9	5.6	6.2	6.8	8.1
26_1894_2	3.8	5.0	5.8	6.6	7.6	8.3	9.1	11.0
26_695_1	4.2	5.5	6.4	7.2	8.3	9.2	10.0	12.1
26_695_3*	4.2	5.5	6.4	7.2	8.3	9.2	10.0	12.1
26_1220_1	6.1	7.9	9.1	10.3	11.9	13.2	14.4	17.3
26_1220_3*	6.1	7.9	9.1	10.3	11.9	13.2	14.4	17.3
26_2239_1	0.7	0.9	1.0	1.2	1.4	1.5	1.6	2.0
26_2239_3	1.3	1.8	2.0	2.3	2.6	2.9	3.2	3.8

*Flow decreasing downstream – value set to match the upstream flow

3.5.1 Climate & Catchment Change

Two possible future scenarios are also to be considered, namely the Mid-Range Future Scenario (MRFS) and the High End Future Scenario (HEFS) that take account of possible future changes such as future development, land use changes and climate change. The relevant future allowances for this Map Update is shown in Table 3.7.

Urbanisation is not applicable in this Map Update as it is a predominantly rural catchment, and is likely to remain so.

Table 3.7 - Allowances for Future Scenarios

	MRFS	HEFS
Flood Flows	+ 20%	+ 30%
Forestation	- 1/6 Tp[1]	- 1/3 Tp[1]
Urbanisation	*No General Allowance – Review on Case-by-Case Basis*	*No General Allowance – Review on Case-by-Case Basis*

Note 1: Reduce the time to peak (Tp): This allows for potential accelerated runoff that may arise as a result of drainage of afforested land

4 Hydraulic Assessment

4.1 Model Build

4.1.1 Overview

As discussed in Section 2.3.1, the CFRAM model for Mohill consisted of extended 1D cross-sections. To more accurately represent the flow mechanism within a Mohill the CFRAM model was adapted to include a 1D-2D domain at Mohill and reduced in size to focus on Mohill. An overview of the Mohill Map Update model is shown in Figure 4-1 - Model Overview. The model begins just upstream of Mohill on the Rinn River and ends downstream of Lough Rinn. The downstream boundary selected for the model was taken from the flow/stage curve calculated by the CFRAM model. Lough Rinn has not been included in the hydrologic assessment but has been included in the model to provide a natural hydraulic boundary.

4.1.2 Survey Data

The CFRAM survey was used for the model build; the survey consisted of a topographical survey of the river channel and structures as required. LiDAR was also captured for the CFRAM AFAs and surrounding areas. LiDAR is available at a 2m horizontal resolution with a typical vertical accuracy of 200mm. The LiDAR was incorporated into the model by providing the ground model for the 2D domain. It was also used where available to extend 1D cross-sections to capture floodplain flow. Where LIDAR was unavailable, IFSAR was used to extend 1D cross-sections. IFSAR data is available at 5m horizontal resolutions with a typical vertical accuracy ranging from 500mm to 1000mm. The extent of LiDAR data and the transition to IFSAR data usage is described in Figure 4-1 - Model Overview.

4.1.3 Model Development

The N02 CFRAM model was used as the base point for this Map Update. The model area (Figure 4-1 - Model Overview) was abstracted from the CFRAM model. The extended cross-sections used for Mohill in the model were removed and a 2D Tuflow model was constructed in its place - see Figure 4-2 - 2D Model Area. To capture the complex urban flood paths a fine cell size of 2m was selected. Selected technical details of the model schematisation have been provided in Table 4.1.

The 2D domain is focused on the banks of the Rinn River as it flows through Mohill (see Figure 4-2). A site visit was undertaken to inform the model build of the 2D area and to ensure key hydraulic features were captured:

- A number of drains were incorporated into the 2D domain – these drains provide a pathway for floodwaters during the onset of flooding;
- A disused railway embankment was defined in the 2D domain;
- On the left bank, a raised access road was identified as an appropriate hydraulic boundary between the 2D and 1D domain as it is a natural hydraulic break;
- Two culverts were identified under the raised access road which provides a hydraulic connection through the access road. No survey was available for these structures; the size of the culverts was estimated by a visual inspection.

There are two culverts of significant length in Mohill – referred to as Main Street Culvert and Car Garage culvert in this report. The Main street culvert although located upstream of the Car Garage culvert is of a much smaller capacity. The Main Street culvert is a hydraulically significant control within the town, and is subject to further sensitivity testing (see Section 4.3.)

Table 4.1 - Technical Summary of Model

Software	**1D domain**	Flood Modeller –5.07695.30453 (Double Precision)	
	2D domain	Tuflow Classic: 2018-03-AB-iDP-w64	
2D Grid Size		2 m	
2D Domain Area		0.3 km^2	
1D Model Sections		No. of Cross Sections	158
1D Model Structures*		No. of Culverts	5
		No. of Bridges	10
		No. of Spills	22

*Full details of modelled structures are detailed in Appendix A.

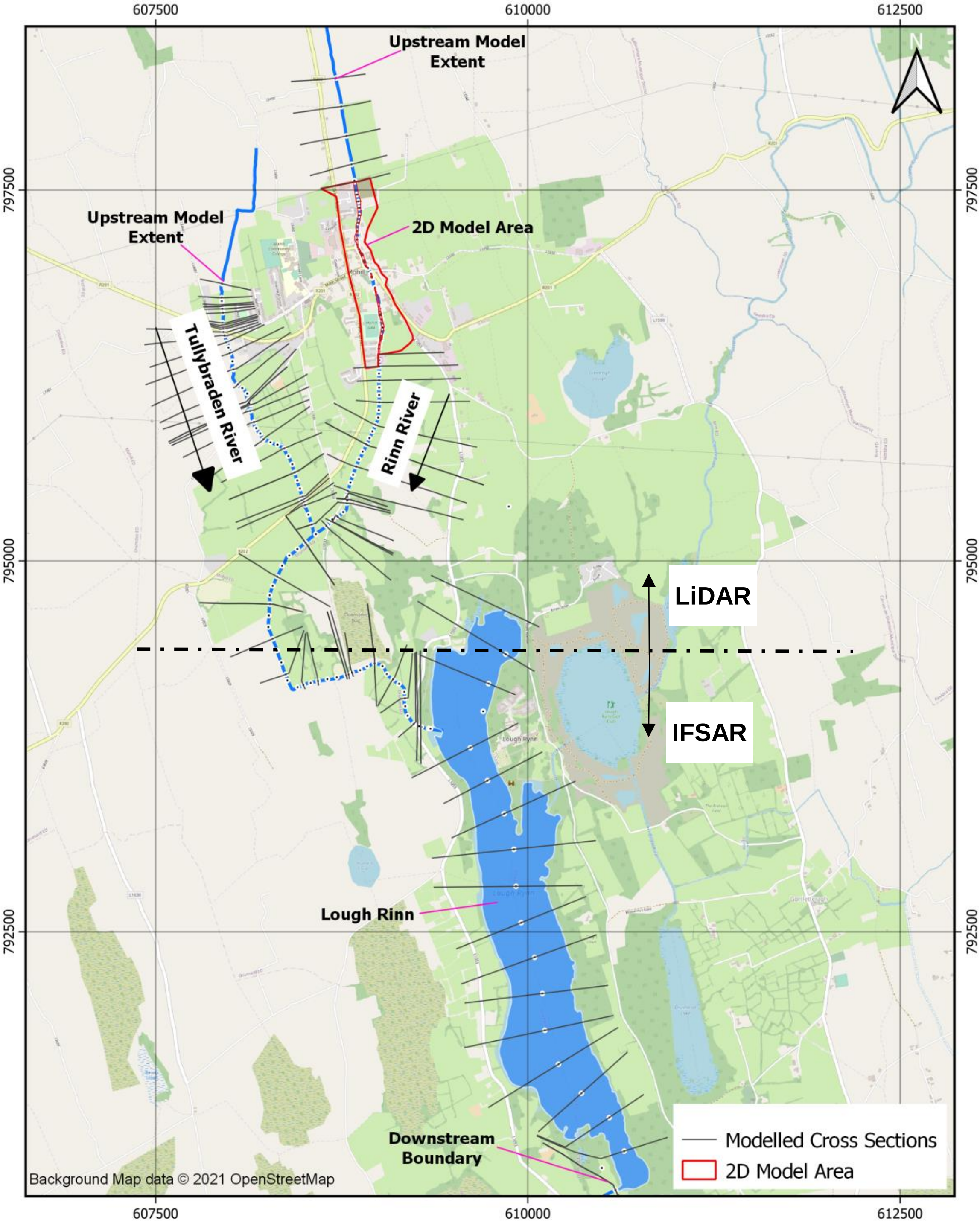

Figure 4-1 - Model Overview

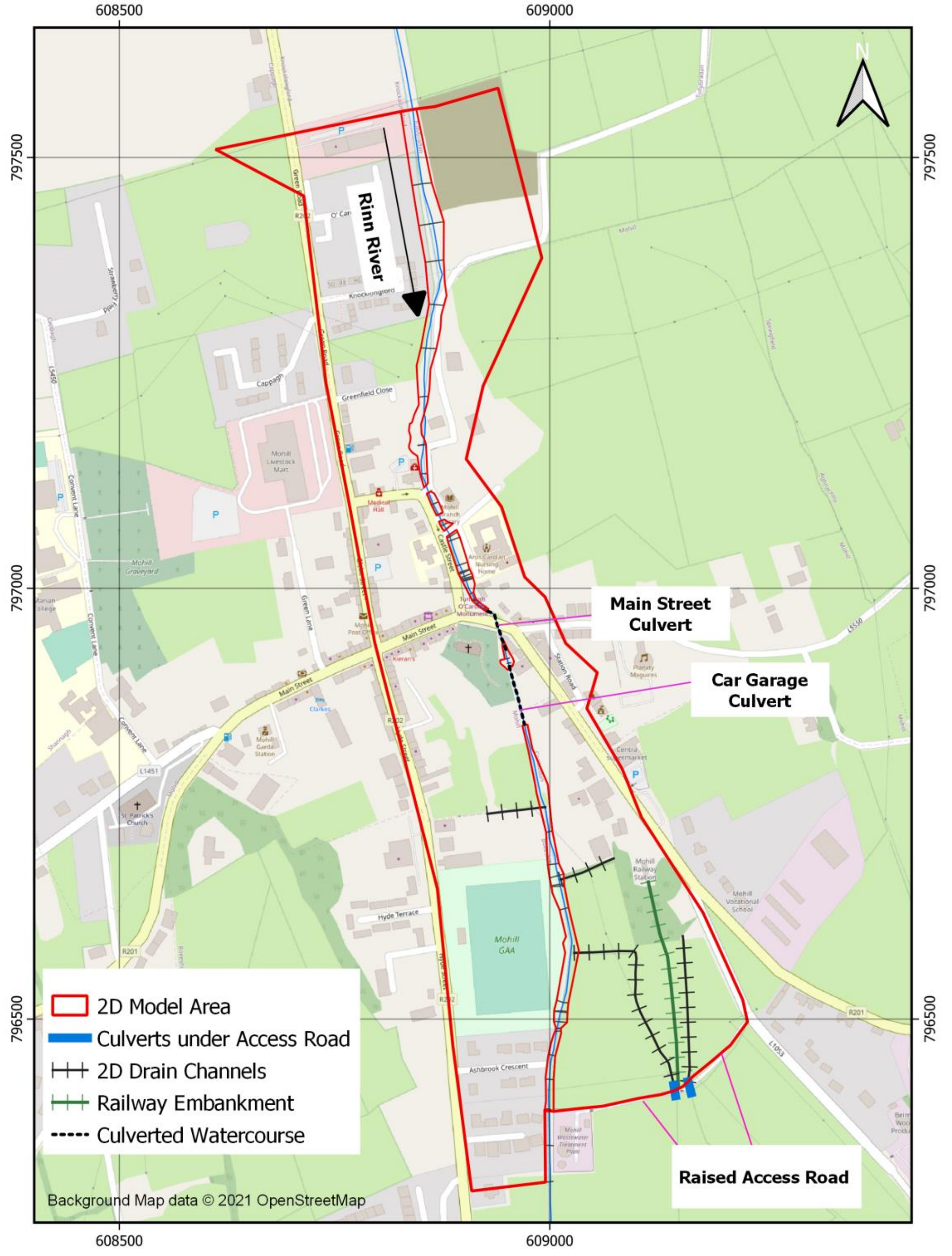

Figure 4-2 - 2D Model Area

4.1.4 Roughness

The Manning's n values used in the CFRAM modelling were reviewed and updated if required. A site visit to Mohill was used to inform the choice of model Manning values.

The OSI Prime2 database was used to assign roughness values within the 2D domain. Prime2 provides information on the location of land uses in vector format, such as vegetation, buildings and roads. Buildings within the 2D domain have been assigned a Manning's 'n' value of 0.100 to account for the associated losses. This allows for the flooding of the footprint of buildings while also accounting for the limited flow of floodwater through them. Appendix B: Roughness Schedule provides full details of the roughness values used on each river reach and within the 2D domain.

4.1.5 Model Calibration

No flow gauge is located within Mohill to undertake a calibration or verification exercise. No alternative data were identified to validate the model during this study. The OPW holds no past flood event data for Mohill. A search of The Irish Times archive and the Irish Newspapers Archive returned no reports of fluvial flooding of properties within Mohill. As described in Section 2.2, the LA is unaware of flooding in recent significant flooding events in the catchment (2009 & 2015/16) or any history of fluvial flooding within the town of Mohill.

The absence of evidence does not necessarily mean that there is no risk of flooding within Mohill. It would indicate that the flooding of properties in the higher probability events (10%, 5% AEP etc.) would not be expected. Due to the lack of gauge data and flood event records the model is un-calibrated.

4.2 Model Inflows & Target Flows

Table 4.2, Table 4.3 and Table 4.4 describe the direct and the lateral inflows derived to achieve the target flows identified in Section 3.5 for each scenario.

Table 4.2 – Model Inflows: Current Scenario

HEP Nodes	Location	Model Inflows m^3/s per AEP							
		50 %	20%	10%	5%	2%	1%	0.5%	0.1%
26_2307_2	02CAP03299	1.5	2.0	2.3	2.6	3.0	3.3	3.6	4.3
26_2307_4	02CAP02191	0.8	0.8	0.8	0.9	1.1	1.2	1.3	1.6
26_2307_7	02CAP0747	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.9
26_2307_9	02CAP00000	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.4
26_2239_1a	01SHA01920	0.7	0.9	1.0	1.2	1.4	1.5	1.7	2.0
26_2239_3	01SHA01320	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.9
26_2239_4	01SHA00000	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
26_1894_2	01CAP02507	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6
26_695_1	01CAP01925u	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.1
26_1220_1	01CAP00936d	1.9	2.5	2.9	3.2	3.7	4.1	4.5	5.4

26_1220_3	01CAP00936d	1.2	1.3	1.7	2.0	2.3	2.5	2.6	3.3

Table 4.3 - Model Inflows: Mid-Range Future Scenario

HEP Nodes	Location	Model Inflows m³/s per AEP							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2307_2	02CAP03299	1.8	2.4	2.8	3.1	3.6	4.0	4.3	5.2
26_2307_4	02CAP02191	1.0	1.0	1.0	1.1	1.3	1.4	1.6	1.9
26_2307_7	02CAP0747	0.8	1.1	1.2	1.4	1.6	1.8	1.9	2.3
26_2307_9	02CAP00000	0.1	0.2	0.2	0.2	0.2	0.4	0.4	0.5
26_2239_1a	01SHA01920	0.8	1.1	1.2	1.4	1.7	1.8	2.0	2.4
26_2239_3	01SHA01320	0.8	1.1	1.2	1.3	1.6	1.7	1.9	2.3
26_2239_4	01SHA00000	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
26_1894_2	01CAP02507	0.2	0.4	0.4	0.5	0.5	0.6	0.6	0.7
26_695_1	01CAP01925u	0.5	0.6	0.7	0.8	1.0	1.0	1.1	1.3
26_1220_1	01CAP00936d	2.3	3.0	3.5	3.8	4.4	4.9	5.4	6.5
26_1220_3	01CAP00936d	1.4	1.6	2.0	2.4	2.8	3.0	3.1	4.0

Table 4.4 - High-End Future Scenario

HEP Nodes	Location	Model Inflows m³/s per AEP		
		10%	1%	0.1%
26_2307_2	02CAP03299	3.0	4.3	5.6
26_2307_4	02CAP02191	1.0	1.6	2.1
26_2307_7	02CAP0747	1.3	2.0	2.5
26_2307_9	02CAP00000	0.3	0.4	0.5
26_2239_1a	01SHA01920	1.3	2.0	2.6
26_2239_3	01SHA01320	1.3	1.8	2.5
26_2239_4	01SHA00000	0.1	0.3	0.3
26_1894_2	01CAP02507	0.4	0.7	0.8
26_695_1	01CAP01925u	0.8	1.0	1.4
26_1220_1	01CAP00936d	3.8	5.3	7.0
26_1220_3	01CAP00936d	3.0	4.3	5.6

Table 4.5 compares the target flows derived to the model outputs for the current scenario. The modelled flows generally correlate well to the theoretical flows and are broadly within 10% of the target. However, the 10% is exceeded in several locations. For the nodes 26_2307_9, & 26_2239_3 this is associated with circular flow at the confluence of the Tullybraden River and Rinn River (see Figure 4-3 - HEPs). A localised increase at the

26_1894_2 is noted in the 0.1% AEP event - this returns to an acceptable value shortly downstream. To allow the modelled flows to correlate to the target flows the flood hydrographs on the Tullybraden River and Rinn River were offset rather than timed to coincide. While both rivers have small catchments, the Tullybraden River is both half the size and twice as steep (S1085) as the catchment of the Rinn River. Due to their proximity both catchments are likely to experience rainfall events simultaneously but due to the smaller and steeper catchment of the Tullybraden River it would likely peak first; therefore, offsetting the hydrographs peaks of the Tullybraden River and Rinn River is a reasonable assumption.

Table 4.5 – Correlation of Modelled Flows to Target Flows

HEP Nodes	AREA (km2)	Return Period (AEP)							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2307_2	3.2	0%	0%	0%	0%	0%	0%	0%	0%
26_2307_4	4.8	16%	2%	0%	0%	0%	2%	0%	0%
26_2307_7	6.4	7%	1%	0%	0%	-1%	0%	-2%	10%
26_2307_9	6.8	1%	-4%	-5%	-5%	-5%	-5%	-6%	16%
26_2239_1	1.9	9%	11%	10%	10%	9%	9%	10%	10%
26_2239_3	2.9	0%	0%	0%	0%	0%	0%	0%	0%
26_1894_2	10.5	1%	-5%	-6%	-6%	-6%	-4%	9%	0%
26_695_1	11.8	1%	-5%	-6%	-6%	-6%	-5%	5%	-4%
26_695_3	12.2	3%	-4%	-5%	-15%	-16%	-7%	-4%	-8%
26_1220_1	21.6	17%	7%	4%	1%	-1%	-2%	2%	-3%
26_1220_3	22.2	16%	6%	3%	0%	-1%	-2%	1%	-4%

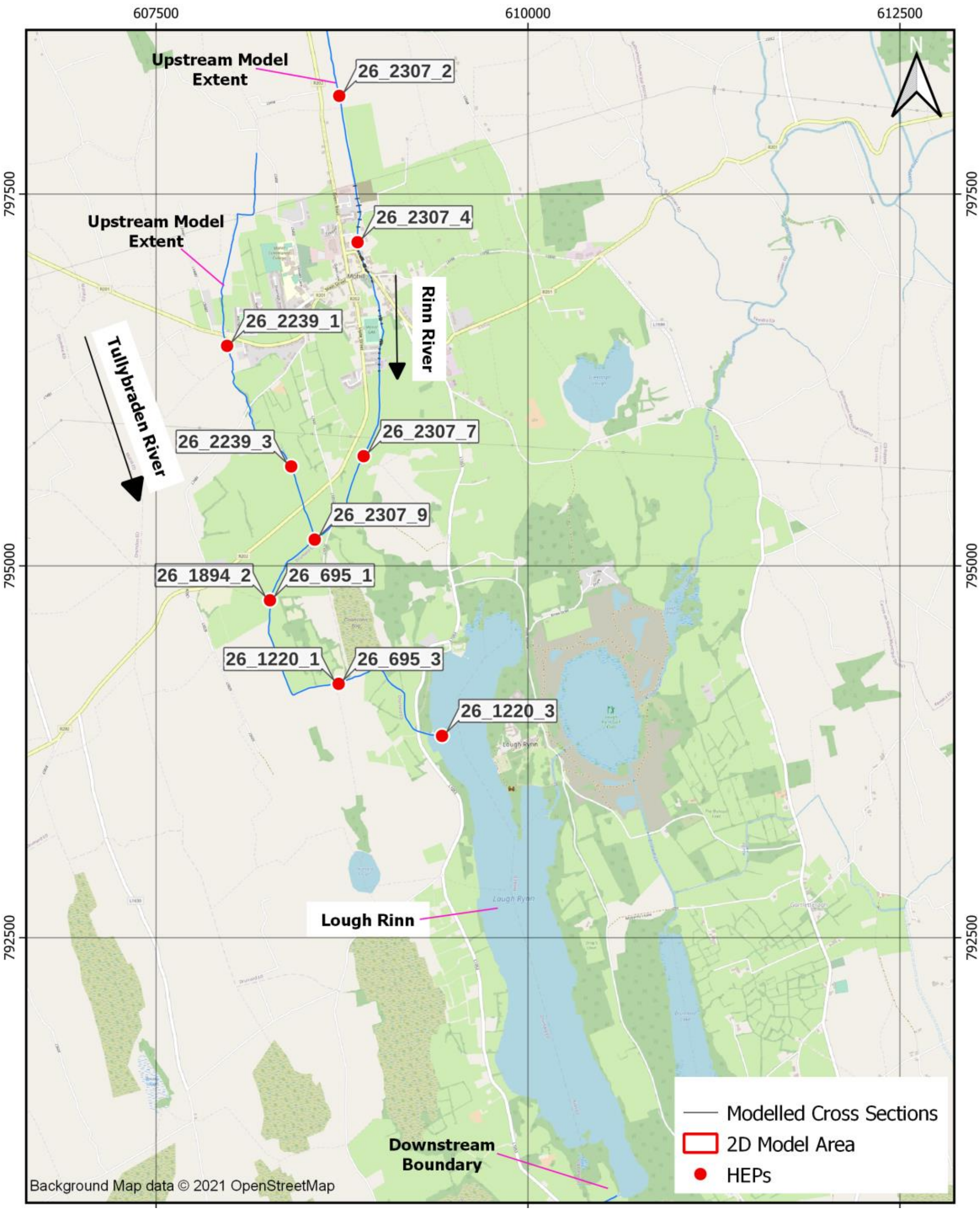

Figure 4-3 - HEPs

4.3 Sensitivity Assessment

4.3.1 General Model Sensitivity

Sensitivity tests have been carried out to assess the sensitivity of the model outputs to changes in roughness, flow, afflux and the downstream model boundary. Selected model nodes for comparison are shown in Figure 4-4. All tests have been carried using the 1% AEP event. Each test consists of a variable either being increased or being decreased by 20%.

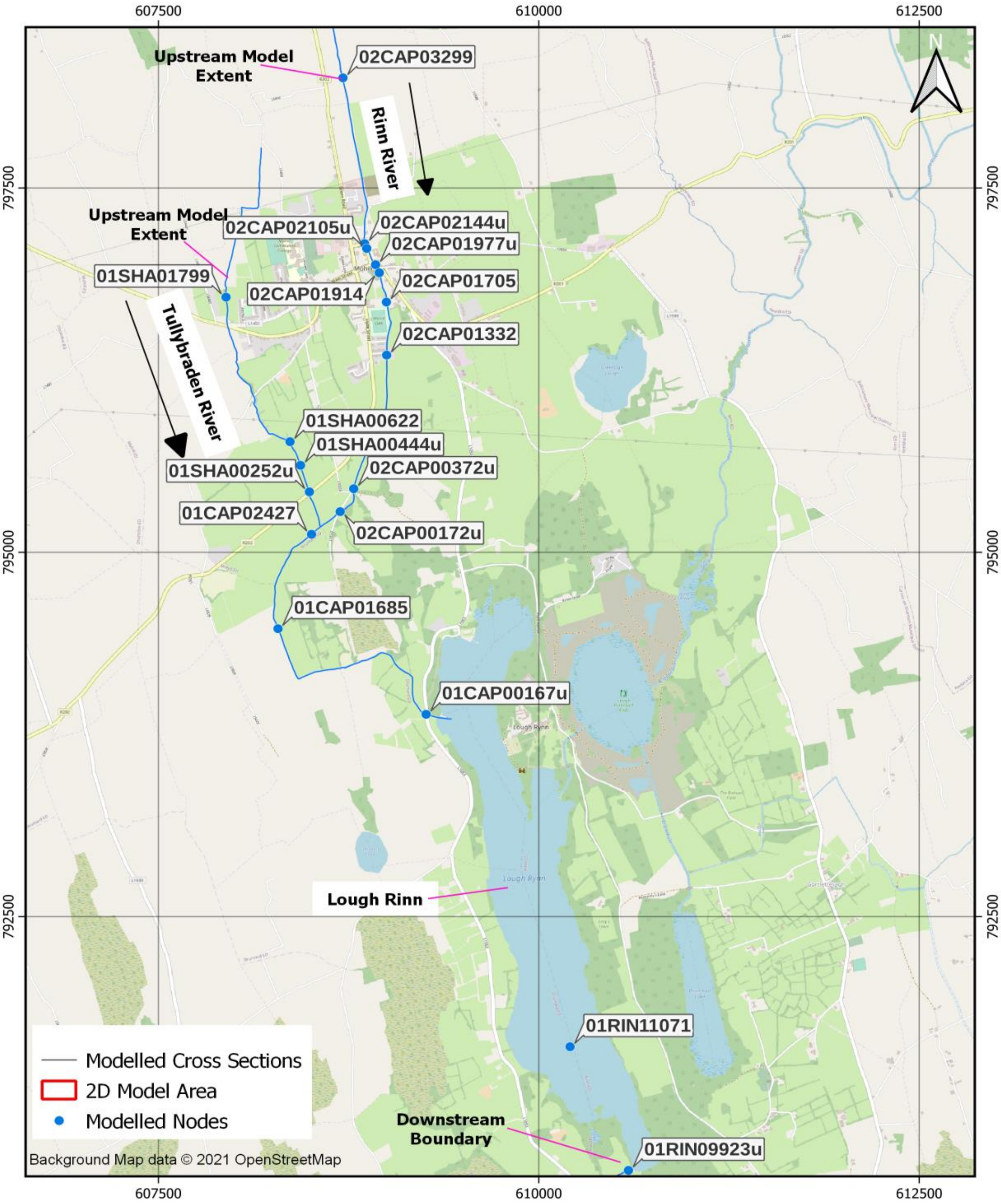

Figure 4-4 - Selected Model Nodes for Comparison

The outputs from the general model sensitivity tests are summarised in Table 4.6. To assess the sensitivity to changes in peak flow, the peak flow of the 1% AEP event has been varied by 20% - increased by 20% in one scenario and decreased by 20% in another. The model was found to be sensitive to changes in flows within Mohill. In particular, at the upstream face of the Main Street Culvert the water level varied by over 0.5m in both flow scenarios.

Table 4.6 indicates that the model is not particularly sensitive to changes in roughness with differences typically less than 100 mm in each test. The downstream boundary for this model is a Flow/Stage relationship extracted from the CFRAM model. The flow was increased/decreased by 20% for the equivalent stage in the flow stage/relationship in each sensitivity test. In each of the tests, the influence is less than 100mm, localised to the downstream reaches of the model and has no influence on levels within Mohill.

Table 4.6- General Sensitivity Analysis

Selected Model Nodes	Comments on Model Nodes	General Sensitivity Tests – 1% AEP Comparison (m)					
		Flow		Roughness		Downstream Boundary	
		+20%	*-20%*	*+20%*	*-20%*	*+20%*	*-20%*
02CAP03299	Upstream Model Extent (Rinn River)	0.05	-0.10	0.04	-0.08	-	-
02CAP02144u		0.60	-0.39	0.04	-0.02	-	-
02CAP02105u		0.53	-0.54	0.08	-0.05	-	-
02CAP01977u	Main Street Culvert (Upstream Face)	0.50	-0.48	0.07	-0.04	-	-
02CAP01914	Main Street Culvert (Downstream Face)	0.24	-0.20	0.08	-0.05	-	-
02CAP01705		0.17	-0.15	0.13	-0.10	-	-
02CAP01332	End of 2D Domain	0.06	-0.05	0.04	-0.05	-	-
02CAP00372u		0.07	-0.04	0.03	-0.01	-	-
02CAP00172u	Local Road Bridge	0.11	-0.15	0.03	-0.04	0.00	0.00
01SHA01799	Upstream Model Extent (Tullybranden River)	0.04	-0.06	0.03	-0.04	-	-
01SHA00622		0.05	-0.07	0.05	-0.06	-	-
01SHA00444u		0.21	-0.31	0.04	-0.06	-	-
01SHA00252u	R202 Road Bridge	0.21	-0.33	0.04	-0.06	-	-
01CAP02427		0.15	-0.15	0.07	-0.08	0.01	0.00
01CAP01685		0.15	-0.17	0.07	-0.09	0.01	-0.01
01CAP00167u	Local Road Bridge	0.19	-0.19	0.06	-0.05	0.03	-0.03
01RIN11071	Lough Rinn	0.06	-0.06	0.04	-0.03	0.06	-0.05
01RIN09923u	Downstream Boundary	0.06	-0.07	0.04	-0.03	0.07	-0.05

4.3.2 Afflux Testing

Three structures within the model were found to have significant afflux associated with them. The locations of the structures (02CAP00172u, 01SHA00252u, 01CAP00167u) can be viewed in Figure 4-4.

The calibration coefficient is a tool to adjust losses associated with structures in Flood Modeller. For each structure, the calibration coefficient was varied by 20% to assess the upstream and downstream impacts of a change in afflux. Table 4.7 summarises the results of the afflux sensitivity testing. All showed minor local variations in level, with no change to the levels within Mohill.

Table 4.7 - Afflux Sensitivity Test

Selected Model Nodes	Comments on Model Nodes	Afflux Sensitivity Tests - 1% AEP Comparison (m)					
		Local Road Bridge (1)		R202 Road Bridge (2)		Local Road Bridge (3)	
		-20%	*+20%*	*-20%*	*+20%*	*-20%*	*+20%*
02CAP03299	Upstream Model Extent (Rinn River)	-	-	-	-	-	-
02CAP02144u		-	-	-	-	-	-
02CAP02105u		-	-	-	-	-	-
02CAP01977u	Main Street Culvert (Upstream Face)	-	-	-	-	-	-
02CAP01914	Main Street Culvert (Downstream Face)	-	-	-	-	-	-
02CAP01705		-	-	-	-	-	-
02CAP01332	End of 2D Domain	-	-	-	-	-	-
02CAP00372u		-	-	-	-	-	-
02CAP00172u	Local Road Bridge **(1)**	-0.02	0.01	0.00	0.00	0.00	-
01SHA01799	Upstream Model Extent (Tullybranden River)	-	-	-	-	-	-
01SHA00622		-	-	-	-	-	0.00
01SHA00444u		-	-	-	-	-0.02	0.02
01SHA00252u	R202 Road Bridge **(2)**	-	-	-	-	-0.02	0.02
01CAP02427		-	-	-0.01	0.01	-	-
01CAP01685		-	-	-0.01	0.01	-	-
01CAP00167u	Local Road Bridge **(3)**	-	-	-0.05	0.05	-	-
01RIN11071	Lough Rinn	-	-	0.00	0.00	-	-
01RIN09923u	Downstream Boundary	-	-	0.00	0.00	-	-

4.3.3 Main Street Culvert

The Main Street Culvert is a hydraulically significant culvert located on the River Rinn in Mohill. Table 4.8 and Figure 4-5 provide a detailed overview of the culvert. The structure does not categorize easily into a typical model unit. The structure consists of an arch opening, which flows into a wider rectangular chamber with structural supports, and then flows into an open channel with ad-hoc property supports encroaching into the river channel. No survey of the interior of the culvert, the downstream face of the culvert, or the open channel is available.

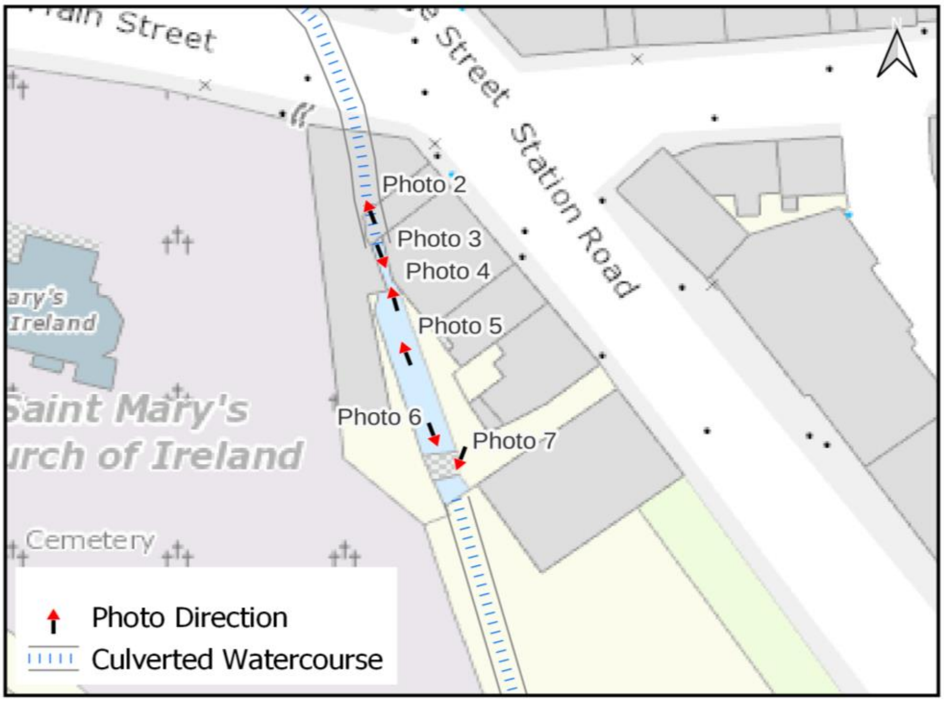

Figure 4-5 – Main Street Culvert: Photo Directions in Table 4.8

The culvert has been modelled as follows (see Table 4.8Table 4.9 for photo references):

1. A circular conduit representing the upstream face of the culvert (Photo 1);
2. An irregular conduit representing the chamber in Photo 2;
3. An irregular conduit based on conditions in Photo 3, 4 & 5.

To represent the losses due to the numerous shape changes several Culvert Bend Loss units have been added. The following sensitivity tests have been carried out on the main street culvert:

- Use of circular culvert similar to upstream face throughout;
- Increase in losses at Culvert Bend Units by 20%;
- Decrease in losses at Culvert Bend Units by 20%.

Table 4.9 summarises the output of the sensitivity testing. The adjustments of Culvert Bend losses showed a small variation (less than 100mm) in peak water levels in both scenarios. The use of a standard circular culvert unit reduces levels upstream of the culvert in Mohill by 0.27m. This is expected as the circular culvert is more hydraulically efficient as it does not account for the in-channel obstacles. This also demonstrates the potential benefit to water levels in Mohill if the culvert is replaced with a standard unit.

Table 4.8 – Main Street Culvert Overview

1

Upstream Face of Main Street Culvert conventional to the 1800 mm pipe found concealed by stone arch facade. No blockages or constrictions identified

2

Downstream face of Culvert not surveyed due to access issues. Below photo looking upstream from just inside culvert. Support for building in middle of channel.

3

Photo is taken looking downstream from Culvert downstream face. Debris is visible at support columns and cast iron supports.

4

Photo is taken looking upstream from underneath domestic oil tank suspended over the watercourse. Debris build-up in the channel visible.

5	Supports for domestic oil tank can be seen in the foreground.  	**6**	Local access bridge downstream of Main Street Culvert 
7	Downstream Car Garage Culvert of higher capacity. 		

Table 4.9 -Main Street Culvert Sensitivity Test

Selected Model Nodes	Comments on Model Nodes	Circular Culvert Unit	Culvert Bend -20%	Culvert Bend 20%
02CAP03299	Upstream Model Extent (Rinn River)	0.00	0.00	-
02CAP02144u		-0.17	0.01	0.04
02CAP02105u		-0.26	-0.01	0.09
02CAP01977u	Main Street Culvert (Upstream Face)	-0.27	-0.03	0.10
02CAP01914	Main Street Culvert (Downstream Face)	0.00	0.00	-
02CAP01705		-	0.00	-
02CAP01332	End of 2D Domain	0.00	-	-
02CAP00372u		-	-	-
02CAP00172u	Local Road Bridge	0.01	-	-
01SHA01799	Upstream Model Extent (Tullybranden River)	0.00	-	-
01SHA00622		0.00	-	-
01SHA00444u		0.00	-	-
01SHA00252u	R202 Road Bridge	0.01	-	-
01CAP02427		0.01	-	-
01CAP01685		0.01	-	-
01CAP00167u	Local Road Bridge	0.01	-	-
01RIN11071	Lough Rinn	0.01	-	-
01RIN09923u	Downstream Boundary	0.01	-	-

4.3.4 Summary of Sensitivity testing

The model was found to be most sensitive to changes in flow and the schematisation of the Main Street Culvert. However, no justification was found for changing the current model parameters. A detailed survey of the Main Street Culvert would reduce the uncertainty associated with it although it would remain an atypical structure and not suitable for standard modelling techniques.

4.4 Key Model Assumptions, Limitations & Recommendations

The following summarises key points related to the hydraulic assessment:

- Two culverts in the 2D domain associated with drains have not been surveyed but were incorporated into the model. The dimensions of the culvert were estimated based on a visual inspection.

- No survey was available for Main Street Culvert bar the upstream face. The dimensions of the downstream face and the structures encroaching into the channel were estimated using the available photographs, site knowledge and best engineering judgement.

- Due to the various structural supports within the river channel downstream of the Main Street Culvert, it is recommended that the LA actively monitor this area to reduce the risk of blockage. The LA should also consider locating a trash screen upstream of the culvert to manage the blockage risk.

- The model includes the entirety of Lough Rinn, however, the model outputs will exclude Lough Rinn from the mapping. Lough Rinn was included only to provide a realistic downstream boundary for the model.

- It was not possible to calibrate the model as no gauge data or flood event data was available. Furthermore, the model sensitivity testing demonstrated that the model was particularly sensitive to changes in peak flows. Typically, the addition of a hydrometric gauge would be recommended to reduce uncertainty. However, in the absence of any history of flooding the addition of a hydrometric gauge is unlikely to be justified in Mohill.

4.5 Flood Mapping

4.5.1 Tie in to existing Flood Mapping

The focus of the Mohill Map Update is to apply 2D mapping in the urban areas of Mohill. The model has been extended to Lough Rinn, see Figure 4-1. The primary purpose of extending the model was to establish an appropriate downstream boundary. Downstream of the 2D Domain for Mohill there is no substantial change in flood extents when the Map Update flood extents are compared to the CFRAM extents. Therefore, it has proposed to tie the Map Update extents into the CFRAM flood extents at the end of the 2D domain.

A comparison of the CFRAM 1% AEP and the outputs of the Mohill Map Update is shown in Figure 4-6.

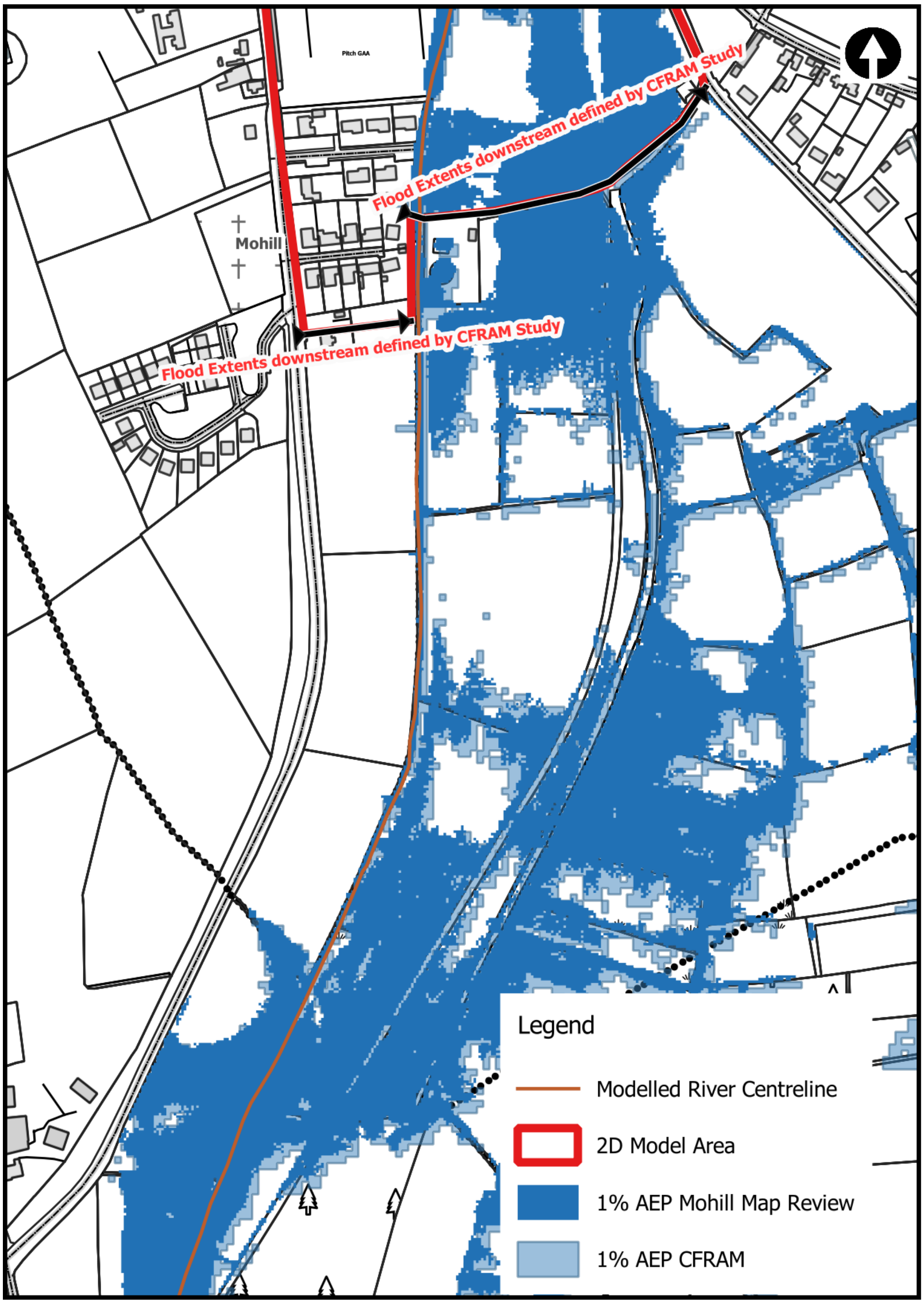

Figure 4-6 - Proposed Boundary between Map Update extents and CFRAM extents

Appendix A Structure Schedule

Table A.1 – Rinn River Structure Schedule

Survey Reference	FM Node	Type of structure	Modelling approach	Structure included in model
26CAPP00487D and 26CAPP00486E	02CAP02144u	Water Street Culvert 10.64m in length	Rectangular Culvert + Bend Unit + Sprung Arch Culvert	Y
26CAPP00483D and 26CAPP00483E	02CAP02105u	Access Road Bridge 9.43m in length	Arch Bridge Unit with single rectangular opening	Y
26CAPP00481D	02CAP02086u	Access Road Bridge 6.68m in length	Arch Bridge Unit with two openings	Y
26CAPP00476D	02CAP02033u	Footbridge 1.41m in length	Arch Bridge Unit with single rectangular opening +Spill	Y
26CAPP00474W and 26CAPP00474X	02CAP02022u	Weir	Inline Spill	Y
26CAPP00473D	02CAP01997u	Footbridge 1.26m in length	Arch Bridge Unit with single rectangular opening	Y
26CAPP00471I	02CAP01977u	Main Street Lower Culvert 14.88m in length	Circular & Irregular Culvert	Y
26CAPP00464D	02CAP01908u	Footbridge 3m in length	Orifice Unit + Spill	Y
26CAPP00462I and 26CAPP00456J	02CAP01902u	Culvert under car park 68.86m in length	Rectangular culvert	Y

26CAPP00437D	02CAP01640u	Access Bridge 4.21m in length	Orifice Unit + Spill	Y
26CAPP00422D	02CAP01490u	Access Bridge 3.29m in length	Orifice Unit + Spill	Y
26CAPP00421D	02CAP01469u	Footbridg e 3.56m in length	Arch Bridge Unit with single rectangular opening	Y
26CAPP00310D	02CAP00372u	Road Bridge 4.36m in length	Arch Bridge Unit with single opening + Spill	Y
26CAPP00309D	02CAP00351u	Road Bridge 4.25m in length	Arch Bridge Unit with single rectangular opening + Spill	Y
26CAPP00290D	02CAP00172u	Road Bridge 5.23m in length	Arch Bridge Unit with single opening + Spill	Y
26CAPP00115D	N/A	Footbridge 2.09m in length		N*
26CAPP00040D	01CAP00167u	L1053 Road Bridge 6.54m in length	Arch Bridge Unit with single rectangular opening + Spill	Y

Table A.2 – Tullybraden River Structure Schedule

Survey Reference	FM Node	Type of structure	Modelling approach	Structure included in model
26SAGH00175D	01SHA01765u	Access Road Bridge 2.86m in length	Orifice Unit + Spill	Y
26SAGH00164D	N/A	Footbridge 2.88m in length		N**
26SAGH00161I and 26SAGH00158J	01SHA01610u	Main Street Upper Road (R201) Bridge 21.77m in length	Circular Culvert + Spill	Y
26SAGH00107D	01SHA01059u	Road Bridge 4.94m in length	Arch bridge Unit with single opening+ spill	
26SAGH00024I and 26SAGH00023J	01SHA00252u	R202 Road Culvert 18.21m in length	Circular Culvert + Spill	Y

Appendix B Roughness Schedule

Table B.1 – FM Roughness Schedule

River Name	FM Node	Typical Manning's n Values	
		Bed Roughness	Floodplain Roughness
Tullybraden	01SHA01920 to 01SHA01205	0.057	0.080
	01SHA01074 to 01SHA00622	0.060	0.035
	01SHA00444u to 01SHA00000	0.055	0.035
Rinn	02CAP03299 to 02CAP02191d	0.060	Defined by 2D
	02CAP02157 to 02CAP01902u	0.035	Defined by 2D
	02CAP01834d to 02CAP01291	0.060	Defined by 2D
	02CAP01197 to 01CAP00747u	0.050	0.035

Table B.2 – 2D Roughness Schedule

Land-use Type	Manning's n
Rural (General)	0.045
Urban (General)	0.060
Dense Vegetation	0.080
Short Grass, Parks, Sport grounds	0.035
Water Bodies	0.02
Roads	0.025
Access Tracks	0.030
Buildings	0.1