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SHANNON CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study

Hydrology Report
Unit of Management 25/26

Final Report

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	Originated by	Checked by	Reviewed by
ORIGINAL	NAME Elmar Torenga James Cullinane Alison Janes Alice Wiggins	NAME Steve Dunthorne	NAME Steve Dunthorne
Approved by	NAME Peter Smyth	As Project Manager I confirm that the above document(s) have been subjected to Jacobs' Check and Review procedure and that I **approve them for issue**	INITIALS
DATE 9 Aug 2013	**DRAFT revision 0.0**		

REVISION 1.0	NAME Elmar Torenga James Cullinane Agnes Adjei Alison Janes Alice Wiggins	NAME Elmar Torenga Steve Dunthorne	NAME Elmar Torenga
Approved by	NAME Peter Smyth	As Project Manager I confirm that the above document(s) have been subjected to Jacobs' Check and Review procedure and that I **approve them for issue**	INITIALS
DATE 6 Dec 2013	**DRAFT revision 1.0**		

REVISION 2.0	NAME James Cullinane Agnes Adjei Alison Janes Alice Wiggins Yiwen Zhao	NAME Elmar Torenga Keshav Bhattarai	NAME David Price
Approved by	NAME Peter Smyth	As Project Manager I confirm that the above document(s) have been subjected to Jacobs' Check and Review procedure and that I **approve them for issue**	INITIALS
DATE 01 June 2016	**Draft Final**		

REVISION 3.0	NAME	NAME	NAME	
	James Cullinane Agnes Adjei Alison Janes Alice Wiggins Yiwen Zhao	Elmar Torenga Keshav Bhattarai	David Price	
Approved by	NAME Peter Smyth	As Project Manager I confirm that the above document(s) have been subjected to Jacobs' Check and Review procedure and that I **approve them for issue**	INITIALS	
DATE	05 July 2016	**Final**		

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Executive Summary

As part of the Shannon Catchment Flood Risk Assessment and Management (CFRAM) study a series of Hydrology Reports has been produced, one for each unit of management within the Shannon River Basin District (RBD). The Shannon RBD consists of Units of Management (UoM) 23, 24, 25/26 and 27.

This Hydrology Report details the hydrological assessment for the CFRAM study in UoM 25/26. This unit of management covers the catchment of the River Shannon and its tributaries. The unit of management is split up in Hydrometric Areas 25 (Lower Shannon) and 26 (Upper Shannon). A review of the available hydrometric data for the unit of management was undertaken and is detailed in the Inception Report (September 2012, Chapters 3, 6 and 7). That report also outlines the methodologies that were adopted.

UoM 25/26 encompasses an area in the Republic of Ireland in the counties Sligo, Leitrim, Roscommon, Longford, Cavan, Meath, North and South Tipperary, Offaly, Galway, Clare, Westmeath, Limerick and small areas of Mayo and Laois. A very small area (2.5 km^2) of County Fermanagh in Northern Ireland contributes to groundwater flow in the headwaters of the River Shannon. The total area of UoM 25/26 is approximately 11,600 km^2. The extent of Limerick City is split between three units of management (24, 25/26 and 27), but for the purpose of the CFRAM study the entire city extent has been considered as part of UoM 25/26.

The influence of soil types and geology was considered in deriving flood estimates. The 'Locally important aquifer' group (LI) is the dominant aquifer in the central and eastern areas of UoM 25/26 basin. In the north-western part of the basin the 'Regionally important karstified aquifer' group (Rkc and Rk) dominates. In the extreme northern, south-eastern and south-western parts of the basin there exists some 'Poor aquifer – bed rock which is generally unproductive' group (Pu, PI). In addition to above, there are some 'locally important karstified aquifer and regionally important karstified aquifer dominated by diffuse flow' group (LK, Rkd) located in the eastern part of the basin.

The soils of UoM 25/26 (Figure 3.4) are dominated by a mixture of well-drained soil and peat, together with some poorly drained soil located mainly in the extreme north, extreme south and western part. Although peat is scattered across the entire catchment, the largest expanses are located in the central, northern, north-western and south-western parts of the basin.

A review of historic flooding was undertaken during the Inception stage and the findings of this review are detailed in the Inception Report for this unit of management (Chapter 8).

Reviews of the stage-discharge ratings were undertaken for 28 gauging stations in this unit of management. For these stations hydraulic modelling was undertaken local to the station to produce a revised rating. Summaries of the rating reviews and the resulting rating equations are provided in this report.

Due to a dearth of sub-daily rainfall data, Jacobs' approach to peak design flow estimation in the Shannon River Basin District (RBD) avoids the use of rainfall data, focussing instead on the use of Flood Study Update (FSU) techniques for flow estimation, supplemented and adjusted using gauged data where available. An index flood approach was adopted to determine the peak design flows at key points

along the modelled watercourses. This approach involves the estimation of QMED, the median of the annual maxima (AMAX) flow series (which equals the 2-year return period [50% annual probability] peak flow), and using growth factors applied to QMED to estimate the peak flows for higher return periods up to 1000 years (0.1% annual probability). These growth factors were obtained by pooling group analysis and single site analysis. The results of these two methods were then compared and a view was taken on the best choice of method and distribution.

Estimates of QMED at key points along the model extents were derived from the Flood Studies Update (FSU) regression equation, which were adjusted using gauged data from gauging stations in the vicinity where available. This was done in accordance with guidance in the FSU with respect to pivotal sites, with the determination of adjustment factors for any model length being guided by the number, quality and similarity of the gauging stations available for selection as pivotal sites.

The hydrograph shapes were estimated for watercourses from gauged data on the subject watercourse or at a hydrologically similar pivotal site if there were no gauged flows available on the subject watercourse.

The hydraulic model of the watercourse was then run with the inflow hydrographs and some reconciliation was carried out to ensure peak flows at key locations along the model extents were sufficiently close to the hydrological estimates at these points. A difference between anticipated total peak flow and hydraulic model peak flow of less than approximately 10% was normally sought.

Where gauged data and other historic flood information of sufficient quality was available, calibration and/or verification of the model was undertaken. Dependent on the available data this could result in re-evaluation of the hydraulic model, the hydrology or both.

The hydrological analysis resulted in a series of inflow hydrographs for each hydraulic model for a range of return periods (annual exceedance probabilities), at the upstream model boundaries and at key locations along the model extent to represent laterally contributing subcatchments. This report includes maps showing the catchment to a model extent, model inflow locations, a table and map showing river reaches for which the same hydrological parameters were adopted, tables with catchment descriptor ranges for each reach, tables with QMED adjustment factors, tables and graphs with flood frequency curves for each reach, tables with hydrological (target) peak flows and peak inflows, and graphs with design inflows for the 100-year return period (1% AEP) floods. The flood estimates detailed herein were used in the hydraulic modelling to produce estimates of water level and flood extent throughout the modelled reaches.

The confidence in flood estimation can be increased by having more high flow check gaugings at gauging stations. This study highlighted which of the rating-reviewed gauging stations would most benefit from high flow check gaugings.

It is recommended that the flood hydrology be reviewed every 5 to 10 years as more annual maxima and flood event data become available.

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Glossary

AEP	Annual Exceedance Probability (%)
AFA	Area for Further Assessment
AMAX	Annual Maxima
ARTDRAIN2	% of the catchment river network included in drainage schemes (catchment descriptor)
BFIsoil	Baseflow index derived from soils data (catchment descriptor)
CFRAM	Catchment-based Flood Risk Assessment and Management
DEM	Digital Elevation Model (retains elevations of structures, vegetation, etc.)
DRAIND	Drainage Density (catchment descriptor)
DTM	Digital Terrain Model (also referred to as bare earth model), level raster where structures and vegetation have been filtered out)
EPA	Environmental Protection Agency
ESB	Electricity Supply Board
EV1	Extreme Value Type 1 distribution (also referred to as Gumbel distribution)
FARL	Flood Attenuation by Reservoirs and Lakes (catchment descriptor)
fse	factorial standard error
FSU	Flood Studies Update
GLO	Generalised Logistic distribution
GSI	Geological Survey of Ireland
HEFS	High-End Future Scenario
HEP	Hydrological Estimation Point
HGF	Highest Gauged Flow (= highest check gauging)
HPW	High Priority Watercourse
IRR	Individual Risk Receptor
LN2, LN3	2- and 3-parameter Log Normal distributions
LO	2-parameter Logistic distribution
MPW	Medium Priority Watercourse
MRFS	Mid-Range Future Scenario
NDHM	National Digital Height Model
NTCG	National Technical Coordination Group
OPW	Office of Public Works
PEAT	% of land area covered by peat bogs (catchment descriptor)
PFRA	Preliminary Flood Risk Assessment
POT	Peaks over Threshold
QMED	Median Annual Flow (median of long-range annual maxima)
RBD	River Basin District
SAAR	Standard Annual Average Rainfall (mm) (catchment descriptor)
S1085	10-85% stream slope (m/km) (catchment descriptor)
UAF	Urban Adjustment Factor: $(1+URBEXT/100)^{1.482}$
UoM	Unit of Management
URBEXT	Urban Extent (%) (catchment descriptor)

WFD	Water Framework Directive
WP	(FSU) Work Package

1 Introduction

The Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) study forms part of the National Flood Risk Assessment and Management Programme.

As part of the Shannon CFRAM Study, there is the requirement to complete a series of Hydrology Reports, one covering each unit of management within the Shannon River Basin District (RBD). The RBD consists of Units of Management (UoM) 23, 24, 25/26 and 27. UoM 25/26 is the amalgam of two hydrometric areas (HA25 and HA26).

A requirement of the Hydrology Report is to detail the hydrological assessment that has been undertaken as part of the study. A review of the available hydrometric data for the unit of management was undertaken and is detailed in the Inception Report (September 2012, Chapters 3, 6 and 7). That report also describes the methodologies that were chosen for this catchment.

A list of towns and villages that are thought to be susceptible to flooding was collated in the flood risk review stage. These towns and villages are referred to as Areas for Further Analysis (AFA). Other important flood risk receptors (e.g. power stations and airports) are defined as Individual Risk Receptors (IRR). Section 3.4 specifies the AFAs and IRRs in this unit of management.

To avoid issues with fluvial and tidal flooding occurring across unit of management boundaries, the AFA of Limerick is considered entirely in the UoM 25/26 hydrology report.

A review of historic flooding was undertaken during the Inception stage and the findings of this review are detailed in the Inception Report for this unit of management (Chapter 8). No significant floods have been experienced in this unit of management since the commencement of the Shannon CFRAM study in January 2011.

During the Inception stage, the catchment boundaries were checked; refer to Chapter 5 of the Inception Report for more details.

This report assumes that the reader has read the Inception Report related to this unit of management, and that he or she has a good understanding of hydrology, in particular statistical methods for flood frequency analysis and the Flood Studies Update (FSU) documentation and calculation techniques.

Chapter 2 of this report outlines the methodology of the design flood hydrograph estimation process. Chapter 3 describes the study area including its flood history. Chapter 4 introduces the sub-catchment wide and model-specific hydrological analysis undertaken, which are detailed in Appendix A (in 11 chapters, one for each sub-catchment) and B (in 16 chapters, one for each hydraulic model). Conclusions and recommendations are provided in Chapter 5. Chapter 6 gives the relevant references. The rating review summary sheets for reviews undertaken in UoM 25/26 are included in Appendix C. Appendix D presents gauging station information sheets with the original and revised AMAX series as used in the design flood hydrology for the sub-catchments within this unit of management. Appendix E shows the flood

frequency curves for flow gauging stations which have been used for design flood estimation. Appendix F contains the calibration sheets for each model, and Appendix G presents pooled analysis audit trails for the unit of management.

2 Methodology

2.1 Introduction

This chapter outlines the general principles of the hydrological methodology employed in the design flood hydrograph estimation process. It discusses briefly the rating reviews in the unit of management, the flood frequency analysis, the selection of a hydrograph shape along with hydrological and model calibration.

2.2 Rating Reviews

Rating reviews were undertaken for 28 stations in this Unit of Management. The rating review gauging stations are shown on Figure 2.1 below and on the model extent maps in the respective sub-catchment sections in Appendix A. For most stations hydraulic modelling was undertaken local to the station to produce a revised rating. Table 2.1 below lists the gauging stations that were included in the review. The results of the analysis are provided in the Rating Review Summary Sheets, which have been included in this report in Appendix C.

The quality of all relevant flow-recording gauging stations in the modelled catchments (both the reviewed and not reviewed stations) within the unit of management is discussed in the respective sub-catchment sections in Appendix A.

Gauging Station Number	Gauging Station Name	Gauging Station Number	Gauging Station Name
25001	Annacotty	26001	Ballinamore
25003	Abington	26002	Rookwood
25006	Ferbane	26004	Bookala
25011	Moystown	26005	Derrycahill
25013	Newell's Bridge	26006	Willsbrook
25014	Millbrook	26007	Bellagill
25015	Pollagh	26008	Johnston’s Bridge
25016	Rahan	26012	Tinacarra
25017	Banagher	26014	Banada Bridge
25021	Croghan	26016	Ballymurray
25022	Syngefield	26019	Mullagh
25024	New Bridge	26021	Ballymahon

Gauging Station Number	Gauging Station Name	Gauging Station Number	Gauging Station Name
25027	Gourdeen	26022	Kilmore
25029	Clarianna	26108	Boyle Abbey Bridge

Table 2.1 UoM 25/26 Gauging Station Rating Reviews

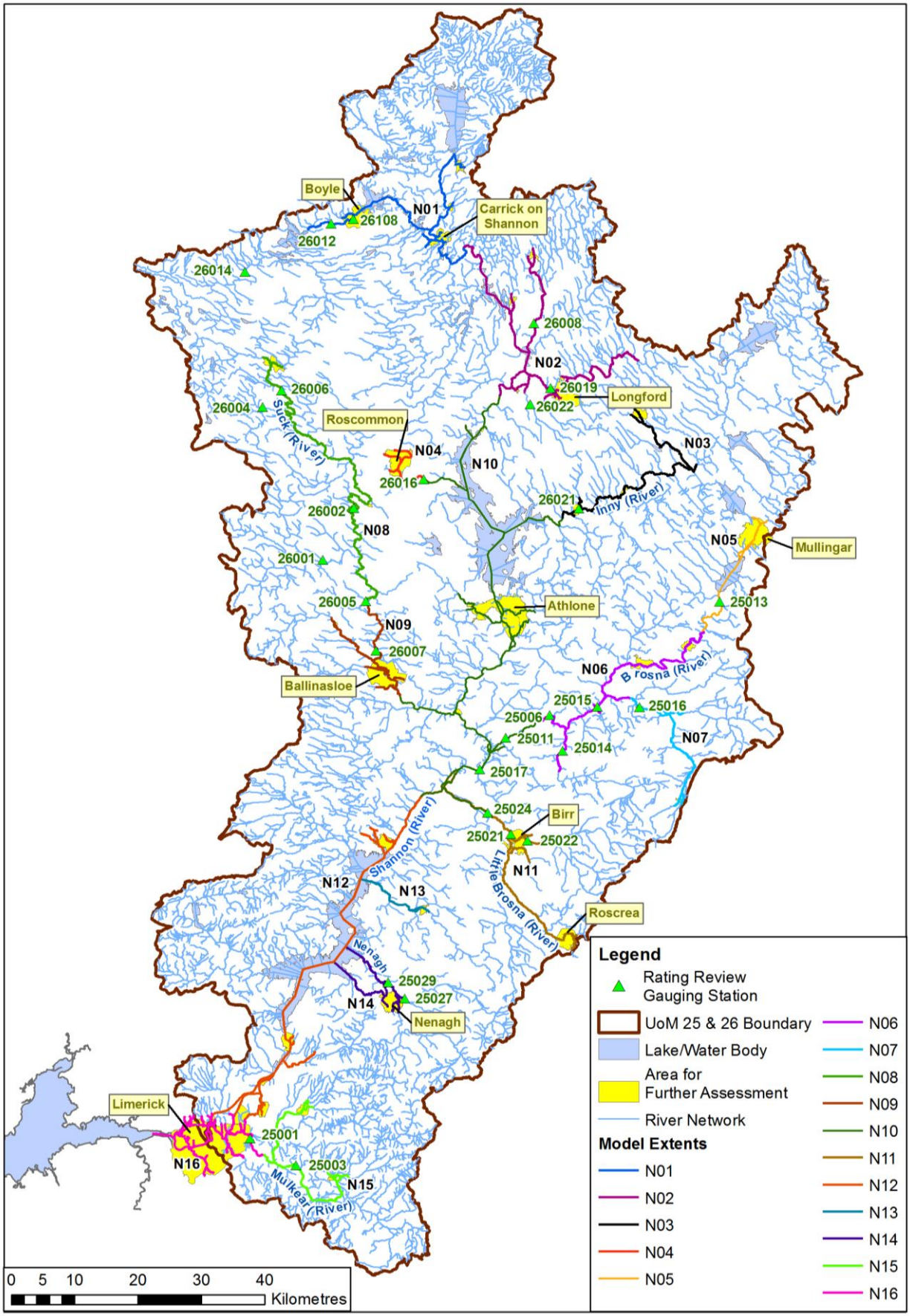

Figure 2.1 Rating Review Stations in UoM 25/26

2.3 Design Hydrology

Due to a dearth of sub-daily rainfall data, Jacobs' approach to peak design flow estimation in the Shannon River Basin District (RBD) avoids the use of such data, focussing instead on the use of gauged flow data, supplemented by Flood Study Update (FSU) techniques where no flow data is available. The Gauging Station Information Sheets in Appendix D provide an overview of each gauging station used with the design hydrology and the existing and revised AMAX series.

The design hydrology approach is summarised below:

1. Gauging station rating reviews provide increased confidence in high flows gauged at specific gauging stations in the catchment. These gauging station reviews are critical in providing reliable information to be used as pivotal sites for hydrological adjustments to flood estimates at ungauged sites.

2. Rework the annual maxima series of flood flows as required at rating reviewed gauging stations.

3. Estimate the median of annual maxima flows (QMED) for key gauging stations (ideally ones that have been subject to a rating review or ones that are otherwise reliable) in or near the model domain from the gauged annual maxima at the site and compare this to the outcome of the FSU regression equation at the gauging station. Divide the two QMED estimates at these stations to obtain a QMED adjustment factor (QMED,observed / QMED,synthetic)

4. Estimate QMED at all ungauged HEPs using the FSU regression equation and adjust these using the QMED adjustment factor found in Step 3 for the key gauging station in the vicinity of the HEPs. This is done in accordance with implementation guidance in the FSU with respect to pivotal sites, with the determination of adjustment factors for any model length being guided by the number, quality and similarity of the gauging stations available for selection as pivotal sites.

   To assess which river sections the QMED adjustment factors and the growth curves (see Step 5 below) will be applied to, ***river reaches*** are defined in the context of this study as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up in river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations.

5. Produce flood frequency estimates at the key gauging stations by multiplying the observed QMED estimate with a suitable set of growth factors to obtain a range of AEP peak flows. The growth factors are obtained by pooling group analysis and single site analysis. The results of these two methods are then compared and a view is taken on the best choice of method and distribution. Refer to Section 2.5 for more detail on the choice between pooling and single site distributions.

6. Estimate the hydrograph shape for the watercourse from gauged data or a pivotal site, using the methodology described in Section 2.6 below.

7. Combine output from Steps 4, 5 and 6 above to estimate design flood hydrographs at each HEP.

8. Run hydraulic models (with appropriate amendments to the model inflows where required) to give consistency of design flows between the hydrological and hydraulic estimates, within a reasonable degree of accuracy (a difference between anticipated total flow and hydraulic model flow of less than approximately 10% is normally sought). The inflow hydrographs resulting from Step 7 above need to be timed in such a way that the peaks of all inflow hydrographs coincide with the peak of the flood wave moving down the river system.

9. Once calibrated, adjust the timings of the downstream tidal boundary such that the flood peak at the downstream end of the model coincides with the tidal peak, taking account of the Guidance Note on Joint Probability Analysis (GN20).

The adopted approach avoids the use of rainfall data, which has the advantage that it does not need to make assumptions about the spatial distribution of calibration rainfall events which is only known at very few point locations. It also avoids having to make assumptions with regard to the runoff coefficients during design events. Instead, the approach relies on gauged flow and level data where these are available, and on the FSU regression equation for QMED where such data is not available (adjusted with pivotal data where appropriate).

The hydraulic models mentioned in Step 8 incorporate the model representations at gauging stations used for the rating reviews in Step 1.

The method described above often required that in branched river systems with a main stem and tributaries separate hydraulic model runs for the main stem and the tributaries were carried out. This was because in many cases it was not possible to capture the critical events on the main stem and on the tributaries in a single run, as the event duration (affecting both hydrograph shape and peak) critical for a tributary may not give the critical water levels on the main stem.

If the critical hydrograph from a tributary was added to the main stem, this typically had a shorter duration and a higher peak than the hydrograph required to maintain the flood frequency and volume on the main stem, and would often result in a peak flow in the main stem that was higher than the target flow. If this difference was significant (adding more than about 5% to the main stem target flow) then two runs were undertaken:

1. Main stem run – this run would maintain flood frequency and volume on the main stem, by applying hydrographs to the tributaries that had the shape of the critical event duration on the main stem, and the peak optimised to obtain the target flows at each HEP (as per Step 8 above);
2. Tributary run – this run would maintain flood frequency and volume on the tributaries, by applying the design hydrograph shape and peak critical for the tributaries, and a suitable flow in the main stem to maintain an appropriate downstream boundary water level. For this study this was taken as the 2-year return period (50% AEP) design peak flow for the main stem, applied as a constant flow.

An additional run was sometimes required for tributaries of tributaries of the main stem. The runs undertaken for each model are described in Appendix B.

The different components of the design event flow estimation process (QMED, growth factors, hydrograph shape) are discussed in Sections 2.4 - 2.6 below.

2.4 Determining QMED

At a gauged site QMED was obtained as the median of the annual maximum flow series. At ungauged sites QMED was estimated using a regression equation based on seven catchment descriptors as detailed in FSU Work Package 2.3.

Where there is no gauged data the approximate 68% and 95% confidence intervals for an estimate of QMED based on the regression equation can be given as:

68% confidence interval = (QMED/fse, QMED x fse)
95% confidence interval = (QMED/fse^2, QMED x fse^2)

Where possible these estimates were improved by adopting a pivotal site, either in the same catchment, a neighbouring catchment, or in a hydrologically similar catchment.

The rainfall runoff response of a catchment can be altered by urbanisation where impervious surfaces inhibit infiltration and reduce surface retention, while increases in surface runoff result in an increase in the speed of response. The effect on the peak flow is accounted for in the hydrological analysis by an urban adjustment factor (UAF) applied to the rural estimate of QMED, as specified in Section 4 of FSU Work Package 2.3.

2.5 Determining Flood Frequency Curves

2.5.1 General

Growth factors may be determined from at-site data, if sufficient good quality data exists. This study includes the estimation of flood peaks with annual exceedance probabilities as low as 1% (1 in 100), 0.5% (1 in 200) and 0.1% (1 in 1000), and at-site data will not normally have long enough records for single site analysis to be appropriate. It is noted that OPW have intimated at the second NTCG meeting that the 1% (1 in 100) AEP event should be considered the target probability. For that target probability pooling group analysis was normally selected in preference over single site analysis, unless it was found that a representative pooling group could not be formed, or the at-site data showed that the pooled curve was not realistic. Where the available information was not decisive on the use of pooled or single site analysis, then when certain conditions (specified in FSU Work Package 2.2) were satisfied a combined approach was considered. A method of combining the two methods is specified in a technical note from OPW (*Combining Site and Pooled Analyses at the Subject Site* (M2.11), 10 December 2012).

The choice between a single site and pooling group analysis was made on a site by site basis. The decision was informed by the reliability of AMAX data, the record length, the presence of extreme floods in the AMAX series, the fit of different statistical distributions, and the homogeneity of the pooling group. The flood frequency curves at each gauging station comparing pooled distributions with at-site data are included within Appendix E. The pooling analysis audit trails are located in Appendix G.

The details of the choice of the distribution for the flood frequency curve for each relevant station are provided in the catchment-wide analysis in Appendix A, Sections A1.6, A2.6, A3.6, etc.

2.5.2 Single Site Analysis

The required flood magnitude may be estimated from a single record of at-site data providing the AMAX series is sufficiently long in relation to the target return period. FSU Work Package 2.2 (Section 14.2) states:

"*The required flood quantile may be estimated from a single record of at-site data providing:*

- *the record length N is at least 10 years long*
- *the required quantile return period T is less than N, or not appreciably larger than N and certainly not more than 2N*"

As indicated in Section 2.5.1, the 1% (1 in 100) AEP storm can be considered the target design event for the hydrological analysis. FSU Work Package 2.2 (Section 14.6) states that: "*in ordinary circumstances a three parameter distribution should not be used with at-site data. An exception could be made if the data series is very long, say > 50 years, and the required return period is small, say 25 years.*" With a focus on a return period of 100 years, two parameter distributions have generally been selected in the Shannon CFRAM study. A few exceptions have been made where long records were available (> 50 years) and three parameter distributions could be shown to give a better fit with the AMAX flows and more realistic AEPs for the highest floods on record.

FSU Work Package 2.2 (Section 14.2) also states that: "*In the case of EV1 the parameters should be estimated by the method of probability weighted moments (or the L-moment equivalent).*" In the Shannon CFRAM study the method of (ordinary) moments was used to fit the EV1 distribution to the on-site data, in accordance with Shaw et al (2011). In the few occasions where three parameter distributions were chosen the more refined L-moments method was employed to fit a flood frequency curve to the observed data.

The selection of the (single site) distribution (EV1, LN2, etc) was done visually from a Gringorten plot showing the ranked AMAX series. Where estimates of the AEP of the highest recorded floods were available, this was used to select the distribution that assigned an AEP to that event that was closest to the estimate.

2.5.3 Pooled Analysis

The 100 year event is considered the target return period for this study. If the 5T rule is applied to the 100 year flood estimation then a minimum of 500 station years of data should be included in the pooling group. FSU suggests that such a pooling group be used for all return periods rather than constructing a separate group for every return period of interest. Pooling groups were selected on the hydrological similarity between sites, although the criteria of nearness and presence in the same catchment may also play a role (the latter particularly in larger catchments).

The initial catchment descriptor limits for the acceptance of sites to the pooling group are shown in Table 2.2 below.

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

Table 2.2 Pooling Analysis Acceptable Ranges

If no homogenous pooling group could be established within these limits, then the limits were relaxed as deemed appropriate for that subject site.

Consideration was given to the choice of using two parameter or three parameter distributions. Two parameter distributions were generally applied, but three parameter distributions were considered in the case of a particularly poor fit. In most cases variations in peak design flows were relatively small between the various pooled distributions.

The pooling group analysis was carried out using a spreadsheet that was based on an example template provided by OPW (120912 - Pooled FloodFrequency Analysis -V4.xls). This spreadsheet was amended by Jacobs to satisfy the FSU methodology for pooling. The spreadsheet includes a plot of L-Moment ratios (L-kurtosis vs L-skewness) in which each 2-parameter distribution is represented as a point in the plot. The average of the same L-Moment ratios of the pooled stations was also plotted in the same graph. In ungauged reaches the distribution which is closest to the pooling group L-Moment ratios in the L-kurtosis vs L-skewness plot is selected to produce the flood frequency curve.

In gauged reaches, if the at-site analysis at a gauging station was based on sufficiently reliable data (with a relatively long record and a few extreme floods), the pooled distribution which matches closest with the single site growth curve was favoured as the latter is based on local flood data. The comparison of single site analysis with pooling group analysis allows a check on the validity of the design floods. Where single site analysis indicates that the pooled distribution may not be representative for the site (e.g. if the pooled 1% AEP [100 year return period] flood has been exceeded several times in a relatively short period of record), then a single site flood frequency curve may be more appropriate than the pooled flood frequency curve.

2.6 Hydrograph Shape

The method of determining the design event hydrograph shape was selected in order to make best use of the available gauged data.

For gauged sites with sufficiently reliable flow records, the highest gauged flows were determined using the AMAX and DMF data. For the majority of stations the four highest recorded floods were selected and the hydrograph that from a visual comparison best represented the median duration at 80% of the peak flow was used in the design hydrology. With typical record lengths of 30 to 60 years these four floods will have return periods roughly in the range of 7 to 200 years (14% AEP to 0.5% AEP) and therefore be representative of the return periods of events of

interest to this study (2 to 1000 years, i.e. 50% to 0.1% AEP). For stations with very short AMAX records (up to 10 years) only the highest three events were considered as the return period of the fourth highest peak would be likely to be too low to be representative for the range of floods that is to be considered for this flood study.

The above method involving the hydrographs of real flood events was preferred over the use of the gauged n, Tr and C parameters detailed in FSU Work Package 3.1 (WP 3.1, Hydrograph Width Analysis) which derives an average shape from the highest N events over a period of N years. That method is skewed towards higher frequency events as half of that set of events occurs more frequently than the 50% (1 in 2) AEP design event, events which are of lesser interest to this study.

On reaches where no gauged data was available an appropriate hydrograph shape was selected from a gauged pivotal site. The pivotal sites were selected in the following order of preference:

1. A reliable gauging station in the same catchment (downstream or upstream of the subject site) with similar catchment descriptors (see Table 2.3 below); or
2. A reliable gauging station in a neighbouring catchment with similar catchment descriptors (see Table 2.3); or
3. A hydrologically similar site, based on the similarity measure Dij which is a function of the three catchment descriptors BFIsoil (geology), FARL (routing) and S1085 (slope). The OPW Hydrograph Generator spreadsheet, (based on the FSU WP 3.1) was implemented for this analysis. The most similar site was compared with the subject site using a range of catchment descriptors to ensure that none of these descriptors were very different from the subject site, within the ranges shown in Table 2.3 below. If the most similar site didn't accord with the ranges in Table 2.3 then the second or third most similar site was compared.

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25%
SAAR	+/- 25%
FARL	+/- 10%
URBEXT	+/- 2.5
S1085	+/- 50%
ARTDRAIN	+/- 10
ALLUV	+/- 3

Table 2.3 Hydrograph Shape Acceptable Ranges

At pivotal sites the design event hydrograph was determined with the FSU WP 3.1 hydrograph shape equations using the gauged n, Tr and C parameters, or using the Top 3-4 of recorded flood peaks if such information was readily available (i.e. at reliable stations in the Shannon RBD).

A consistency check was undertaken to ensure that the synthetic hydrograph duration for a tributary was shorter than that of its main stem (gauged or pivotal), or another nearby larger watercourse, if (all other parameters being similar) the catchment was smaller. Where a pivotal site failed this consistency test, another pivotal site was considered if available.

The presence of karst features in the catchment was also taken into consideration. A pivotal site with a different geology with regard to karst than the subject site may not be considered a suitable pivotal site.

In small ungauged tributary catchments where no suitable pivotal site could be found, the FSU WP 3.1 regression equations were employed to derive a synthetic hydrograph shape. For larger catchments this is not generally the preferred approach because the correlation between the catchment descriptors and the shape parameters n, Tr, and C is weak, and the regression equations do not feature the catchment area as an independent variable, whilst the catchment area can be expected to be one of the key parameters affecting the flood duration.

However, for small ungauged tributaries for which no suitable pivotal site was available, the FSU WP 3.1 method was considered acceptable and was adopted if a consistency check between the subject catchment and other catchments showed that the resulting flood duration was reasonable. The consistency check ensured that the flood duration for a tributary was shorter than that of its main stem (gauged or pivotal), or another nearby larger watercourse, if (all other parameters being similar) the catchment was smaller.

At ungauged sites where no suitable pivotal station could be found and the synthetic hydrograph was considered unrealistic or inconsistent, the FSR (NERC 1975, Volume I, Section 6.8.2) method for producing a flood hydrograph shape was used as a last resort.

The required design flood hydrograph was calculated by linear scaling of the hydrograph's ordinates so that the peak agreed with the target peak flow obtained from the statistical analysis for each specified return period. The selected hydrograph shape is used for each HEP in a river reach as defined in Section 2.3 (Step 4) above. Following an initial hydraulic model run the modelled total flow hydrograph at the subject site was compared with the selected design hydrograph to ensure that the resulting hydrograph has a similar volume.

2.7 Calibration

2.7.1 General

The dearth of sub-daily rainfall records for the catchment severely limits the application and accuracy of traditional rainfall-runoff techniques to simulate historical events. The uncertainty arising in the calibration of such models and the subsequent need to adjust the model flood flow predictions to align with the flood frequencies derived from local flow gauge records renders rainfall-runoff modelling ineffective. Rainfall-runoff modelling of historical events has therefore been discounted. The use of radar rainfall data was dismissed for rainfall-runoff modelling due to known issues with the calibration of such data, and the relatively short radar record length. This data may still be useful for qualitative assessment of the distribution of rainfall during calibration events, where such information is required.

Hence a combination of Hydrological Estimation Point calibration and hydraulic calibration is proposed as detailed in the sections below. The detailed Calibration Strategy Sheets for the hydraulic calibration of each model extent are located in Appendix F.

2.7.2 Hydrological Estimation Point (HEP) Calibration

Within the broader context of hydraulic model calibration, there was the need for consistency and continuity moving downstream through the catchments with regard

to flows and flow frequency. Therefore, for a given AEP the peak flow at one HEP derived from the hydrological analysis should match broadly with the total flow in the model at that location, and there should be only a small discrepancy between the estimates. The accepted discrepancy for this study was 10%.

If a discrepancy greater than 10% was found, normally because the routing/storage effect in the catchment was greater than the hydrological flow estimation method predicts, then inflows were reworked to obtain a better match between modelled flows and anticipated flows based on the hydrological analysis. It should be noted that locally the discrepancy can be different for a wide range of physical reasons not represented by the hydrological methods, and that the inflows were only adjusted if the discrepancy was consistent over a range of HEPs and for a range of AEPs.

2.7.3 Hydraulic Calibration

Where a flow gauge was located at a suitable location upstream or downstream of an AFA and suitable historic (anecdotal) flood information existed, two in-bank events and two out of bank events were selected. The relevant hydrographs were obtained from the gauging station and applied to the hydraulic model to allow the gauged reach through (or very close to) the AFA to be calibrated and verified. Intervening ungauged catchments contributing to the watercourse through the AFA were scaled according to the ratio of the peaks of the gauged calibration event and QMED at the gauged location. Clearly, the closer the gauge was to the AFA and the fewer the number of ungauged contributing catchments between the gauge and the AFA, the more successful the calibration was.

Where no historic (anecdotal) flood information existed, it was sometimes still possible to calibrate the model using gauged water levels. To calibrate the hydraulic model this level gauge should not normally be the same gauge as the one that provides the historic flows to the model, as such flows are derived from water levels at the gauge, and the model run would only provide a localised comparison of the model rating with the rating previously established at the gauge. Especially at rating review stations, where the rating used to establish the calibration event hydrograph may be based on a hydraulic model, this would be a circular argument and not actually test the modelled flood outlines. Where two or more gauging stations were close to each other (on the same main watercourse), the upstream flow gauge could be used to provide flow data to the model, and the observed water levels at the downstream gauge could be compared with the modelled water levels at the same location. This method was not normally successful if significant tributaries joined the main watercourse between the two stations, unless the tributary had a reliable flow gauge close to the confluence.

In areas without a nearby flow gauging station, anecdotal and historical flood information (if suitably reliable information was available) was compared to the flood outlines derived from the design events. This served as a reality check and helped determine whether the frequency of flooding experienced in the past was broadly replicated by the model.

Where reaches that were suitable for calibration were tidally influenced, and suitable historic tidal hydrographs existed, these hydrographs were applied to the models as part of the calibration process.

With regard to data gathering for use within the model calibration exercise, the focus was to draw on data included within www.floodmaps.ie where this provides sufficient information, supplemented with additional data provided by Local

Authorities where details were known. To facilitate the data collection and provide an indication of when flooding may have occurred, the dates of the AMAX data for specific gauges have been used to identify the worst floods within particular AFAs.

2.8 Fluvial-Tidal Joint Probability Analysis

Theoretically it can be expected that fluvial and tidal flooding are not fully independent, based on the consideration that intense rainfall (causing fluvial flooding) and tidal surge (causing tidal flooding) are both likely to be associated with low air pressure events, in particular for small catchments.

Fluvial flow and tidal level data was analysed to assess the potential for dependency between the fluvial and tidal data. The available tidal data for the Shannon estuary is limited. Many of the gauges are located within areas where levels are significantly influenced by river flows. Hence many of the values in the AMAX series of levels represent fluvial flow peaks rather than extremes of tide and surge. Other tidal gauges have only a relatively short period of data available.

One gauge (Feale at Moneycashen [23068]) was identified where peak levels appear to be largely uninfluenced by river flows and therefore this gauge approximates to a tide gauge. AMAX data for this gauge is summarised in Figure 2.2 below.

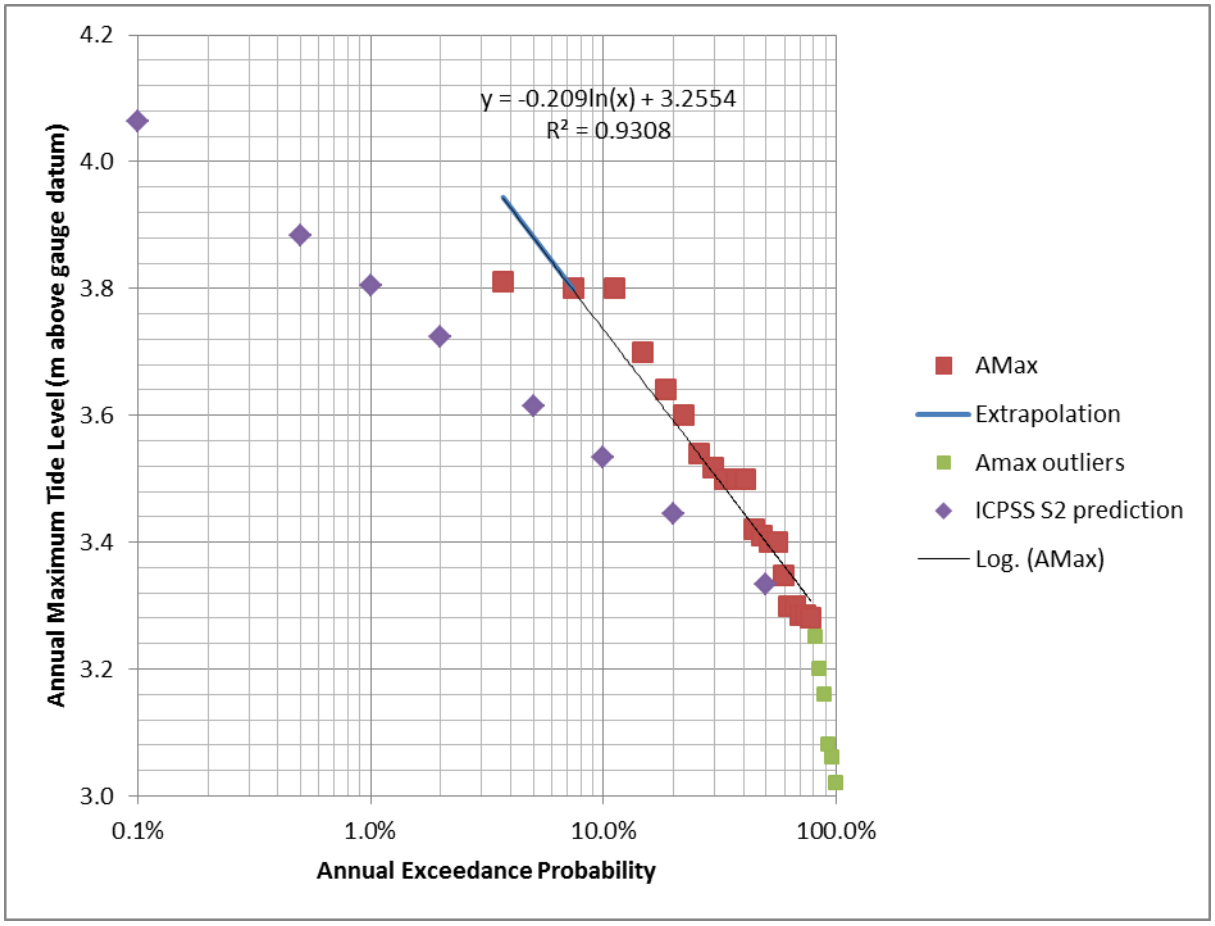

Figure 2.2 AMAX Levels for Gauging Station 23068

Predicted extreme water levels associated with combined tide and surge have been derived as part of the Irish Coastal Protection Strategy Study (ICPSS - Phase IV South West Coast). The closest prediction point to GS 23068 is ID S2. For a given AEP the AMAX series shows higher levels at the gauge location within the Feale estuary by up to 0.3m compared with ICPSS for prediction point ID S2. It is possible that this small difference could be explained by local hydraulic effects. The gauged data for the day of the maximum recorded level is shown on Figure 2.3.

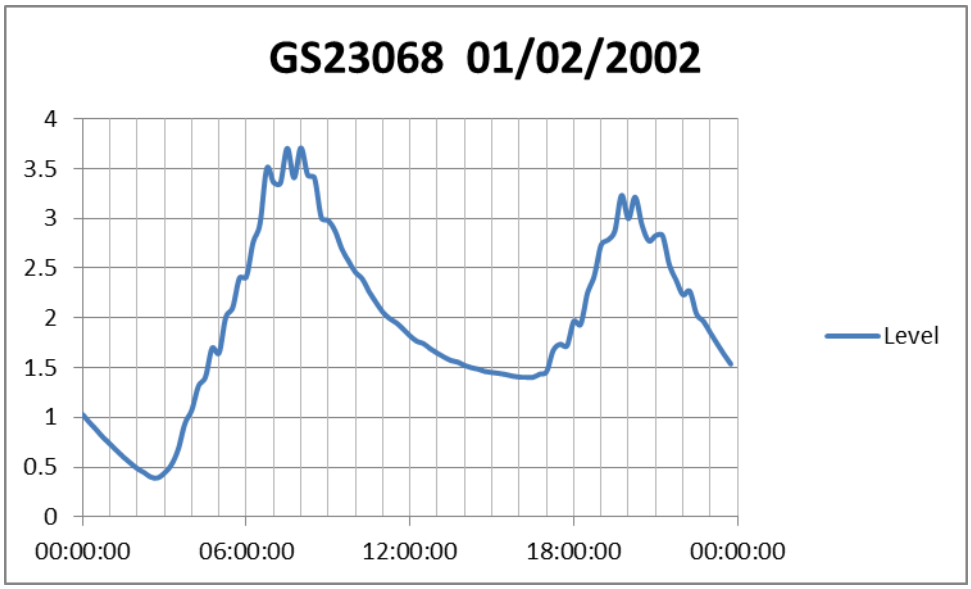

Figure 2.3 Gauging Station 23068 Maximum Recorded Tide Level

An analysis of the coincidence of AMAX tidal levels at Gauging Station 23068 with peak river flows at Gauging Station 23001 (see Figure 2.4 for gauge locations) around the time of the tidal peak has been undertaken as well as a corresponding analysis of peak tidal levels coincident with the AMAX river flows. The results are plotted on Figure 2.5.

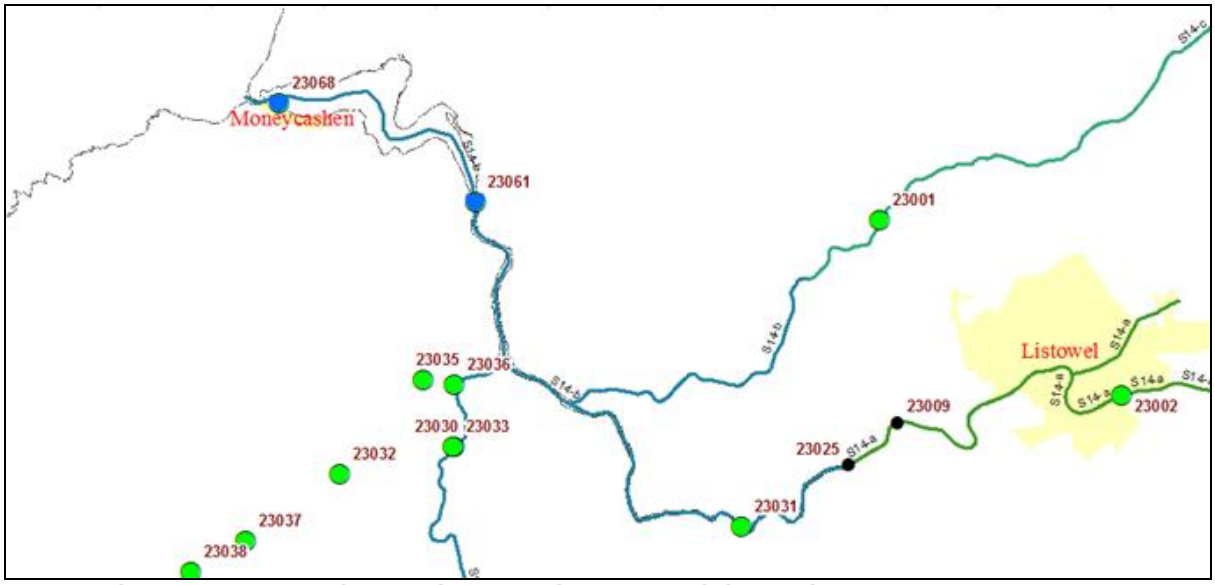

Figure 2.4 Gauging Station Locations around the Feale Estuary

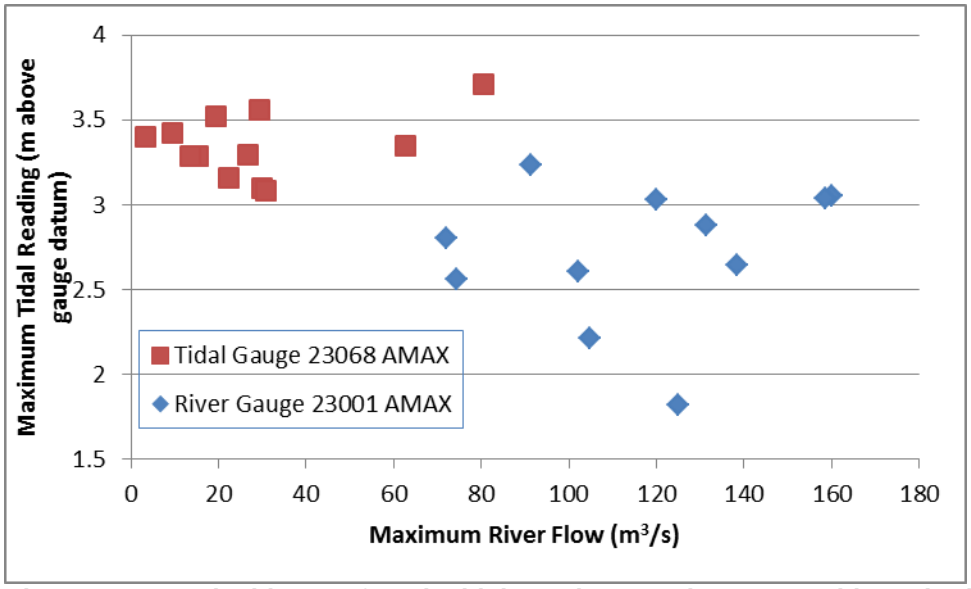

Figure 2.5 Coincidence of Peak Tidal Levels at Station 23068 with Peak River Flows at Station 23001

This analysis shows that, for the 11 years of available data, the highest AMAX river flow coincided with a tidal level of 3.23m which is 0.17m below the 50% AEP figure of 3.40m. It can therefore be concluded that the likelihood of a high river flow coinciding with an abnormally high tidal level is relatively low. Similarly, it can be inferred from Figure 4 that the likelihood of abnormally high tidal levels coinciding with peak river flows is also relatively low.

The available data series are not sufficiently long to make any definitive conclusions regarding the joint probability of more extreme events and it would be appropriate to allow for some degree of dependency for these more extreme events.

Limited tidal data for around 8 years is available for tidal gauge Station 27062 (Carrigaholt) on the north side of the Shannon estuary. An AMAX series for this gauge has been derived, excluding spurious readings in excess of 6m above gauge datum. The data is broadly consistent with that for ICPSS prediction point ID S4. The annual maximum level tidal data has been combined with peak flow data for three river catchments of varying sizes (and with level data for one gauge where flow is not available). Plots similar to Figure 2.5 for these combinations of gauges are shown on Figures 2.6 to 2.9.

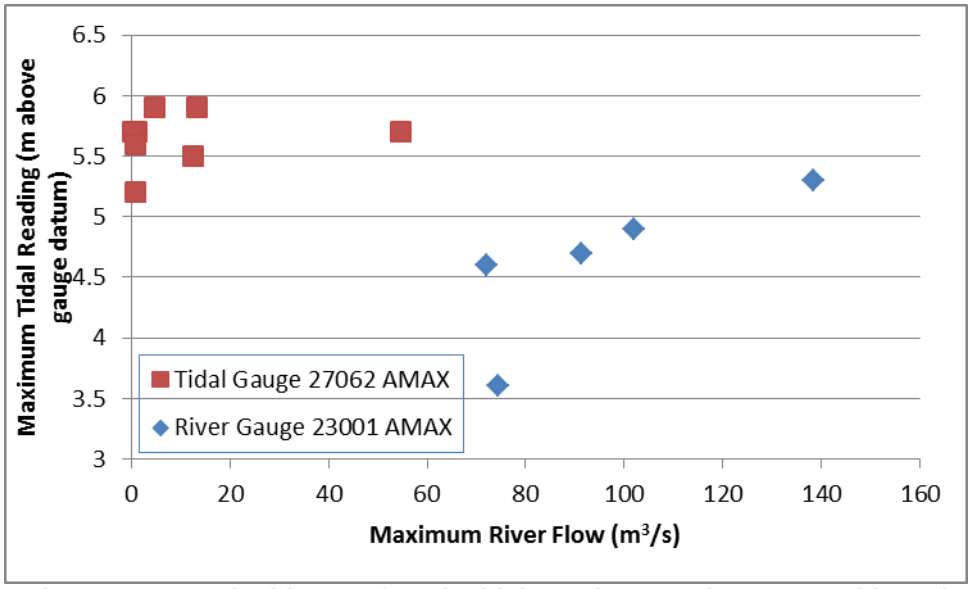

Figure 2.6 Coincidence of Peak Tidal Levels at Station 27062 with peak river flows at Station 23001

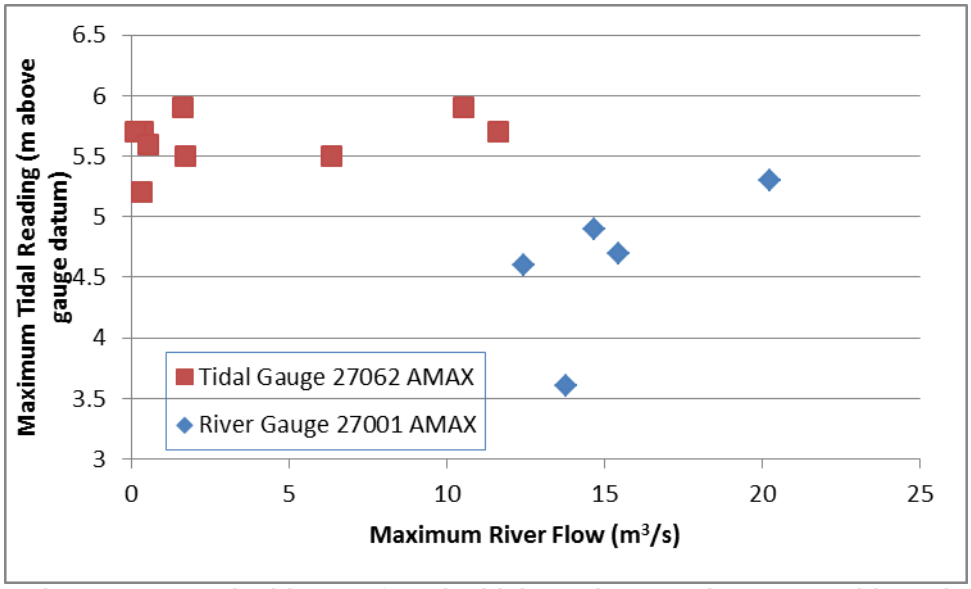

Figure 2.7 Coincidence of Peak Tidal Levels at Station 27062 with Peak River Flows at Station 27001

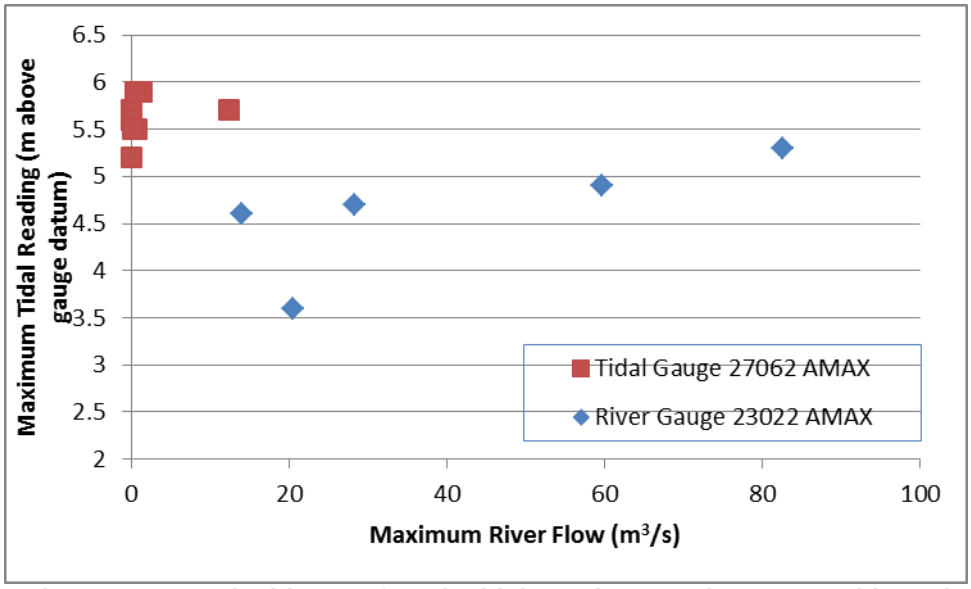

Figure 2.8 Coincidence of Peak Tidal Levels at Station 27062 with Peak River Flows at Station 23022

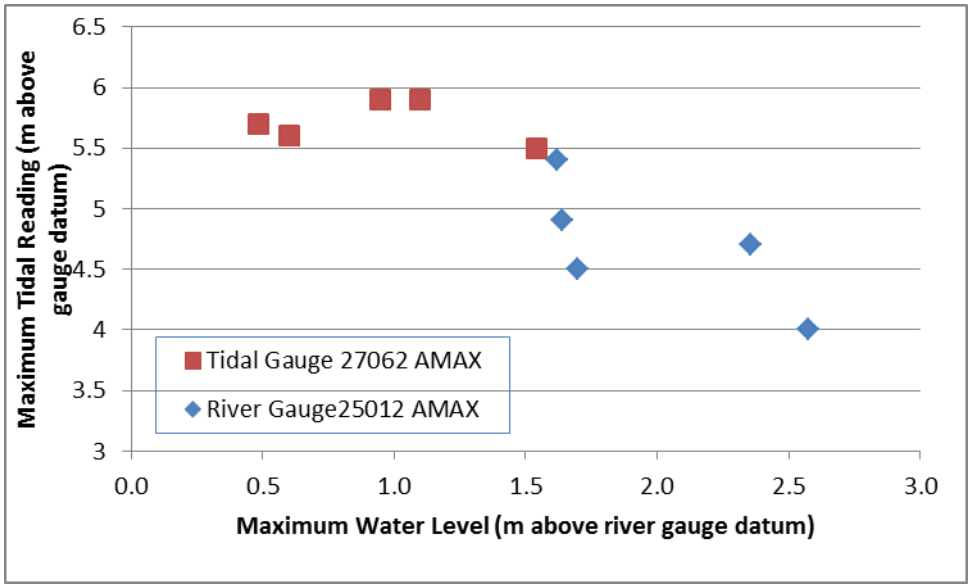

Figure 2.9 Coincidence of Peak Tidal Levels at Station 27062 with Peak River Levels at Station 25012

Figures 2.6 to 2.9 all show a similar pattern to Figure 2.5. However, as the available data covers a shorter period of record, the conclusions that can be drawn regarding dependency are less certain. A degree of dependency should be assumed based on the theoretical argument that fluvial and tidal floods are both associated with low pressure systems.

It is proposed that the joint probability of fluvial and tidal conditions for the Shannon CFRAM work in all catchments except the River Shannon catchment should be based on the combinations indicated in Table 2.4. The River Shannon catchment is discussed below.

Scenario	Joint Probability Design Event		Return Periods (Years) from Analysis		Return Periods (Years) Adopted for Modelling	
	Overall AEP	*Return Period (Years)*	*Fluvial*	*Tidal*	*Fluvial*	*Tidal*
1	50%	2	2	0.2	Scenario not required	
2	50%	2	*0.2*	2	2	2
3	20%	5	5	0.2	5	0.2
4	20%	5	*0.2*	5	2	5
5	10%	10	10	0.5	10	0.5
6	10%	10	*0.5*	10	2	10
7	5%	20	20	1	20	1
8	5%	20	*1*	20	2	20
9	2%	50	50	2	50	2
10	2%	50	2	50	2	50
11	1%	100	100	5	100	5
12	1%	100	5	100	5	100
13	0.5%	200	200	10	200	10
14	0.5%	200	10	200	10	200
15	0.1%	1000	1000	50	1000	50
16	0.1%	1000	50	1000	50	1000

Table 2.4 Design Scenarios Proposed for Adoption

Where fluvial flows less than those for a 2-year return period (50% AEP) are shown in Table 2.4 (underlined and italicised), design event data is not readily available. Therefore the tidally dominated scenarios 2, 4, 6 and 8 were run with a 50% AEP fluvial flow as indicated in column 6. Under these circumstances Scenario 2 (with 2 year fluvial and 2 year tidal) will never show less flooding than Scenario 1 (with 2 year fluvial and 0.2 year tidal), so when it comes to mapping the worst flood outline of the varying scenarios for a given overall AEP Scenario 1 will never be more severe than Scenario 2, so there is no need to run Scenario 1.

Where tidal levels lower than that for a 2-year return period (50% AEP) are shown in Table 1, these can readily be derived from the ICPSS analysis for the relevant prediction point as shown in Figure 2.10.

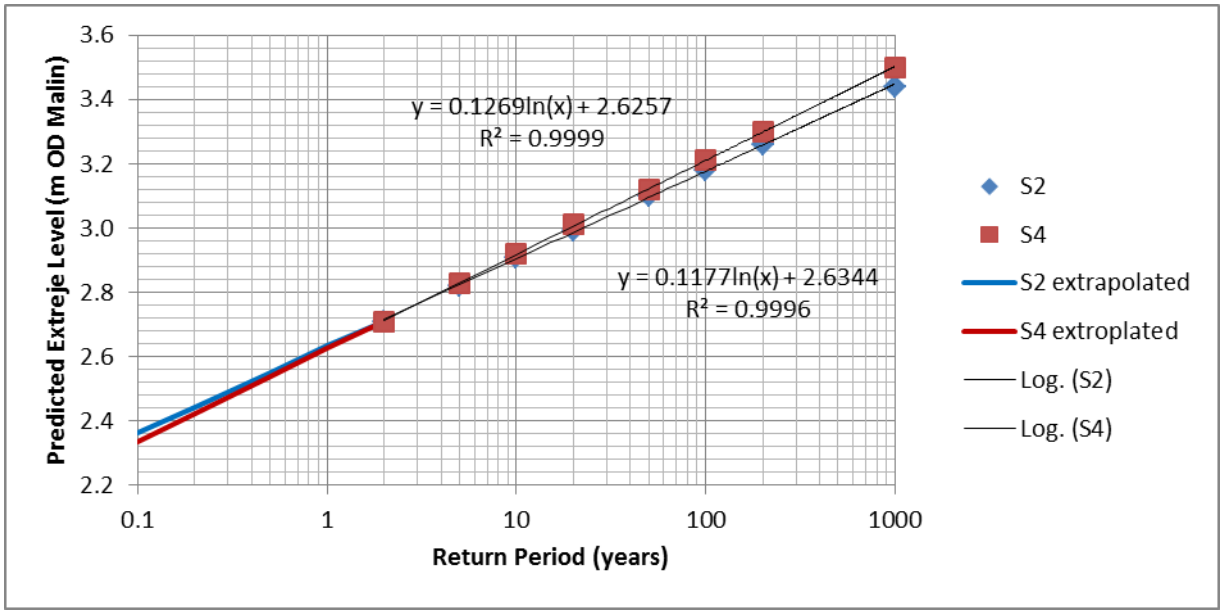

Figure 2.10 Extrapolation of ICPSS data for more frequent tidal events

On the same theoretical grounds that for small catchments it can be assumed that some dependency between fluvial and tidal floods exists, it can be assumed that for the largest catchment in the Shannon RBD the dependency is minimal. The RBD has one river catchment which is much larger than any of the other catchments. The River Shannon has a catchment area of 11,600 km^2 to its outflow point into the Shannon Estuary, and a catchment rainfall-runoff response time of several weeks (Section A6.6 in Appendix A of this report shows four historic hydrographs for Parteen Weir [Station 25075], immediately downstream of Lough Derg). In these conditions it can be expected that the dependency between fluvial flooding and tidal flooding is minimal due to the time delay between the low pressure system causing the floods and the fluvial flood wave arriving in the tidal zone. Therefore a more refined approach was adopted for the River Shannon that gives insight in the sensitivity of flood extents to the different combinations of fluvial and tidal events under the assumption of minimal dependency. In addition to the flood event combinations of Table 2.4 flood extents have been created for the following flood combinations:

1. 1% (1 in 100) AEP fluvial and 50% (1 in 2) AEP tidal
2. 50% (1 in 2) AEP fluvial and 0.5% (1 in 200) AEP tidal
3. 2% (1 in 50) AEP fluvial and 2% (1 in 50) AEP tidal

It should be noted that the third combination has a combined annual exceedance probability of only 0.04% (1 in 2500) when no dependency between tidal and fluvial events is assumed. The modelling showed that only in a very small transition zone the third combination (2% AEP fluvial and 2% AEP tidal) was critical. This shows that the floods along the Shannon are dominated by the critical tidal events (in the lower reach) and the critical fluvial events (in the upper reach). A comparison of the additional runs with the runs from Table 2.4 also confirms that in the tidal zone there is little sensitivity to the fluvial flood source and vice versa. The results of these sensitivity runs have been presented in the hydraulic modelling report.

Once this sensitivity test had been completed, the fluvial design events were all run with the 50% (1 in 2) AEP tidal downstream boundary, and the tidal design events were all run with the 50% (1 in 2) AEP fluvial downstream boundary.

3 Study Area

3.1 Introduction

The boundary of the Shannon CFRAM study area is delineated by the Shannon River Basin District (RBD) as defined for the Water Framework Directive.

3.2 Shannon River Basin District

The Shannon River Basin District is the largest River Basin District (RBD) in Ireland, covering approximately 17,800 km^2 and more than 20% of the island of Ireland. The Shannon RBD extends into Northern Ireland, although the part in Northern Ireland is very small and does not include any areas identified as being at particular risk of flooding. The RBD includes the entire catchment of the River Shannon and its estuary as well as some catchments in North Kerry and West Clare that discharge to the Atlantic (ref. Figure 3.1).

The RBD includes parts of 17 counties: Limerick, Clare, Tipperary, Offaly, Westmeath, Longford, Roscommon, Kerry, Galway, Leitrim, Cavan, Sligo, Mayo, Cork, Laois, Meath and Fermanagh. The population of the RBD is approximately 670,000 (based on CSO census data 2006). While much of the settlement in the RBD is rural there are five significant urban centres within the RBD: Limerick City (90,800), Ennis (24,300), Tralee (22,700), Mullingar (18,400), Athlone (17,500) and Tullamore (12,900). Agriculture is the primary land use in the district, using 70% of the land, and this is reflected in the district's settlement patterns.

3.3 Units of Management

Units of management, as defined by the OPW, constitute major catchments / river basins (typically greater than 1000 km^2), or conglomerations of smaller river basins and their associated coastal areas.

There are five units of management (UoM) within the Shannon River Basin District (see Figure 3.1):

- Unit of Management 23 Tralee Bay – Feale
- Unit of Management 24 Shannon Estuary South
- Unit of Management 25/26 Shannon Lower and Upper
- Unit of Management 27 Shannon Estuary North
- Unit of Management 28 Mal Bay

This report appraises only the Lower and Upper Shannon Unit of Management (UoM 25/26). Analysis and discussion for the remaining units of management are presented in separate reports. There is no hydrology report for UoM 28 as there are no AFAs within this UoM. For more details please refer to the Unit of Management 28 Inception Report (Chapter 9).

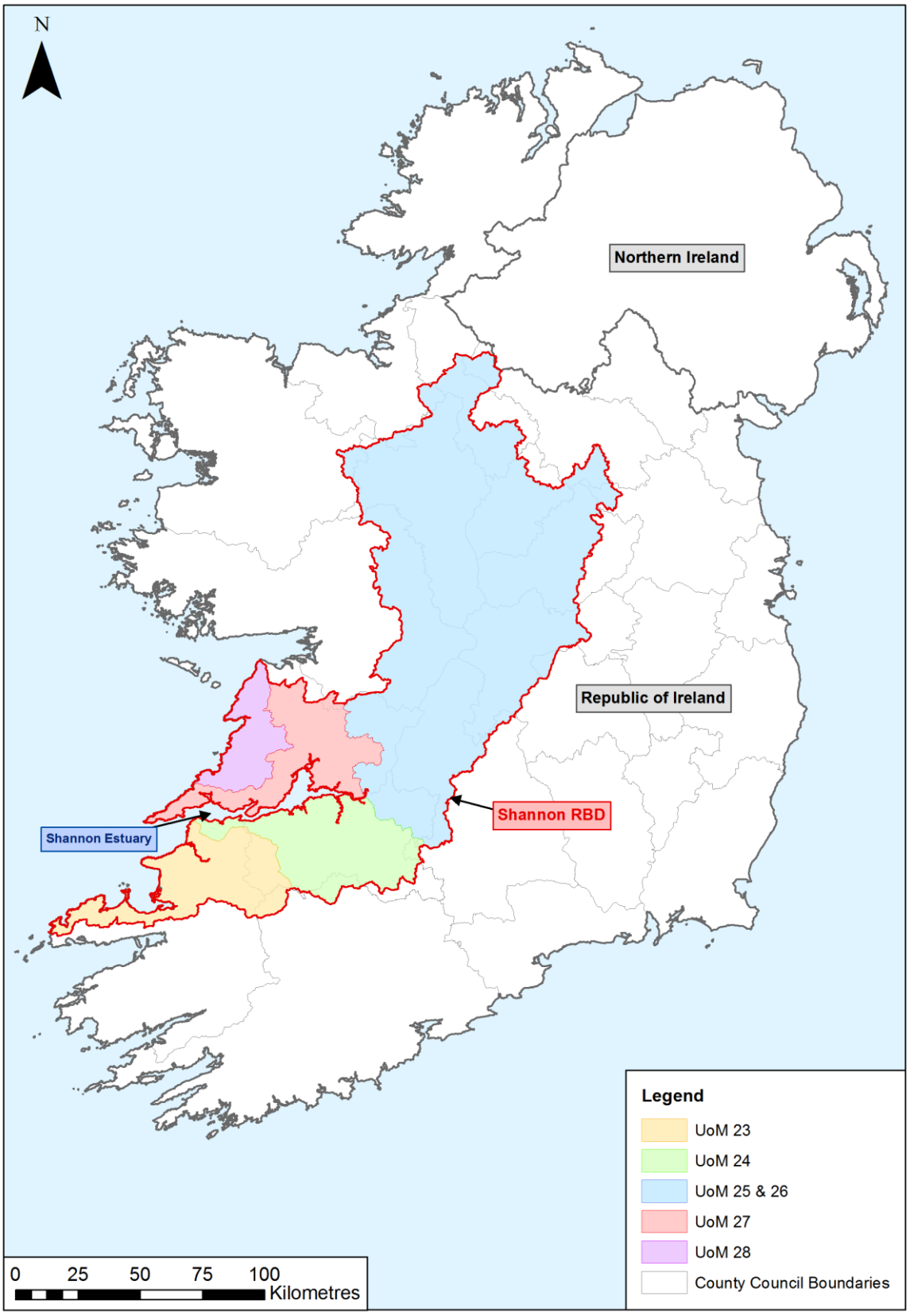

Figure 3.1 Shannon River Basin District and its Units of Management

3.4 Shannon Lower and Shannon Upper (Unit of Management 25/26)

The Shannon Lower and Upper Unit of Management (or UoM 25/26), encompasses areas of the following counties; Sligo, Leitrim, Roscommon, Longford, Cavan, Meath, North and South Tipperary, Offaly, Galway, Clare, Westmeath, Limerick and small areas of Mayo and Laois. A very small area (approximately 2.5 km^2) of County Fermanagh in Northern Ireland contributes to flow in the headwaters of the River Shannon. The total area of UoM 25/26 is approximately 11,600 km^2.

The unit of management is defined by the catchment of the River Shannon to its tidal limit just upstream of Limerick City. The River Shannon reportedly rises in the Shannon Pot, around a pond on the slopes of Cuilcagh Mountain in County Cavan, from which a small stream emerges. However, the true source of the river is probably in County Fermanagh where a small stream disappears into a sinkhole. The whole upper part of Cuilcagh Mountain consists of a porous limestone and is full of sinkholes and risers. From the Shannon Pot, the river is joined by a number of tributaries, some of which are larger than itself, and emerges into the head of Lough Allen.

From Lough Allen the Shannon flows south through a series of navigation locks to Lough Ree. It is joined on its way by major tributaries including the Boyle and Inny, but also by the Shannon-Erne Waterway.

Lough Ree discharges at Athlone and continues south. Between Athlone and Portumna the Shannon is wide and passes through an area of extensive peat bogs which form part of the natural floodplain. In the areas of mechanised peat extraction, by Bord Na Móna, silt from the peat bogs has encroached into the upper portions of Lough Derg. The silt is conveyed through a series of drainage networks used to convey runoff from the peat bogs. Historically these networks discharged directly into the Shannon. Some effort has been made to regulate this discharge with the intention of reducing the volume of silt leaving the bogs and entering the river. Prior to entering Lough Derg, the Shannon is joined by the River Suck, which flows through the town of Ballinasloe, as well as the River Brosna, the Little Brosna and the Grand Canal. The area between Athlone, Ballinasloe and Lough Derg form the Shannon Callows.

On the final reach between Lough Derg and the tidal limit at Limerick, the Shannon is joined by the Mulkear on the left bank.

There are 35 Areas for Further Assessment (AFAs) in Unit of Management 25/26:

Abbeyshrule	Cappamore	Edgeworthstown	O'Briens Bridge
Ahascragh	Carrick on Shannon	Kilbeggan	Pollagh
Athleague	Castleconnell	Killaloe / Ballina	Portumna
Athlone	Castlerea	Leitrim Village	Rahan
Ballinasloe	Clara	Longford	Roscommon
Ballymahon	Clonaslee	Mohill	Roscrea
Birr	Cloondara	Mullingar	Shannon Harbour
Borrisokane	Dromod	Nenagh	Springfield
Boyle	Drumshanbo	Newport	

There are two Individual Risk Receptors (IRRs) in UoM 25/26:

Lanesboro (Power Station)	Shannonbridge (Power Station)

To assist with the hydrological analysis, the unit of management has been divided into sub-catchments. These are the Upper Shannon, Inny, Hind, Brosna, Suck, Middle Shannon, Little Brosna, Ballyfinboy, Nenagh, Lower Shannon and Mulkear. These sub-catchments are shown on Figure 3.2 and the hydrology for each of these catchments is discussed in detail in Appendix A, Chapters A1 to A11.

3.5 Geology

The spatial distribution of geological features of UoM 25/26 including hydrogeological groupings of the aquifer, soil drainage types and Karst geological features are presented in Figures 3.3, 3.4 and 3.5 respectively. The classification of the aquifer groups are presented in Table 3.1. Figures 3.3 and 3.4 are based on the same data that is used in Figures 4.1 and 4.2 in FSU WP 5.2 (OPW 2009).

Figure 3.3 and Table 3.1 show that the 'Locally important aquifer' group (LI) is the dominant aquifer in the central and eastern areas of UoM 25/26 basin. In the north-western part of the basin the 'Regionally important karstified aquifer' group (Rkc and Rk) dominates. In the extreme northern, south-eastern and south-western parts of the basin there exists some 'Poor aquifer – bed rock which is generally unproductive' group (Pu, PI). In addition to above, there are some 'locally important karstified aquifer and regionally important karstified aquifer dominated by diffuse flow' group (LK, Rkd) located in the eastern part of the basin.

The soils of UoM 25/26 (Figure 3.4) are dominated by a mixture of well-drained soil and peat, together with some poorly drained soil located mainly in the extreme north, extreme south and western part. Although peat is scattered across the entire catchment, the largest expanses are located in the central, northern, north-western and south-western parts of the basin.

Where a limestone aquifer is exposed, karst features like springs, swallow holes (or sinkholes) and turloughs may be present on the surface. A turlough is a depression or lake from which water drains into the porous substrata. Springs, swallow holes and turloughs may be connected to underground drainage paths. These features can affect the local hydrological response to rainfall, as surface water may disappear into the ground and reappear elsewhere. For very large floods the effect of karst can be expected to diminish as the capacity of the karst features and the underground pathways will not usually be sufficient to accommodate the largest floods.

A detailed analysis of the hydrological response of individual karst features in the unit of management falls outside the scope of the CFRAM study. To best allow for the effects of karst features in a catchment, this study will rely on locally observed flow data where this is available. Therefore in a karst catchment it may be decided that locally gauged data is preferred over data transferred from pivotal sites. If a karst catchment has no reliable gauging station then a pivotal site from another (similar) karst catchment is likely to be more appropriate than the use of pivotal sites that are hydrological similar only in terms of their catchment descriptors.

The locations of karst features and of geological strata that can exhibit karstic behaviour are shown on Figure 3.5. The Geological Survey of Ireland (GSI) has provided the base data for the information shown on this map. The karst features shown forms a detailed inventory of surveyed karst features in Ireland. However,

this information is not complete and may not show the features in certain counties where no survey has yet taken place.

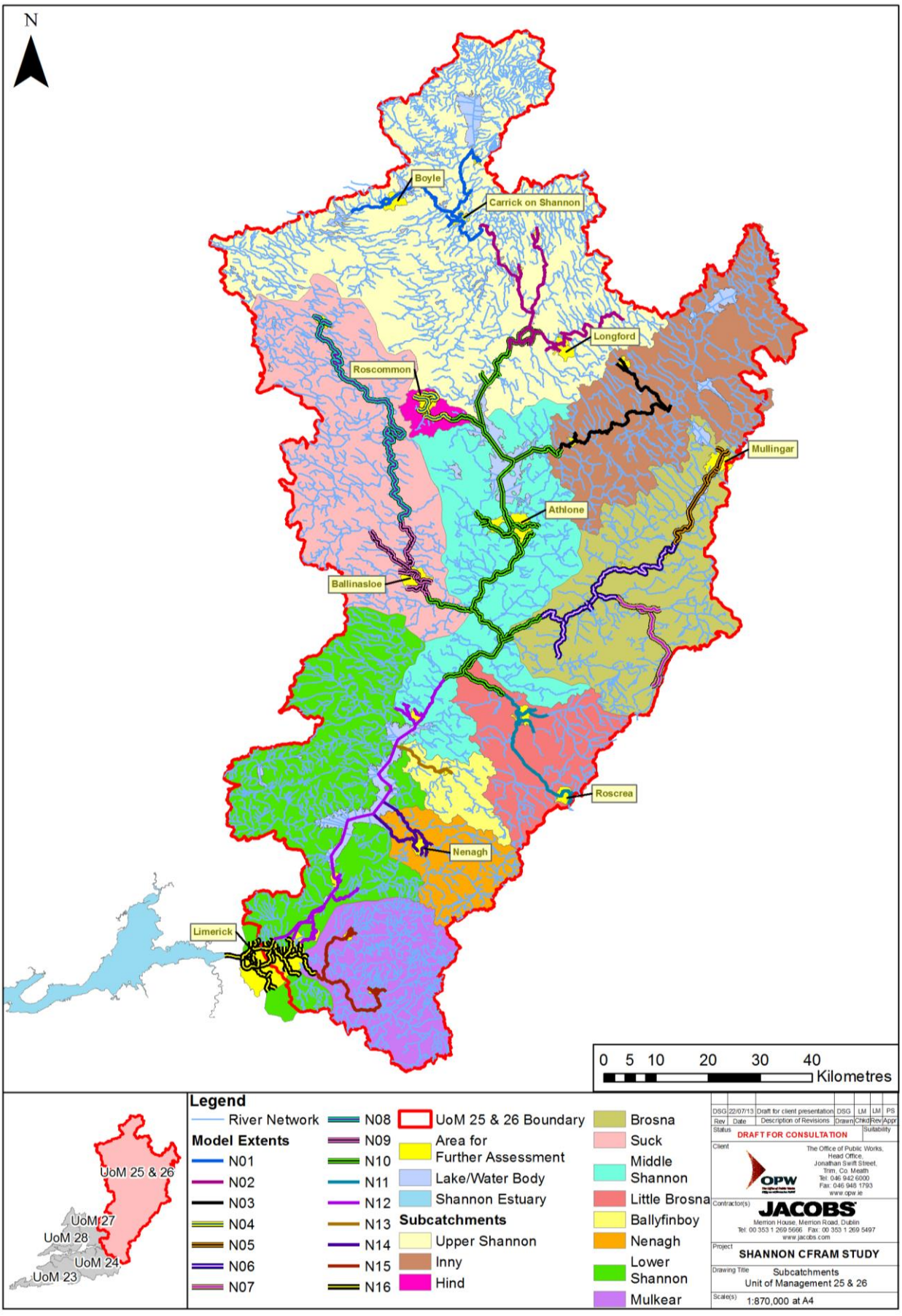

Figure 3.2 UoM 25/26 Sub-catchments

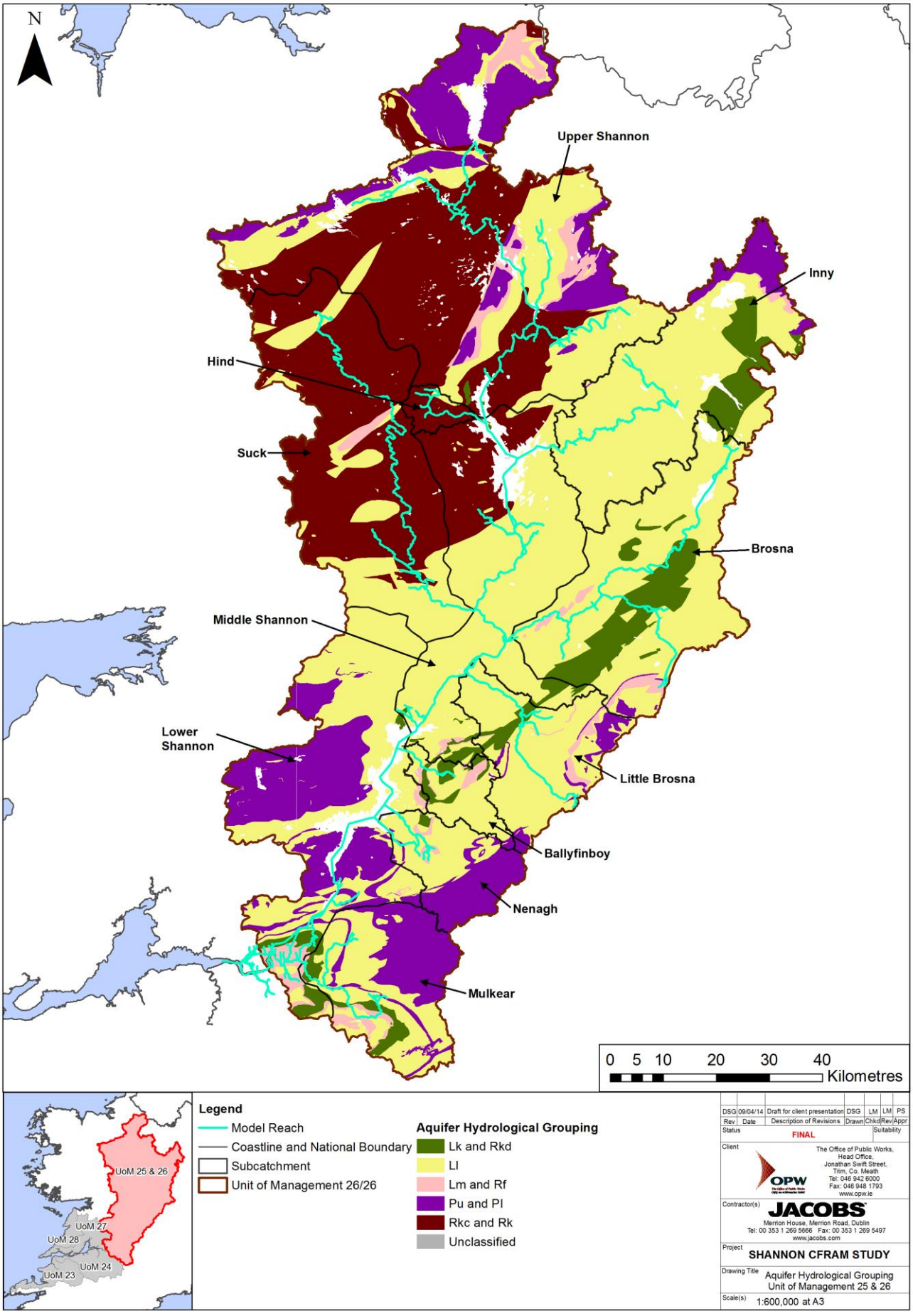

Figure 3.3 UoM 25/26 Aquifer Hydrological Grouping

Aquifer Type	Class Code	Hydrological Grouping
Regionally important karstified aquifer dominated by conduit flow	Rkc	Rkc_Rk
Regionally important karstified aquifer	Rk	
Regionally important karstified aquifer dominated by diffuse flow	Rkd	Rkd_Lk
Locally important Aquifer karstified	Lk	
Locally important aquifer which is generally moderately productive.	Lm	Lm_Rf
Regionally important fissured bedrock aquifer	Rf	
Locally important aquifer – Bedrock which is moderately productive only in Local Zones	Ll	Ll
Poor Aquifer – Bedrock which is generally unproductive	Pu	Pu_Pl
Poor Aquifer – Bedrock which is generally unproductive except for Local Zones.	Pl	
Locally important sand gravel aquifer	Lg	Lg_Rg
Regionally important sand gravel aquifer	Rg	

Table 3.1 Aquifer Hydrological Groupings (as shown on Figure 3.3)

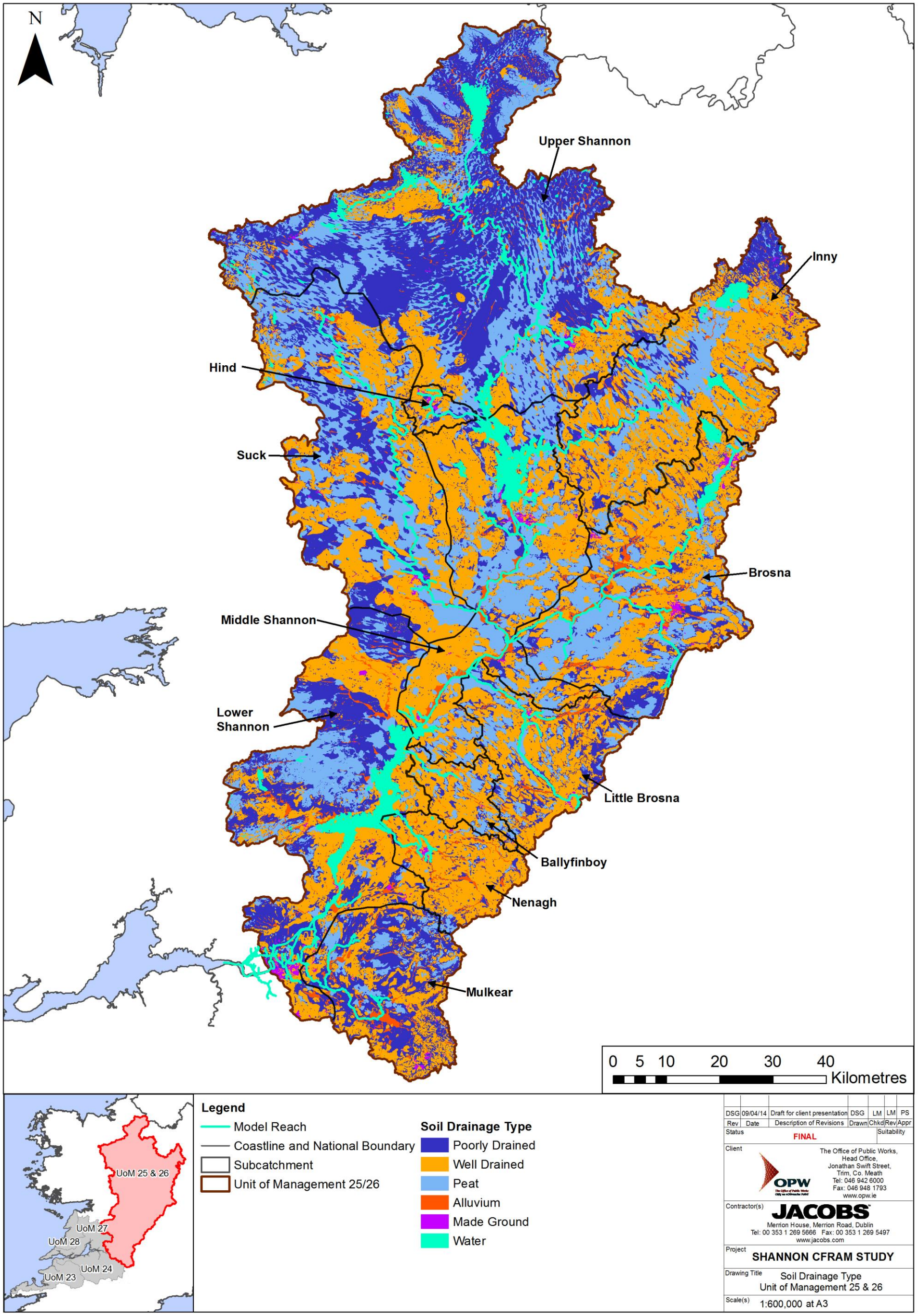

Figure 3.4 UoM 25/26 Soil Drainage Type

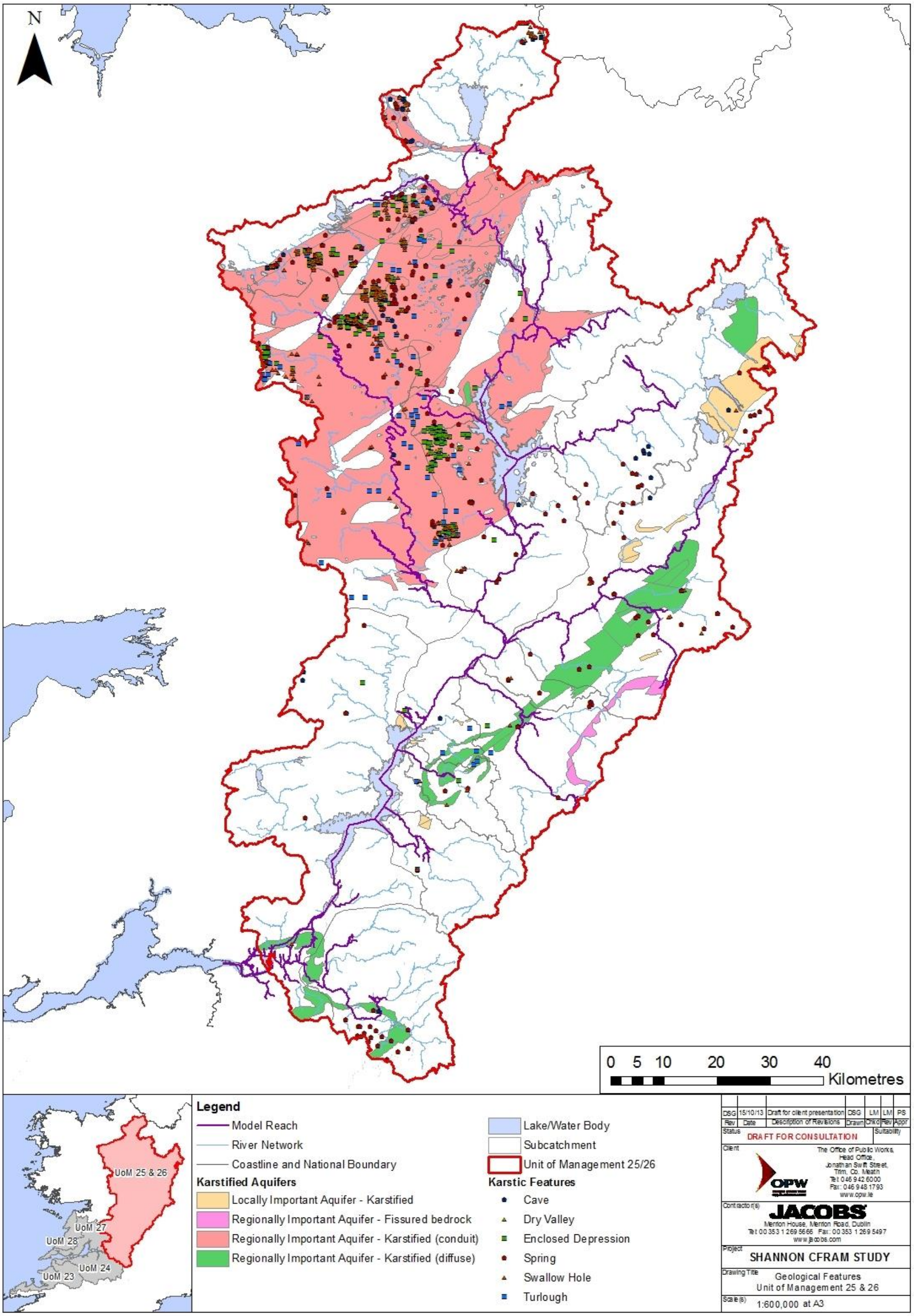

Figure 3.5 UoM 25/26 Karst Geological Features

3.6 History of Flooding

Flood records were studied as part of the Inception Study to determine a flood history for the sub-catchments making up UoM 25/26. The findings are summarised below. Further information on the flood events that were of employed for calibration or verification of the hydraulic models, as well as details of the calibration for each of the hydraulic models can be found in Appendix B, Chapters B1 to B16. Calibration strategy summary sheets are provided in Appendix F.

3.6.1 Suck Catchment

In the Suck catchment flooding has been recorded in Ballinasloe. These events are likely to have been caused by high runoff from the Suck catchment, possibly exacerbated by high water levels on the Shannon causing a backwater effect on the Suck. Major flood events have been recorded at Ballinasloe in December 1954, January 1965, February 1990, January 1995 and November 2009.

3.6.2 Brosna Catchment

In Clara, the mechanism for flooding was determined to be out of bank flows from the River Brosna after heavy rainfall. The inadequacy of the surface water system in various locations in Clara also contributed to the flooding. The low lying areas of Ballicknahee, Aghamore, Clara Bog and Woodfield Bog have reportedly flooded due to 'runoff'. No event dates are available. Major flood events have been recorded in the Brosna catchment that affected Clara, Kilcormac, Mullingar, Pollagh and/or Rahan in December 1944, 1954, November 1965, November 1967, winter 1968/1969, October 1987, January 1990, January 1995 and/or August 2008. No flooding information is available for the December 1944 event and there is no flood event data for Clonaslee and Kilbeggan.

3.6.3 Little Brosna Catchment

Major events have been recorded in Birr in 1965, January 1990, January 1995 and August 1997. However, there are no details for the flood events of 1965 and 1997. There is no flood event data for Roscrea.

3.6.4 Shannon Catchment

Several major flooding events are known to have occurred on the Shannon catchment since 1925. Major flood events including January 1925, August 1946, December 1954, winter 1994/1995, winter 1999/2000, November/December 2006, August 2008 and November 2009 are discussed below. For the AFAs considered under this unit of management there are no flooding event details for Abbeyshrule, Borrisokane and Edgeworthstown.

Most AFAs are affected by the main River Shannon. Some sites are associated with smaller rivers, for example, the River Bilboa, Lung, Camlin, Nenagh and Newport. In such locations floods may be expected to be of a flashier nature.

For the River Boyle, drainage works under the Land Reclamation Act of 1949 were undertaken between Lough Key and Lough Gara from 1951 to 1954 by OPW. This stretch of the River Boyle was subsequently included in the Boyle Arterial Drainage Scheme for maintenance purposes only.

OPW Flood Hazard Mapping information indicates a recurrent flooding problem in **Athlone** due to heavy rain and the River Shannon or River Al overflowing their banks. The River Shannon historically overflowed its banks at Strand, Deerpark, Priory Park, Gallows Hill, Iona Park, Clonown Road and Wolfe Tone Terrace. Kilmacuagh, Derries, Loughandonning, Creggan, Willow Park and Golden Island were affected by the overflow of the River Al. Low lying areas at Railway Bridge, Ballymahon Road, Retreat Road, Railway Bridge, Coosan, Central Terrace, Cartron Drive, Auburn Heights and Marine View flood after heavy rain every year. Land north of Athlone has also flooded by the River Shannon (dates or frequency not provided). According to the OPW Flood Hazard Mapping information, Roscommon County Council has installed, unblocked and replaced culverts to alleviate the flooding in Athlone.

In **Boyle**, road and land flooding have occurred for an unspecified number of times during recent winters from the section of the Boyle River downstream of Boyle town. No houses appear to have flooded to date but an unspecified number of properties are believed to be at risk. The Breandrum Turlough water level rises every year causing the adjacent road to flood. However, the road level has been raised according to the OPW Flood Hazard Mapping Phase 1 information.

In **Cappamore**, numerous houses in the village flood and a number of roads were rendered impassable once every 3 to 4 years. According to the OPW Flood Hazard Mapping Phase 1 information, the flooding problem has been alleviated by a bypass channel scheme from the Bilboa River around the village in the late 1990s. The problem has not recurred since the construction of the bypass channel.

In **Carrick on Shannon** the old N4 road at Lough Eidin, Cleaheen and Sroankeeragh (R237) has been subject to flooding (with unspecified dates or frequency). The low lying land at Sroankeeragh has also flooded. According to the OPW Flood Hazard Mapping Phase 1 information, Roscommon County Council has raised the road to alleviate the flooding problem.

In **Limerick City**, Rosbrien Road has frequently flooded; 100 acres of callow land between Rosbrien Road and Ballinacurra Bridge floods for some months every year. There has also been flooding of roads, industries and open ground in the vicinity of the Tipperary Roundabout and Ballysimon Road. At Ashbrook Gardens there have been flooding problems to back gardens of the existing houses. In the South Circular area there has been considerable flooding at the entrance of Mary Immaculate College (no date provided). Water has also ponded at a number of locations on Laurel Hill Avenue, off the South Circular Road.

In **Longford**, flooding from the River Camlin and its tributaries affected the N52 road at Mullagh/Ballyminion, properties at Springlawn, Little Water Street and Whiterock. The road and some unspecified properties at Glack 1 and Glack 2 are liable to flooding due to the runoff from high land and the golf course. The low lying area at the Driving Range and Whiterock floods after heavy rain with a reported frequency of ‘every year’.

In **Mohill**, road and land flooding has occurred in the Clooncahir area during periods of heavy rain. According to the OPW Flood Hazard Mapping Phase 1 information, the road has been raised and has not been flooded since.

In **Nenagh**, there was regular flooding on the N7 Bypass (Nenagh/Newport Road) which caused it to be impassable sometimes. The roads at the Ballynaclogh Junction (Ballynaclogh and Thurles Road) and Coolaholliga (North of Nenagh) are

also known to flood after heavy rain. Coolaholliga was flooded to a depth of 0.5m and impacted access to 10 houses (no date specified). The Ballygraigue Estate and Creamery has flooded from the Clareen Stream, but the frequency is not specified. A road and house at Springfort Cross and Shannon Development Industrial Estate have flooded (no date or frequency known). According to the OPW Flood Hazard Mapping information, some remedial works have been carried out at the Ballygraigue Estate and Creamery, Springfort Cross and Shannon Industrial Estate including construction of embankments at the Shannon Development Industrial Estate. No flooding has subsequently been recorded at the Industrial Estate in the last 20 years.

In **Roscommon** there appear to be significant flooding issues. The low lying marsh area and turlough Loughnaneane, as well as Cloonyourish and land at Lisamult reportedly flood 'every year'. The low lying marsh land of the golf course near N61, Fearagh and Portrunny Bay also flood frequently. At Roscommon town, the tributary of the Hind flood the N63 road every winter and the Jiggy overflows its banks between the N61 road and a country road and alongside the N63 regularly. According to the OPW Flood Hazard Mapping Phase 1 information, Roscommon County Council did install, unblock and replace culverts to alleviate this flooding problem. However, no details of the works were provided.

3.6.5 Other (Tidal) Catchments

In addition to the fluvial floods (detailed in Section 3.6.4) Limerick City is subject to tidal flood risk. The mechanism of tidal flooding in Limerick City appears to be associated with high tide coincident with a surge due to low atmospheric pressure and westerly winds. The high tides have caused water to seep through the flood wall or back up the drainage system. Some of the events are reported to have been caused by the coincidence of heavy rain with high tide. Major tidal events have been recorded in Limerick City from 1961 to 2002. However, there are little or no flooding details for the flooding events in 1961, 1994, February 2000 and October 2001.

4 Hydrological Analysis

The estimation of design event hydrographs for the model extents in the unit of management requires the analysis of the hydrological response of its sub-catchments. For this purpose 11 sub-catchments were defined, as shown on Figure 3.2. The analysis of each of the 11 sub-catchments is described in Appendix A, Chapters A1 to A10. The Lower and Middle Shannon have been grouped together in Appendix A.

Subsequent to the sub-catchment analysis the hydrological analysis involves calibration of the 16 individual models, and design event hydrograph estimation at HEPs in each of the models. The model-specific analysis is summarised in Appendix B, Chapters B1 to B16. Appendix B also discusses the calibration of each model.

The rating review summary sheets for the 28 gauging stations that were reviewed are provided in Appendix C. Gauging station information sheets for all gauging stations used in the design hydrology are included in Appendix D. These sheets include a table of the AMAX series used for the design hydrology. Appendix E shows all flood frequency curves used in the design hydrology. The calibration strategy for each model is described in the calibration strategy summary sheets in Appendix F. Appendix G details the audit trails for the pooling group analysis that informs the pooled growth curves at key locations in the model domains.

5 Uncertainty in Design Flow Estimates

5.1 Introduction

Flood flow estimation is based on the interpretation of historical gauged flood data. In general, the more that is known about the flood history of a site, the better the design flow estimate can be. However, the uncertainty in most flood flow estimates is considerable, and may well be the largest contribution to the uncertainty in the flood maps.

There are several sources of uncertainty in the design flood flow estimates.

(a) The length of gauged record and the extreme value analysis techniques
(b) Data accuracy
(c) Changes to the land use, drainage network and climate over the period of record
(d) Model uncertainty

These sources of uncertainty are discussed in more detail below.

(a) Record Length and Extreme Value Analysis

The longer a gauging station record, the greater the confidence in the estimate of the design flows at the station. A short record length increases the uncertainty in a flood estimate, as there is a higher chance that the observed flows to date are a-typical. This uncertainty is statistically quantifiable for a given annual exceedance probability, and FSU WP 2.2 (OPW 2009) reports that for Ireland the standard error (SE) for QMED is:

$$SE(QMED) = (0.36/\sqrt{N}) \times QMED$$

(where N is the number of years in the AMAX record length)

If the error can be assumed to be normally distributed on a log-scale, then the confidence intervals can be approximated by:

68% confidence interval: $(QMED/FSE , QMED \times FSE)$
95% confidence interval: $(QMED/FSE^2 , QMED \times FSE^2)$

(where FSE is related to SE as follows: $FSE = 1 + SE/QMED = 1+ 0.36/\sqrt{N}$)

For design peak flows greater than QMED single site or pooling group analysis is undertaken, dependent on the return period of interest. In this study the target return period is 100 years, and as this is generally longer than the period of record, pooling is preferred over single site analysis. In pooling the AMAX record is extended by including the data from stations that are hydrologically similar to the subject site. Section 13.4 of FSU Work Package 2.2 specifies that the uncertainty in flow estimates from pooling for return periods greater than 2 years is dominated by the uncertainty in QMED, suggesting that the standard error for a return period T (Q_T) can be approximated using the same equation as that used for QMED above:

$$SE(Q_T) = (0.36/\sqrt{N}) \times Q_T$$

However additional sources of uncertainty are brought into the estimation of rarer events based upon the pooling group approach. These include:

- The assumption that hydrological similarity can be achieved in the selection of pooling group members. No catchment will have exactly the same mixture of characteristics as the target catchment and therefore cannot be considered an exact facsimile.
- Individual pooling group members are assumed to have independent flow records.
- The flood frequency analysis relies on the accuracy of all the data points within the AMAX series, including the highest floods which by virtue of their rareness and magnitude inevitably come with greater uncertainty This is in contrast with the estimation of QMED for which the extreme AMAX values are irrelevant;
- The assumptions imposed upon the flood frequency relationship when fitting a statistical distribution to the data - the uncertainties of which are magnified when extrapolating the flood frequency curve beyond the magnitude of the largest events on record. This includes issues concerning the choice of what statistical distribution to use, and the choice of fitting procedures of the distribution to the data, etc.

It is difficult to quantify the magnitude of these uncertainties and no established and practical means of achieving this is available. Consequently the estimates based on the equation for SE (Q_T) above should be considered to offer a lower limit measure of the uncertainty in the design flood estimates.

Some sense of the scale of the uncertainty related to the choice of statistical distribution can be obtained from Appendix A. There the growth curves from at-site data and from different statistical distributions used to fit the data to (generally EV1, LN2 and 2-parameter logistic distributions) are shown together with the Gringorten plotting position of the AMAX series. Although techniques exist to help judge which distribution best fits the data these often give a rather ambiguous steer and there can be little to choose between distributions that give different extrapolated estimates.

Similarly, the resulting growth factors related to the use of different statistical distributions in the pooling analysis are tabulated in the pooling group audit trails in Appendix G. These also give a sense to the scale of uncertainty related the flood frequency analysis.

(b) Data Accuracy

Only a few gauging stations in the unit of management have a stage-discharge rating that is known to be reliable for high flows. Only when it has been possible to undertake check gaugings during several floods, and these are not scattered (i.e. they form a line on a stage-discharge plot), can one have confidence that a rating can be trusted for flood conditions.

Reasons for scatter in check gaugings are many and include: difficulty in undertaking a satisfactory gauging on the day (conditions can be challenging), poor performance of the equipment, weed-growth (seasonal variation), geomorphological changes at the gauge, transitory downstream backwater effects and hysteresis in the stage discharge relationship.

The extrapolation of the rating beyond the highest check gaugings (which is nearly always needed to estimate the biggest flows) is particularly prone to introducing errors. There is a reliance that the relationship based upon the check gaugings

holds – yet as the water rises there can be distinct changes in the cross sectional profile that the water is passing through (e.g. the transition from solely channel flow to a combination of channel flow and out-of-bank flow). Also depending on the local circumstances the high flow hydraulic control may change, also leading to a change in the stage-flow relationship.

Changes to a rating can occur as a consequence of: changes to the geo-morphological characteristics of the channel, (seasonal) weed growth, drainage works, changes to the gauge structure if there is one, station datum changes, rating reviews based on new gauging data or refined understanding which may only be applicable to part of the record. Capturing these variations accurately within the station information database can be difficult, introducing additional uncertainty.

Rating uncertainty is largely station-specific and difficult to quantify. A qualitative appreciation of the uncertainty can be obtained from a stage-discharge plot showing the check gaugings with the rating, though this can be a non-trivial comparison as different check gaugings may attract different levels of confidence. For gauging stations that were subject to a CFRAM rating review in UoM 25/26, stage-discharge plots were produced and included in the rating review summary sheets in Appendix C.

(c) Land Use, Drainage Network and Climate Change

The statistical analysis of floods assumes that the available flow records are formed in a stationary climate and from a catchment whose flood controlling characteristics are not changing. Some change is likely, though if the changes are small then the statistical analysis can still be considered to have sufficient validity.

Land-use changes do not generally have large effects on flood flows at a catchment scale. The exception to this may be in small catchments where there is more potential for extensive change to occur. For example the extensive urbanisation of a small rural catchment is likely to result in a marked change to the flood event runoff characteristics.

Drainage works were carried out throughout Ireland from the late 1940s to the early 1990s. These may have had some effects on the flood flows in the watercourses downstream of these works.
A non-stationary climate is another source of uncertainty. Climate change as a consequence of global warming is projected to increase the risk of flooding in the future. Such a long-term sustained change to climatic conditions has the distinct potential to alter the flood frequency relationship of a catchment, though some uncertainty exists as to the precise magnitude of these changes. It is also likely that climate change has already started to influence the hydrology to some extent meaning that the available flood records may already incorporate some non-stationarity. The influence of climate change therefore introduces further uncertainty.

Future climate change and future changes to the principal forms of land use in Ireland (urbanisation and afforestation) are discussed in more detail in Chapter 6.

(d) Model Uncertainty

In ungauged watercourses QMED (the 2-year return period flow) is estimated from a regression equation developed from gauging station data that samples the range of catchment conditions across Ireland.

The FSU Work Package 2.2 (OPW 2009) reports a factorial standard error (FSE) of 1.37 for the estimate of $QMED_{rural}$, and confidence intervals as:

68% confidence interval: (QMED/FSE, QMED x FSE)
95% confidence interval: ($QMED/FSE^2$, QMED x FSE^2)

The regression estimate of QMED is often adjusted using one or more pivotal stations. In this study up to five pivotal stations were used. This should have a beneficial effect on the confidence intervals, but this cannot be quantified as the effect is different for each location dependent on the quality and suitability of a pivotal station.

Urban and permeable catchments are subject to more uncertainty than others. This is because urban and permeable sites are underrepresented in the list of gauging stations used to derive the QMED regression equation, and due to the added complexity of their runoff responses which are seen to exhibit greater variability between similar catchments compared to other types of catchment. In urban settings the interaction of the urban landscape and its particular location specific drainage system has a large effect on flood event runoff. In permeable catchments the location specific characteristics of the underground hydrogeology play an important role in determining the runoff.

Similarly, catchments affected by lakes and reservoirs can also be expected to yield larger errors than other catchments.

For ungauged sites that are on a gauged watercourse, upstream or downstream from it, the confidence in a peak flow estimate will become smaller with increasing distance to the gauging station. This uncertainty has not been studied in the FSU and is not quantified. However, it should be borne in mind when assessing the accuracy of flow estimates and flood outlines along the CFRAM model extents.

5.2 Confidence Quantified

Tables 5.1 and 5.2 provide a list of HEPs within the AFAs in UoM 25/26, one HEP for each modelled watercourse. For each of the 65 locations the tables summarise the method of flow estimation for QMED: ‘statistical’ where the FSU regression method was used (with or without a QMED adjustment from pivotal stations), or ‘gauged’ if it is based on a gauged reach. The tables provide the catchment, model extent, reach number and 68% confidence intervals for the 50% (1 in 2 year) and 1% (1 in 100 year) AEP design floods respectively. In all instances the 1% AEP design peak flow was determined with pooling group analysis. These confidence intervals are explained and caveated in Section 5.1.

On a gauged reach the confidence limits apply to the gauging station location. Moving away from the gauging station the uncertainty will increase.

It is worth bearing in mind that the uncertainty specified here is only that caused by the limited record length (at gauged locations) and the regression model inaccuracy (at ungauged locations). Other uncertainties are described in Section 5.1.

AFA	Model	HEP	QMED Estimation Method	50% AEP Design Peak Flow (m^3/s)		
				68% Lower Limit	Central Estimate	68% Upper Limit
Carrick on Shannon	N01	26_1470_1	Statistical	2.06	2.82	3.86
Carrick on Shannon	N01	26_1881_1	Statistical	84	115	158
Leitrim Village	N01	26_3490_1	Statistical	2.82	3.87	5.30
Drumshanbo	N01	26_59_1	Statistical	3.38	4.63	6.34
Boyle	N01	26_3583_1	Gauged	40.8	44.1	47.7
Boyle	N01	26_164_2	Statistical	4.74	6.49	8.89
Longford	N02	26_2118_1	Statistical	0.22	0.30	0.41
Longford	N02	26_643_1	Statistical	0.27	0.37	0.51
Longford	N02	26_3215_1	Gauged	18.4	19.5	20.7
Dromod	N02	26_4022_3	Statistical	4.66	6.39	8.75
Mohill	N02	26_2239_1	Statistical	0.66	0.91	1.25
Mohill	N02	26_2307_4	Statistical	1.58	2.17	2.97
Ballymahon	N03	26_959_2	Gauged	67.2	71.3	75.7
Ballymahon	N03	26_3975_1	Statistical	2.72	3.73	5.11
Abbeyshrule	N03	26_1427_3	Statistical	41.4	56.7	77.7
Edgeworthstown	N03	26_3884_6	Statistical	1.12	1.54	2.11
Roscommon	N04	26_2111_5	Statistical	0.78	1.07	1.47
Roscommon	N04	26_876_1	Statistical	2.66	3.64	4.99
Mullingar	N05	25_3682_3	Statistical	4.45	6.10	8.36
Mullingar	N05	25_3125_1	Statistical	4.82	6.60	9.04
Kibeggan	N06	25_559_6	Statistical	9.01	12.4	16.9
Clara	N06	25_565_24	Statistical	11.0	15.0	20.6
Clonaslee	N07	25_582_6	Statistical	8.74	12.0	16.4
Clonaslee	N07	25_570_14	Statistical	7.30	10.0	13.7
Castlerea	N08	26_1249_1	Gauged	16.7	17.5	18.4
Castlerea	N08	26_3795_6	Statistical	11.7	16.0	22.0
Ballinasloe	N09	26_3041_5	Statistical	13.2	18.1	24.8
Ballinasloe	N09	26_3977_4	Statistical	7.96	10.9	14.9
Ballinasloe	N09	26_3033_5	Statistical	0.34	0.47	0.64
Ballinasloe	N09	26_1436_4	Gauged	108	113	118
Ballinasloe	N09	26_3824_10	Statistical	0.88	1.20	1.64

AFA	Model	HEP	QMED Estimation Method	50% AEP Design Peak Flow (m^3/s)		
				68% Lower Limit	Central Estimate	68% Upper Limit
Ahascragh	N09	26_3748_2	Statistical	10.8	14.8	20.3
Athlone	N10	26_4018_4	Statistical	5.51	7.55	10.3
Athlone	N10	26_4000_5	Gauged	235	246	258
Birr	N11	25_3344_8	Statistical	1.97	2.70	3.70
Birr	N11	25_816_4	Gauged	25.9	27.1	28.4
Roscrea	N11	25_2454_3	Statistical	0.36	0.50	0.69
Roscrea	N11	25_892_5	Gauged	3.33	3.60	3.90
Birr	N11	25_628_2	Statistical	35.2	48.2	66.0
Portumna	N12	25_655_4	Statistical	347	475	651
Portumna	N12	25_3708_1	Statistical	0.28	0.39	0.53
Portumna	N12	25_811_6	Statistical	0.47	0.64	0.88
Portumna	N12	25_2616_1	Statistical	1.20	1.65	2.26
Killaloe / Ballina	N12	25_1019_4	Statistical	1.08	1.48	2.03
Killaloe / Ballina	N12	25_2360_6	Statistical	2.12	2.90	3.97
Castleconnell	N12	25_3823_9	Statistical	147	201	275
Borrisokane	N13	25_3530_5	Statistical	3.53	4.84	6.63
Nenagh	N14	25_3773_5	Statistical	0.51	0.70	0.96
Nenagh	N14	25_335_1	Gauged	24.5	26.3	28.2
Nenagh	N14	25_1844_1	Gauged	50.0	52.9	56.0
Cappamore	N15	25_833_1	Statistical	2.64	3.61	4.95
Cappamore	N15	25_502_1	Statistical	20.5	28.1	38.5
Newport	N15	25_2323_6	Statistical	5.09	6.97	9.55
Newport	N15	25_475_1	Statistical	21.9	30.0	41.1
Limerick City	N16	25_527_3	Gauged	119	126	134
Limerick City	N16	25_1203_4	Gauged	212	221	230
Limerick City	N16	25_3329_2	Statistical	17.7	24.2	33.2
Limerick City	N16	25_2067_1	Statistical	5.47	7.50	10.3
Limerick City	N16	25_3904_3	Statistical	218	299	410
Limerick City	N16	24_121_12	Statistical	0.69	0.95	1.30
Limerick City	N16	24_1718_3	Statistical	2.70	3.70	5.07
Limerick City	N16	24_1720_4	Statistical	1.39	1.90	2.60
Limerick City	N16	27_1150_1	Statistical	5.47	7.50	10.3

AFA	Model	HEP	QMED Estimation Method	50% AEP Design Peak Flow (m^3/s)		
				68% Lower Limit	Central Estimate	68% Upper Limit
Limerick City	N16	27_158_2	Statistical	8.18	11.2	15.3
Limerick City	N16	25_3896_1	Statistical	3.65	5.00	6.85

Table 5.1 AFAs with 50% AEP Design Peak Flow Confidence Intervals (in m^3/s)

AFA	Model	HEP	QMED Estimation Method	1% AEP Design Peak Flow (m^3/s)		
				68% Lower Limit	Central Estimate	68% Upper Limit
Carrick on Shannon	N01	26_1470_1	Statistical	4.42	6.05	8.29
Carrick on Shannon	N01	26_1881_1	Statistical	158	216	296
Leitrim Village	N01	26_3490_1	Statistical	5.20	7.13	9.77
Drumshanbo	N01	26_59_1	Statistical	6.21	8.51	11.7
Boyle	N01	26_3583_1	Gauged	71.2	76.9	83.1
Boyle	N01	26_164_2	Statistical	9.27	12.7	17.4
Longford	N02	26_2118_1	Statistical	0.52	0.71	0.97
Longford	N02	26_643_1	Statistical	0.64	0.88	1.21
Longford	N02	26_3215_1	Gauged	32.9	34.8	36.9
Dromod	N02	26_4022_3	Statistical	8.32	11.4	15.6
Mohill	N02	26_2239_1	Statistical	1.58	2.17	2.97
Mohill	N02	26_2307_4	Statistical	3.76	5.15	7.06
Ballymahon	N03	26_959_2	Gauged	120	127	135
Ballymahon	N03	26_3975_1	Statistical	5.53	7.58	10.38
Abbeyshrule	N03	26_1427_3	Statistical	74.0	101	139
Edgeworthstown	N03	26_3884_6	Statistical	2.82	3.87	5.30
Roscommon	N04	26_2111_5	Statistical	2.01	2.76	3.78
Roscommon	N04	26_876_1	Statistical	6.84	9.37	12.8
Mullingar	N05	25_3682_3	Statistical	7.66	10.5	14.4
Mullingar	N05	25_3125_1	Statistical	8.32	11.4	15.62
Kibeggan	N06	25_559_6	Statistical	16.0	21.9	30.0
Clara	N06	25_565_24	Statistical	19.4	26.6	36.4
Clonaslee	N07	25_582_6	Statistical	15.7	21.4	29.4
Clonaslee	N07	25_570_14	Statistical	13.1	17.9	24.5
Castlerea	N08	26_1249_1	Gauged	42.2	44.1	46.2
Castlerea	N08	26_3795_6	Statistical	29.5	40.4	55.3
Ballinasloe	N09	26_3041_5	Statistical	23.4	32.0	43.8
Ballinasloe	N09	26_3977_4	Statistical	15.6	21.3	29.2
Ballinasloe	N09	26_3033_5	Statistical	0.80	1.10	1.51
Ballinasloe	N09	26_1436_4	Gauged	223	234	245
Ballinasloe	N09	26_3824_10	Statistical	1.97	2.70	3.70
Ahascragh	N09	26_3748_2	Statistical	19.1	26.2	35.9

AFA	Model	HEP	QMED Estimation Method	1% AEP Design Peak Flow (m^3/s)		
				68% Lower Limit	Central Estimate	68% Upper Limit
Athlone	N10	26_4018_4	Statistical	10.9	14.9	20.4
Athlone	N10	26_4000_5	Gauged	399	418	438
Birr	N11	25_3344_8	Statistical	3.94	5.4	7.40
Birr	N11	25_816_4	Gauged	50.9	53.2	55.7
Roscrea	N11	25_2454_3	Statistical	0.80	1.10	1.51
Roscrea	N11	25_892_5	Gauged	6.93	7.50	8.12
Birr	N11	25_628_2	Statistical	69.1	94.6	130
Portumna	N12	25_655_4	Statistical	588	806	1104
Portumna	N12	25_3708_1	Statistical	0.78	1.07	1.47
Portumna	N12	25_811_6	Statistical	1.00	1.37	1.88
Portumna	N12	25_2616_1	Statistical	2.58	3.54	4.85
Killaloe / Ballina	N12	25_1019_4	Statistical	3.01	4.12	5.64
Killaloe / Ballina	N12	25_2360_6	Statistical	4.57	6.26	8.58
Castleconnell	N12	25_3823_9	Statistical	384	526	721
Borrisokane	N13	25_3530_5	Statistical	6.95	9.52	13.0
Nenagh	N14	25_3773_5	Statistical	1.46	2.00	2.74
Nenagh	N14	25_335_1	Gauged	44.3	47.5	50.9
Nenagh	N14	25_1844_1	Gauged	87.7	92.9	98.4
Cappamore	N15	25_833_1	Statistical	4.17	5.71	7.82
Cappamore	N15	25_502_1	Statistical	32.5	44.5	60.9
Newport	N15	25_2323_6	Statistical	8.04	11.0	15.1
Newport	N15	25_475_1	Statistical	34.6	47.5	65.0
Limerick City	N16	25_527_3	Gauged	188	200	212
Limerick City	N16	25_1203_4	Gauged	535	557	580
Limerick City	N16	25_3329_2	Statistical	29.5	40.4	55.4
Limerick City	N16	25_2067_1	Statistical	11.7	16.0	21.9
Limerick City	N16	25_3904_3	Statistical	497	681	933
Limerick City	N16	24_121_12	Statistical	1.46	2.00	2.74
Limerick City	N16	24_1718_3	Statistical	5.84	8.00	11.0
Limerick City	N16	24_1720_4	Statistical	2.92	4.00	5.48
Limerick City	N16	27_1150_1	Statistical	11.7	16.0	21.9
Limerick City	N16	27_158_2	Statistical	19.0	26.0	35.6

AFA	Model	HEP	QMED Estimation Method	1% AEP Design Peak Flow (m^3/s)		
				68% Lower Limit	Central Estimate	68% Upper Limit
Limerick City	N16	25_3896_1	Statistical	8.32	11.4	15.6

Table 5.2 AFAs with 1% AEP Design Peak Flow Confidence Intervals (in m^3/s)

6 Future Environmental and Catchment Changes

6.1 Introduction

The CFRAM study considers how design floods may change in the future by the use of two scenarios that combine climate change and land-use change allowances. The two scenarios are referred to as the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS), as described below (from OPW CFRAM brief):

- The MRFS is intended to represent a 'likely' future scenario, based on the wide range of predictions available and with the allowances for increased flow, sea level rise, etc. within the bounds of widely accepted projections.
- The HEFS is intended to represent a more extreme potential future scenario, but one that is nonetheless not significantly outside the range of accepted predictions available, and with the allowances for increased flow, sea level rise, etc. at the upper the bounds of widely accepted projections.

The allowances provided by OPW to be used across the CFRAM studies for a time horizon of 100 years are provided in Table 6.1 below.

Parameter	MRFS	HEFS
Extreme Rainfall Depths	+20%	+30%
Flood Flows	+20%	+30%
Mean Sea Level Rise	+500mm	+1000mm
Land Movement[1]	-0.5mm/year	-0.5mm/year
Urbanisation	Review case-by-case	Review case-by-case
Afforestation[2]	-1/6 Tp	-1/3 Tp +10% SPR[3]

[1] Applicable to southern part of the country only (Dublin-Galway and south of this)
[2] Reduce the time to peak (Tp) by a sixth or third. This allows for potential accelerated runoff that may arise as a result of drainage of afforested land
[3] Add 10% to the Standard Percentage Runoff (SPR) rate: This allows for increased runoff rates that may arise following felling of forestry.

Table 6.1 Allowances for Future Scenarios (Time Horizon 100 Years)

Given that the hydrological approach applied to the Shannon RBD is based solely on river flows and does not use rainfall the rainfall allowance has not been used in the Shannon work. Mean sea-level rise and land movement are considered in the hydraulic modelling (see the hydraulic modelling report for UoM 25/26 for more details) and are therefore not discussed here.

The flow allowances for climate change, urbanisation and afforestation are discussed in more detail in the following section.

6.2 Future Changes Quantified

(a) Flood Flows and Climate Change

The potential future effects of increases in flood flows due to climate change have been incorporated in the hydraulic modelling by undertaking separate runs in which the original design inflows are scaled up proportionally by a factor 1.2 and 1.3 for the MRFS and HEFS respectively. As per the CFRAM brief, flood maps have been produced for the MRFS runs, whereas the HEFS model results are provided in GIS format but not mapped.

(b) Urbanisation

The process of urbanisation and the associated increase in impervious surfaces can be expected to typically result in higher runoff rates and faster catchment response times. Kjeldsen (2010) reports that '*it is well established in the literature that the effect of urbanisation can be detected in the magnitude of individual annual maximum series of peak flow (Packman, 1980; Sheng and Wilson, 2009), and thereby lead to changes in the flood frequency characteristics.*' There is evidence that urbanisation tends to affect low return period flows more than high return period flows (Kjeldsen, 2010).

Most methods that quantify the effect of urbanisation on design flows, including the adjustment for QMED in the FSU, are based on the analysis of flood data from existing urbanised catchments. These catchments include a wide range of development types, from all eras. Many existing developments have no or limited systems in place to limit the runoff from developed areas. Planning authorities now generally require new developments to limit their runoff rates to the pre-development rates for a range of design storms, and the downstream impacts on flood flows of future development should be lower than in the past. Extrapolation of the effects of urbanisation from the past is therefore likely to overestimate the real effect of future change.

As the locations of future urbanisation and their effects on flood risk are highly uncertain, they have not been accounted for in the flood mapping for this study. However the potential effects of urbanisation on design flows at AFAs in the unit of management are considered in more detail below.

The Environmental Protection Agency (EPA) reports in their CORINE Land Cover updates for 2000, 2006 and 2012 that 'artificial surfaces' ('urban' areas) increased by 31% in the period 1990-2000 throughout Ireland, by another 15% in the period 2000-2006 and by approximately 4% from 2006 to 2012 (Section 5.2.1 in EPA 2014). These figures are subject to some uncertainty due to changes in the methodologies and technologies used, though attempts were made to compare like for like, and as such they represent the best available data.

The recent CORINE datasets suggest that the high growth rate seen in the period 1990-2006 has slowed down. The 4% growth over 6 years (2006 to 2012) comes down to an annual (compound) growth rate of approximately 0.7% per year. Assuming that this growth rate will be sustained into the future this suggests an increase of 100% (i.e. a doubling) of the urban extents over the 100 year time horizon of the future scenarios considered in this study. Because of planning rules (as discussed above) increases in runoff rates from future development can be expected to be mitigated for (in attenuation tanks, detention basins, soakaways, swales, etc.) more than in the past, and an effective increase in urban extent of about 50% or less seems more appropriate for the prediction of future river flows.

To assess the sensitivity of the design flows to increased urban extent, increases of 25% (for the MRFS) and 50% (for the HEFS) in the URBEXT catchment descriptor have been applied to points in AFAs that have relatively high URBEXT values already. Where the present day URBEXT value contributes less than 5% to the peak flow rates (i.e. results in an FSU Urban Adjustment Factor [UAF] smaller than 1.05, with $UAF=(1+URBEXT/100)^{1.482}$) it is assumed that future changes in the urban extent will not have a significant effect on the catchment runoff response.

The same increase in URBEXT, and therefore the same UAF, has been applied to all return periods, thus ignoring any variation of the effect with return period, as this is difficult to quantify and no method was proposed in the FSU research. As the effect of urbanisation is thought to decrease for higher return periods the allowances may be conservatively high for such floods.

A list of AFAs with present day URBEXT values (ranked by the URBEXT descriptor) is presented in Table 6.2 below. One HEP was selected for each watercourse within an AFA, at a location close to the urban centre. Where multiple HEP nodes were situated in or close to the urban centre, then the downstream point was selected. Where multiple watercourses flow through an AFA, Table 6.2 presents multiple HEP nodes. Where a tributary joined a river in an AFA, the HEP at the most downstream node of the tributary was selected.

The HEP node numbers are shown on the model extent maps in Chapters B1 to B16 in Appendix B for Models N01, N02, N03, N04, N05, N06, N07, N08, N09, N10, N11, N12, N13, N14, N15 and N16respectively.

AFA	Model	HEP	URBEXT (%)	UAF
Portumna	N12	25_3708_1	36.1	1.579
Killaloe / Ballina	N12	25_1019_4	30.5	1.483
Limerick City	N16	24_1720_4	24.3	1.381
Mullingar	N05	25_3125_1	16.2	1.249
Longford	N02	26_643_1	13.6	1.207
Roscommon	N04	26_876_1	12.6	1.193
Roscrea	N11	25_2454_3	10.6	1.162
Limerick City	N16	25_3896_1	7.79	1.118
Ballinasloe	N09	26_3033_5	7.30	1.110
Mullingar	N05	25_3682_3	6.86	1.103
Limerick City	N16	25_2067_1	6.21	1.093
Nenagh	N14	25_3773_5	5.86	1.088
Roscommon	N04	26_2111_5	4.58	1.069
Ballinasloe	N09	26_3824_10	4.03	1.060
Limerick City	N16	27_1150_1	3.93	1.059

AFA	Model	HEP	URBEXT (%)	UAF
Roscrea	N11	25_892_5	3.91	1.058
Limerick City	N16	27_158_2	3.45	1.052
Edgeworthstown	N03	26_3884_6	3.35	1.050
Clara	N06	25_565_24	3.12	1.047
Limerick City	N16	24_121_12	3.08	1.046
Kibeggan	N06	25_559_6	2.99	1.045
Mohill	N02	26_2307_4	2.74	1.041
Drumshanbo	N01	26_59_1	2.42	1.036
Birr	N11	25_3344_8	2.34	1.035
Limerick City	N16	24_1718_3	2.29	1.034
Borrisokane	N13	25_3530_5	1.95	1.029
Portumna	N12	25_2616_1	1.68	1.025
Ballinasloe	N09	26_3977_4	1.55	1.023
Carrick on Shannon	N01	26_1470_1	1.43	1.021
Mohill	N02	26_2239_1	1.40	1.021
Portumna	N12	25_811_6	1.29	1.019
Birr	N11	25_628_2	1.25	1.019
Nenagh	N14	25_335_1	1.12	1.017
Longford	N02	26_3215_1	1.05	1.016
Nenagh	N14	25_1844_1	1.03	1.015
Cappamore	N15	25_833_1	0.91	1.014
Newport	N15	25_2323_6	0.91	1.014
Ballymahon	N03	26_3975_1	0.89	1.013
Portumna	N12	25_655_4	0.83	1.012
Limerick City	N16	25_3904_3	0.83	1.012
Limerick City	N16	25_1203_4	0.78	1.012
Castleconnell	N12	25_3823_9	0.78	1.012
Athlone	N10	26_4000_5	0.64	1.009
Limerick City	N16	25_527_3	0.55	1.008
Birr	N11	25_816_4	0.54	1.008
Ahascragh	N09	26_3748_2	0.52	1.008
Boyle	N01	26_3583_1	0.52	1.008
Castlerea	N08	26_3795_6	0.52	1.008
Ballinasloe	N09	26_1436_4	0.48	1.007

AFA	Model	HEP	URBEXT (%)	UAF
Castlerea	N08	26_1249_1	0.44	1.007
Ballinasloe	N09	26_3041_5	0.42	1.006
Abbeyshrule	N03	26_1427_3	0.42	1.006
Ballymahon	N03	26_959_2	0.41	1.006
Clonaslee	N07	25_582_6	0.39	1.006
Carrick on Shannon	N01	26_1881_1	0.31	1.005
Newport	N15	25_475_1	0.28	1.004
Athlone	N10	26_4018_4	0.26	1.004
Limerick City	N16	25_3329_2	0.22	1.003
Cappamore	N15	25_502_1	0.13	1.002
Leitrim Village	N01	26_3490_1	0.13	1.002
Clonaslee	N07	25_570_14	0.01	1.000
Killaloe / Ballina	N12	25_2360_6	0.00	1.000
Longford	N02	26_2118_1	0.00	1.000
Dromod	N02	26_4022_3	0.00	1.000
Boyle	N01	26_164_2	0.00	1.000

Table 6.2 AFAs with Present Day URBEXT and Urban Adjustment Factor

There are 18 locations in UoM 25/26 with a UAF greater than 1.05 (i.e. a greater than 5% increase in statistical peak flows due to the present day urbanisation). For these locations Table 6.3 tabulates the present-day design (target) flows as reported in Appendix B, whilst Tables 6.4 and 6.5 present the effects on the design flows when the urban extent (URBEXT) is increased by 25% for the MRFS and by 50% for the HEFS conditions.

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Portumna (N12)	25_3708_1	0.39	0.57	0.69	0.81	0.96	1.07	1.18	1.45
Killaloe/ Ballina (N12)	25_1019_4	1.48	2.19	2.65	3.10	3.68	4.12	4.55	5.56
Limerick City (N16)	24_1720_4	1.90	2.40	2.80	3.10	3.60	4.00	4.30	5.10
Mullingar (N05)	25_3125_1	6.6	8.1	9.1	9.8	10.7	11.4	12.2	13.7
Longford (N02)	26_643_1	0.37	0.51	0.60	0.68	0.79	0.88	0.96	1.16
Roscommon (N04)	26_876_1	3.64	5.21	6.22	7.18	8.44	9.37	10.31	12.50
Roscrea (N11)	25_2454_3	0.50	0.70	0.80	0.90	1.00	1.10	1.20	1.40
Limerick City (N16)	25_3896_1	5.0	6.7	7.8	8.9	10.3	11.4	12.5	14.9
Ballinasloe (N09)	26_3033_5	0.47	0.63	0.74	0.84	0.98	1.10	1.20	1.40
Mullingar (N05)	25_3682_3	6.1	7.4	8.4	9.0	9.8	10.5	11.2	12.6
Limerick City (N16)	25_2067_1	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
Nenagh (N14)	25_3773_5	0.70	1.00	1.30	1.50	1.80	2.00	2.20	2.70
Roscommon (N04)	26_2111_5	1.07	1.53	1.83	2.11	2.48	2.76	3.03	3.67
Ballinasloe (N09)	26_3824_10	1.20	1.60	1.80	2.10	2.40	2.70	2.90	3.50
Limerick City (N16)	27_1150_1	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
Roscrea (N11)	25_892_5	3.60	4.70	5.40	6.00	6.90	7.5	8.10	9.50
Limerick City (N16)	27_158_2	11.2	14.6	16.8	19.0	21.8	23.9	26.0	30.8
Edgeworth-stown (N03)	26_3884_6	1.54	2.16	2.57	2.97	3.48	3.87	4.25	5.13

Table 6.3 Present Day Design Flows

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Portumna (N12)	25_3708_1	0.43	0.63	0.76	0.89	1.06	1.18	1.30	1.59
Killaloe/ Ballina (N12)	25_1019_4	1.61	2.38	2.88	3.37	4.00	4.48	4.95	6.05
Limerick City (N16)	24_1720_4	2.04	2.58	3.01	3.33	3.86	4.29	4.62	5.47
Mullingar (N05)	25_3125_1	6.9	8.5	9.6	10.3	11.3	12.0	12.8	14.4
Longford (N02)	26_643_1	0.39	0.53	0.63	0.71	0.83	0.92	1.00	1.21
Roscommon (N04)	26_876_1	3.79	5.43	6.48	7.48	8.79	9.76	10.7	13.0
Roscrea (N11)	25_2454_3	0.52	0.73	0.83	0.93	1.04	1.14	1.24	1.45
Limerick City (N16)	25_3896_1	5.1	6.9	8.0	9.1	10.6	11.7	12.8	15.3
Ballinasloe (N09)	26_3033_5	0.48	0.65	0.76	0.86	1.00	1.13	1.23	1.44
Mullingar (N05)	25_3682_3	6.3	7.6	8.6	9.2	10.0	10.8	11.5	12.9
Limerick City (N16)	25_2067_1	7.7	9.9	11.6	13.0	14.9	16.4	17.8	21.1
Nenagh (N14)	25_3773_5	0.71	1.02	1.33	1.53	1.84	2.04	2.25	2.76
Roscommon (N04)	26_2111_5	1.09	1.55	1.86	2.14	2.52	2.80	3.08	3.73
Ballinasloe (N05)	26_3824_10	1.22	1.62	1.83	2.13	2.43	2.74	2.94	3.55
Limerick City (N16)	27_1150_1	7.6	9.8	11.5	12.9	14.8	16.2	17.6	20.9
Roscrea (N11)	25_892_5	3.7	4.8	5.5	6.1	7.0	7.6	8.2	9.6
Limerick City (N16)	27_158_2	11.3	14.8	17.0	19.2	22.1	24.2	26.3	31.2
Edgeworth-stown (N03)	26_3884_6	1.56	2.19	2.60	3.01	3.52	3.92	4.30	5.19

Table 6.4 Design Flows for Future Urbanisation – MRFS (URBEXT+25%)

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Portumna (N12)	25_3708_1	0.47	0.69	0.83	0.97	1.15	1.29	1.42	1.74
Killaloe/ Ballina (N12)	25_1019_4	1.74	2.58	3.12	3.65	4.33	4.85	5.36	6.55
Limerick City (N16)	24_1720_4	2.18	2.76	3.22	3.56	4.13	4.59	4.94	5.86
Mullingar (N05)	25_3125_1	7.3	9.0	10.1	10.8	11.8	12.0	13.5	15.1
Longford (N02)	26_643_1	0.40	0.56	0.65	0.74	0.86	0.96	1.05	1.26
Roscommon (N04)	26_876_1	4.0	5.7	6.7	7.8	9.2	10.2	11.2	13.5
Roscrea (N11)	25_2454_3	0.54	0.75	0.86	0.96	1.07	1.18	1.29	1.50
Limerick City (N16)	25_3896_1	5.3	7.1	8.2	9.4	10.9	12.02	13.2	15.7
Ballinasloe (N09)	26_3033_5	0.49	0.66	0.78	0.88	1.03	1.16	1.26	1.47

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Mullingar (N05)	25_3682_3	6.4	7.8	8.8	9.4	10.3	11.0	11.7	13.2
Limerick City (N16)	25_2067_1	7.8	10.1	11.8	13.3	15.2	16.7	18.2	21.5
Nenagh (N14)	25_3773_5	0.73	1.04	1.35	1.56	1.87	2.08	2.29	2.81
Roscommon (N04)	26_2111_5	1.10	1.58	1.89	2.18	2.56	2.85	3.13	3.79
Ballinasloe (N05)	26_3824_10	1.23	1.65	1.85	2.16	2.47	2.78	2.98	3.60
Limerick City (N16)	27_1150_1	7.7	10.0	11.6	13.1	15.0	16.5	17.9	21.2
Roscrea (N11)	25_892_5	3.7	4.8	5.6	6.2	7.1	7.7	8.3	9.8
Limerick City (N16)	27_158_2	11.5	15.0	17.2	19.5	22.3	24.5	26.7	31.6
Edgeworth-stown (N03)	26_3884_6	1.58	2.21	2.63	3.04	3.56	3.96	4.35	5.25

Table 6.5 Design Flows for Future Urbanisation – HEFS (URBEXT+50%)

Although the National Spatial Strategy and county-level core strategies include details of national and local government intentions with regard to the quantities and location of housing and industrial development, these tend to only look to the near future, up to 20 years or less. It is considered likely that areas that are not currently favoured for development may become favoured in the future (e.g. when the areas currently favoured have been filled), and that there may be considerable differences between the target growth numbers and those realised. It was not considered appropriate to use the details of these strategies for the 100-year time horizon adopted here.

(c) Afforestation

Ireland is seeing an increase in forest cover, which is expected to continue into the future. The majority of this increase is related to the expansion of commercial forestry.

Converting the land use to forest (afforestation) or its opposite (deforestation) has the potential to affect the runoff response from a catchment if the changes cover a large proportion of the catchment. The effects of an increase in forest cover on peak flows in the catchment may be positive or negative.

It is generally assumed (Nisbet et al 2006) that replacing grass cover with tree cover will serve to reduce peak flows due to a combination of:

a. an increase in the infiltration rates and storage capacity in the soils which tend to be more open-structured than grassed soils.
b. Interception of water by the trees
c. Increased roughness and local attenuation in floodplains, e.g. by wooden debris dams within stream channels, the presence of trees, shrubs and deadwood on the floodplain and greater unevenness of the ground surface

Although these effects are the subject of continued research, they are thought to be relatively small in the case of extreme floods (EA/Defra 2004) and may be

counteracted if land preparation includes a network of extensive drainage ditches designed in such a way as to convey water more quickly to the natural watercourses. Table 6.1 includes a reduced time-to-peak to allow for the effects of these drainage systems. Newly afforested land with young trees will not show much of the advantages listed above, and if a dense network of drainage ditches is installed may well see an increase in peak runoff rates. Over the following decades, as the drainage ditches fall into disrepair and become less effective and the trees get bigger, the positive effects on reducing flood runoff are likely to manifest themselves more strongly – redressing the balance and possibly reducing peak flood flows compared to the original state.

Defra/EA (2004) concludes at the time of writing that: 'Overall, no clear evidence has emerged to show that forests either mitigate or increase flooding to a significant extent.'

In addition, it may be assumed that the commercial use of forests means that after several decades trees are felled and young trees re-planted in a cyclical fashion, with different areas at different stages of the cycle, potentially cancelling out significant effects on runoff rates.

It is pertinent to note that during the FSU research the FOREST catchment descriptor was not found to exert a significant influence on describing variation in floods in relation to QMED, growth curve or hydrograph shape.

The pragmatic approach followed in this study to investigate the possible peak flow sensitivity to afforestation in the AFA catchments is described below.

The proportion of forest in the catchments to all AFAs was determined, and the sensitivity to a doubling of the amount of forest considered, in which it was assumed that the effect of afforestation is that peak runoff rates from the new forest areas will increase by 10% in the MRFS and 20% in the HEFS.

The present-day proportion of forest cover in the catchments to the AFAs was determined, as captured in the FSU catchment descriptor FOREST[1]. The ranked present-day forest proportions for each AFA are presented in Table 6.6. The locations considered are the same as those in Table 6.2. The node numbers are shown on the model extent maps in Chapters B1 to B16 in Appendix B for ModelsN01-N16 respectively.

Projections of the increase in future forestry were not available. It was assumed that forestry doubles over the 100-year horizon considered in this chapter. However for catchments with less than 25% forest cover it was assumed that changes to flow at the AFA due to afforestation would not be significant. Where more than 25% of a catchment is currently covered a doubling of the forest surface area is considered as having more of a possibility of significantly affecting the flood flows. Noting that the research discussed above suggests that changes in flood runoff due to afforestation are generally small, an increase in peak flows of 10% and 20% was applied for the MRFS and HEFS conditions over the proportion of new forest in the catchments to the AFAs. As an example, if 25% of a catchment is covered by forest, then it is assumed that the forest cover will increase by another 25%, and the design flow at the AFA is increased by 10% (MRFS) and 20% (HEFS) of 25%, i.e. by 2.5% and 5%.

[1] This parameter is produced from a composite of the CORINE dataset for the year 2000 with the Coillte Teoranta forestry database and the Forest Inventory Parcel System from the Forest Service of 1998 (Compass Informatics, 2009).

There are five locations where the proportion of forest in the upstream catchment is greater than 25%. For these locations the effects of afforestation on design flows have been assessed in the above mentioned manner. Refer to Tables 6.7-6.9 for the present day, MRFS and HEFS peak design flows.

AFA	Model	HEP	FOREST (%)
Clonaslee	N07	25_582_6	63.0
Clonaslee	N07	25_570_14	48.5
Newport	N15	25_2323_6	48.4
Newport	N15	25_475_1	43.0
Cappamore	N15	25_502_1	28.0
Birr	N11	25_816_4	23.7
Roscrea	N11	25_892_5	20.7
Boyle	N01	26_164_2	20.5
Limerick City	N16	25_3329_2	20.4
Limerick City	N16	25_527_3	20.1
Cappamore	N15	25_833_1	16.7
Drumshanbo	N01	26_59_1	16.5
Castlerea	N08	26_3795_6	14.7
Limerick City	N16	27_1150_1	14.7
Carrick on Shannon	N01	26_1881_1	14.2
Castlerea	N08	26_1249_1	13.3
Birr	N11	25_628_2	13.0
Nenagh	N14	25_335_1	12.7
Limerick City	N16	27_158_2	12.7
Killaloe / Ballina	N12	25_2360_6	11.8
Boyle	N01	26_3583_1	11.3
Limerick City	N16	25_3904_3	9.79
Roscrea	N11	25_2454_3	9.73
Nenagh	N14	25_1844_1	9.71
Castleconnell	N12	25_3823_9	9.20
Limerick City	N16	25_1203_4	9.18
Mullingar	N05	25_3682_3	8.43
Athlone	N10	26_4000_5	8.21
Ballinasloe	N09	26_1436_4	8.13

AFA	Model	HEP	FOREST (%)
Ballinasloe	N09	26_3041_5	7.93
Portumna	N12	25_655_4	7.91
Ahascragh	N09	26_3748_2	7.63
Ballinasloe	N09	26_3824_10	7.54
Abbeyshrule	N03	26_1427_3	7.35
Ballymahon	N03	26_959_2	7.30
Longford	N02	26_3215_1	6.70
Ballinasloe	N09	26_3977_4	6.55
Kibeggan	N06	25_559_6	6.13
Limerick City	N16	25_3896_1	6.02
Borrisokane	N13	25_3530_5	5.86
Portumna	N12	25_2616_1	5.82
Dromod	N02	26_4022_3	5.78
Clara	N06	25_565_24	5.46
Ballymahon	N03	26_3975_1	4.11
Birr	N11	25_3344_8	3.98
Mullingar	N05	25_3125_1	2.89
Leitrim Village	N01	26_3490_1	2.63
Limerick City	N16	24_121_12	1.65
Limerick City	N16	24_1718_3	1.37
Carrick on Shannon	N01	26_1470_1	1.19
Athlone	N10	26_4018_4	0.76
Mohill	N02	26_2307_4	0.69
Killaloe / Ballina	N12	25_1019_4	0.58
Limerick City	N16	25_2067_1	0.46
Ballinasloe	N09	26_3033_5	0.37
Limerick City	N16	24_1720_4	0.28
Roscommon	N04	26_876_1	0.21
Mohill	N02	26_2239_1	0.17
Portumna	N12	25_3708_1	0.00
Portumna	N12	25_811_6	0.00
Nenagh	N14	25_3773_5	0.00
Edgeworthstown	N03	26_3884_6	0.00
Roscommon	N04	26_2111_5	0.00

AFA	Model	HEP	FOREST (%)
Longford	N02	26_2118_1	0.00
Longford	N02	26_643_1	0.00

Table 6.6 AFAs and Present Day FOREST Catchment Descriptors

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Clonaslee (N07)	25_582_6	12.0	13.7	16.5	18.1	20.0	21.4	22.8	25.9
Clonaslee (N07)	25_570_14	10.0	12.3	13.8	15.1	16.7	17.9	19.0	21.6
Newport (N15)	25_2323_6	7.0	8.2	8.9	9.6	10.4	11.1	11.6	13.1
Newport (N15)	25_475_1	30.0	35.3	38.4	41.2	44.8	47.5	50.1	56.3
Cappamore (N15)	25_502_1	28.1	33.0	35.9	38.6	42.0	44.5	47.0	52.7

Table 6.7 Present Day Design Flows

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Clonaslee (N07)	25_582_6	12.7	14.6	17.6	19.2	21.3	22.8	24.2	27.5
Clonaslee (N07)	25_570_14	10.5	12.9	14.5	15.8	17.5	18.8	19.9	22.7
Newport (N15)	25_2323_6	7.3	8.6	9.3	10.0	10.9	11.6	12.2	13.7
Newport (N15)	25_475_1	31.3	36.8	40.0	43.0	46.7	49.5	52.3	58.7
Cappamore (N15)	25_502_1	28.9	34.0	36.9	39.7	43.1	45.7	48.3	54.2

Table 6.8 Design Flows for Future Afforestation – MRFS (FOREST+10%)

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Clonaslee (N07)	25_582_6	13.5	15.5	18.6	20.4	22.5	24.1	25.6	29.1
Clonaslee (N07)	25_570_14	11.0	13.5	15.1	16.6	18.3	19.6	20.8	23.7
Newport (N15)	25_2323_6	7.6	9.0	9.8	10.5	11.4	12.1	12.8	14.3

AFA (and Model)	HEP	Annual Exceedance Probability (%)							
		50	20	10	5	2	1	0.5	0.1
Newport (N15)	25_475_1	32.6	38.3	41.7	44.7	48.6	51.5	54.4	61.1
Cappamore (N15)	25_502_1	29.7	34.9	37.9	40.7	44.3	47.0	49.6	55.6

Table 6.9 Design Flows for Future Afforestation – HEFS (FOREST+20%)

7 Conclusions and Recommendations

7.1 Conclusions

There is a scarcity of flow recording gauging stations on the River Shannon upstream of Lough Ree. The hydraulic modelling results for a range of AEPs were used in a trial-and-error process to obtain reliable hydrological flow estimates. This was done by comparing the modelled flood levels and extents with the observed flooding in AFAs along the Shannon, and amending the flows until a good fit with observations was obtained. In doing so it was found that Station 25017 (Banagher) on the River Shannon downstream of Lough Ree appears to be a suitable pivotal station for the estimation of QMED on the Upper Shannon, which can be explained by the fact that it is on the same watercourse, downstream of the area of interest, and has a similarly low value of the FARL catchment descriptor, indicating that the effect of lakes is comparable. However the growth curve for the Upper Shannon appears to be steeper than that at Banagher (which is particularly flat), and closer to the FSR national growth curve. Significant flood storage in the Callows, the low-lying area along the banks of the River Shannon between Lough Ree and Banagher, may contribute to the flat growth curve at Banagher.

With several high flow gaugings the OPW rating at Station 25017 (Banagher) is considered reliable. The station has a long record from 1950 to present. It was observed that there is a small upward trend in the AMAX level and flow series, which may result from the cumulative effect of drainage works in the upstream catchments during the past decades. For this reason older flow data should be used with some caution.

As part of the CFRAM study rating reviews 28 gauging stations in UoM 25/26 were reviewed, the findings of which are documented in this report.

Station 25015 (Pollagh) on the River Brosna only has one high flow check gaugings (of Sep 2010). OPW have reported concern on the suitability of the site for check gaugings, and report that regular drainage maintenance appears to affect the rating. More high flow check gaugings will be required to confirm whether the works affect the station for high flows. If so OPW should consider moving the station.

Station 26012 (Tinacarra) on the River Boyle has a few check gaugings just below QMED from the mid-90s. Its flow series suggests that its flood flows are considerable higher than those further downstream at Station 26108 (Boyle Abbey Bridge). The hydraulic modelling does not indicates that significant above-surface flood storage between the two stations occurs, suggesting that either the rating at (at least) one of the stations is incorrect, or that between the two stations flow is lost into the permeable geology and karst features that are present in the area.

Of the two stations on the River Boyle Station 26108 is considered more reliable because high flow check gaugings undertaken in the Nov 2009 flood (significantly above QMED) broadly confirm the existing OPW rating. That station was therefore adopted as the pivotal station for the River Boyle.

The hydraulic gauging station models at both sites produced a good fit with the check gaugings and original rating, which lends weight to the hypothesis that flow may be lost to the subsurface between the two stations.

7.2 Recommendations

Due to the reported poor nature of Gauging Station 25013 (Brosna at Newell's Bridge), evident in the scatter in the check gaugings, the station cannot currently be used for flood estimation purposes. It is recommended that the gauge be moved to a geomorphologically stable section and that a formal control be used to reduce the scatter in the check gaugings.

Station 25021 (Croghan) seems unstable, and hence requires either improvement or relocation to a stable location in the vicinity of the current gauging location.

Of the 28 stations that were reviewed for this study, the 21 listed in Table 5.1 below were found to have few or no recent high flow gaugings. It is recommended that such gaugings are undertaken to improve the confidence in the high flow ratings.

Number	Name
25001	Annacotty
25006	Ferbane
25014	Millbrook
25015	Pollagh
25016	Rahan
25021	Croghan
25022	Syngefield
25024	New Bridge
25027	Gourdeen
25029	Clarianna
26001	Ballinamore
26002	Rookwood
26004	Bookala
26006	Willsbrook
26012	Tinacarra
26014	Banada Bridge
26016	Ballymurray
26019	Mullagh
26021	Ballymahon

Number	Name
26022	Kilmore
26108	Boyle Abbey Bridge

Table 7.1 Rating review gauging stations requiring high flow check gaugings

8 References

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Appendix A Sub-catchment Hydrological Analysis

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A1 Upper Shannon Catchment

A2 Inny Catchment

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A6 Lower and Middle Shannon Catchment

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A10 Mulkear Catchment

A1 Upper Shannon Catchment

A1.1 Catchment Description

The general description of the Upper Shannon catchment (Figure A1.1) is given in Table A1.1.

Attribute	Description
Unit of Management (UoM)	25/26
Main water courses	Rivers Shannon, Boyle, Aghagrania, Eslin, Rinn, Camlin, Camlin South, Cappagh (tributary of Rinn)
Outflow point	Lough Ree
Total catchment area	2779 km^2
Areas for Further Assessment (AFAs)	Drumshanbo, Boyle, Carrick on Shannon, Leitrim Village, Dromod, Mohill, Longford, Cloondara
Individual Risk Receptors (IRRs)	None
Model Extents*	N01, N02 and part of N10
General topology	Min altitude = 40 mAOD Max altitude = 640 mAOD The Upper Shannon catchment is delineated in the north by small areas of higher ground draining into Lough Allen, which is the first major lake (and third largest) on the River Shannon. The remainder of the catchment is delineated by rolling hills, with water draining in from the north, east and west towards a large plain forming the central lowlands. The central lowlands are gently undulating. The extensive drumlins and eskers dotting the landscape, remnants of the last glaciation, are ideal for bog formation. Localised sediment accumulation has resulted in the formation of varying sized water bodies across the central plain. The downstream boundary of the catchment is denoted by Lough Ree, the second largest lake on the River Shannon. The numerous loughs in the catchment will cause attenuation of flows, producing a delayed response with a lower peak flow downstream. The FARL value for the catchment to the upstream end of Lough Ree is 0.74, and the lowest value of FARL is 0.68 which occurs in Reaches 4 and 5.
Average annual rainfall**	919 mm to 1561 mm
Soils and geology	Subsoils comprise predominantly peat and low to moderate permeability glacial tills over limestone and sandstone bedrock. Glacial sands and gravels occur within the till to the south west of Ballaghaderreen and form a locally important gravel aquifer. Sandstone bedrock underlies the catchment east of a major fault line running between Mohill and Roscommon and forms the higher ground around Lough Allen to the north, the sandstone is both a poor and a locally important bedrock aquifer. Basic intrusive rocks occur west of Ballaghaderreen and form isolated surface outcrops. The remainder of the catchment is underlain by limestone bedrock which is predominantly a regionally important karstified aquifer containing many karstic features, particularly north of Roscommon. Refer to Figure 3.3 in the Main Report for the

	hydrogeological characteristics of the underlying rock formations. Poorly drained soils and peat predominate with limited well drained soils occurring along the far south and southeast edges of the catchment and around Boyle in the north. Refer to Figure 3.4 in the Main Report for the distribution of differing soil drainage classes.
Urban areas	The Upper Shannon is predominantly rural and this dominates the low URBEXT values across the large catchment. The three most significant urban areas across the Upper Shannon at Boyle, Carrick on Shannon and Longford all have major watercourses flowing through them; the Rivers Boyle, Shannon and Camlin respectively. The highest URBEXT values in the catchment are found on small tributaries draining these urban areas; the Drummagh at Carrick on Shannon (34%) and the Farranyoogan draining Longford (21%). However, the influence of these urban tributaries on URBEXT values on the larger rivers is limited due to the generally rural nature of the catchment. The River Camlin upstream of Longford has an URBEXT value of 0.1% only rising to 1.3% downstream, and at Carrick on Shannon, the URBEXT value on the River Shannon upstream is 0.3% only rising to 0.4% downstream. At Boyle, the URBEXT values upstream and downstream are 0.3% and 0.5% respectively, dropping further at the confluence of the River Boyle with the River Shannon

* Specific hydrological details for the models are provided in Appendices B1, B2 and B10.
** range of SAAR values taken from the FSU catchment descriptors covering the extent of modelling

Table A1.1 Upper Shannon Catchment description

A1.2 Hydrometric Stations in the Upper Shannon Catchment

The gauging stations in the Upper Shannon catchment are shown on Figure A1.1. Details of the gauging stations in the Upper Shannon catchment that were considered relevant for the hydrological analysis in the hydraulic model extents are tabulated in Table A1.2.

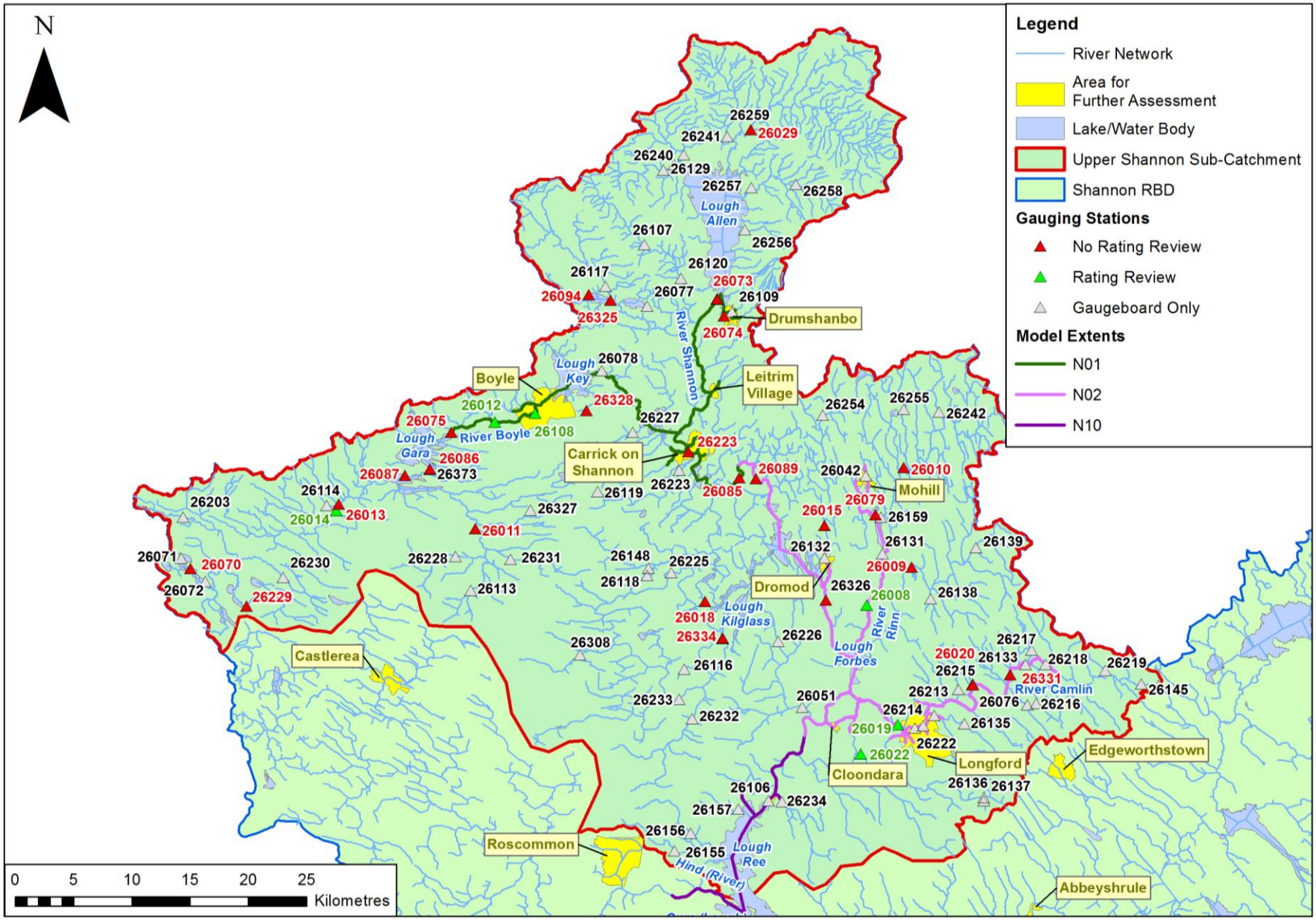


Figure A1.1 Upper Shannon Catchment with model extents and hydrometric stations

Model	Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments
N01	26012	TINACARRA	1957 - 2009	Level and Flow	A1	Yes	
	26014	BANADA BR	1989-2009	Flow and Level	B	Yes	
	26030	L. ALLEN D/S	2001 - 2012	Level and Flow	HGF/QMED = 2.8	No	
	26073	L. ALLEN U/S	Not known	Level only	N/A	No	
	26074	BLACKROCK LOCK	1994 - 2009	Level only	N/A	No	
	26075	CUPPANAGH	1980 - present	Level only	N/A	No	
	26078	DRUMCORMICK	Not known	Level only	N/A	N/A	
	26085	JAMESTOWN	1957 - 2009	Level only	N/A	No	
	26108	BOYLE ABBEY BR.	1990 - 2009	Level and Flow	A1	Yes	
	26324	CARRICK ON SHANNON	2004 - 2009	Level only	N/A	No	
N02	26008	JOHNSTON'S BR.	1955 - 2009	Level and Flow	A1	Yes	
	26015	CORRASCOFFY	1972 - 2009	Level and Flow	HGF/QMED = 1.6	No	
	26019	MULLAGH	1953 - 2009	Level and Flow	A1	Yes	1
	26020	ARGAR	1972 - 2009	Level and Flow	A1	No	
	26022	KILMORE	1957 - 2009	Level and Flow	A2	Yes	2
	26079	LOUGH RINN	1997 - 2006	Level and Flow	No data	No	
	26085	JAMESTOWN	1957 - 2009	Level only	N/A	No	
	26089	DRUMSNA	1984 - 2009	Level only	N/A	No	
	26326	ROOSKY BR	Not known	Level and Flow	No data	No	3
	26331	KILNAGARROW BR	2008 - present	Level and Flow	N/A (Insufficient data)	No	

Table A1.2 Upper Shannon Catchment Gauging Stations

1	The CFRAM model rating is based on the current geometry of the river which follows the completion of channel works (Oct 2010) and covers a period when the site is still stabilising. Insufficient data is available to identify whether the model rating is suitable and whether the site is stable. OPW have agreed that no further work should be completed on the rating review for Mullagh. It is recommended that only AMAX pre-2010 should be used for flood estimation. If the pre-2010 data at this station is considered for flood estimation it should be used with caution as the check gaugings from the 1990s and 2000s show that the latest rating is not representative for that 20 year period.
2	There is scatter evident in the check gaugings. Therefore it is recommended that flow data is used with caution. There are few high flow check gaugings, but the 2009 gauging fits well to rating. This station is suitable for QMED estimation but not for flood frequency analysis (insufficient confidence in accuracy of flows above QMED).
3	There is little data available for this GS; not fit for use - confirmed by Waterways Ireland and Leitrim County Council.

Table A1.3 Upper Shannon Hydrometric Data Quality Comments

A1.3 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A1.2 above. The river reaches are tabulated in Table A1.4 and shown on Figure A1.2. The variation in catchment descriptors for each reach is tabulated in Tables A1.5 to A1.25 below.

Please note that the hydrology relating to Lough Ree is discussed in Appendix A6.

Reach	Description	Model Extent
1	Aghagrania River – Tributary to Lough Allen flowing through Drumshanbo AFA (upstream HEP 26_3589_2a, downstream HEP 26_59_3)	N01
2	Main River Shannon (d/s of Lough Allen 26_3594_1 to HEP 26_3594_7)	N01
3	Main River Shannon (downstream HEP 26_4149_1 to confluence between the River Shannon & Boyle River (HEP 26_124_2)	N01
4	Main River Shannon d/s of confluence between River Shannon and Boyle River (26_3561_1) to Lough Ree (26_4162_2.	N01, N02, N10
5	River Boyle tributary (upstream HEP 26_851_1a, downstream HEP 26_133_2)	N01
6	River Easky, tributary to River Boyle at Boyle (upstream HEP 26_2884_2a, downstream HEP 26_164_2)	N01
7	Ballinamore and Ballyconnell Canal (upstream node 26_3488_1a, downstream HEP 26_3490_3) and tributary Tawnycurry (upstream HEP 26_3489_1, downstream HEP 26_3489_3). Tributary to River Shannon, flowing through Leitrim Village AFA.	N01
8	Tributaries to River Shannon flowing through Carrick-on-Shannon AFA; Guiltyconeen/Mullaghmore River (Upstream HEP 26_4143_1a, downstream HEP 26_1470_3), Lisnabrak (upstream HEP 26_3603_1, downstream HEP 26_3603_4), Drummagh (upstream HEP 26_3554_1a, downstream HEP 26_3554_2) & Keenaghban (upstream HEP 26_3566_1a, downstream HEP 26_1540_2).	N01
9	Camlin Main – tributary to River Shannon, extending from HEP 26_3074_1 to its confluence with Camlin South (at HEP 26_992_8) and Camlin South (upstream HEP 26_459_5 to HEP 26_3932_9)	N02
10	Tributaries to River Camlin: River Knockmartin (upstream HEP 26_3606_1a, downstream HEP 26_3606_2), River Ardnacassagh (upstream HEP 26_3214_4a0, downstream HEP 26_3214_4a1), River Farranyoogan (upstream HEP 26_643_1a, downstream HEP 26_991_2), Tributary to Farranyoogan- Ballyminion (upstream HEP 26_2118_1a, downstream HEP 26_2118_3),	N02
11	Tributaries to River Camlin: River Carrickglass Demesne (upstream HEP 26_813_17a, downstream HEP 26_1197_4), River Clookeen (upstream HEP 26_4116_11, downstream HEP 26_4116_16)	
12	River Fallan, tributary to River Camlin South (upstream HEP 26_2726_4a, downstream HEP 26_2726_8)	N02
13	River Cappagh (HEP 26_2307_2) to upstream extent of Lough Rinn (HEP 26_1220_3) and it's tributary River Shannagh (upstream HEP 26_2239_1a, downstream HEP 26_2239_4)	N02
14	River Rinn from downstream of Lough Rinn (HEP 26_2666_1) to Lough Forbes (HEP 26_3711_5)	N02
15	River Eslin to confluence with River Shannon (upstream HEP 26_2723_2, downstream HEP 26_3953_1)	N02

Table A1.4 River Reaches in the Catchment

Reach 1		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.7 (26_91_3)	12 (26_59_3)
BFIsoil	0.40 (26_3589_5)	0.51 (26_91_3)
SAAR (mm)	1243 (26_91_3)	1290 (26_3589_5)
FARL	0.87 (26_3589_5)	1.00 (26_91_3)
DRAIND	1.05 (26_91_3)	2.45 (26_3589_5)
S1085 (m/km)	18.2 (26_91_3)	23.7 (various)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	2.4 (various)	3.3 (26_59_3)

Table A1.5 Reach 1 Catchment Descriptor Range

Reach 2		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	442 (26_3594_1)	446 (26_3594_7)
BFIsoil	0.52 (all)	0.52 (all)
SAAR (mm)	1557 (26_3594_7)	1561 (26_3594_1)
FARL	0.71 (26_3594_1)	0.72 (26_3594_7)
DRAIND	1.36 (26_3594_7)	1.37 (26_3594_1)
S1085 (m/km)	2.5 (26_3594_7)	2.8 (26_3594_1)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0.1 (all)	0.1 (all)

Table A1.6 Reach 2 Catchment Descriptor Range

Reach 3		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	564 (26_4149_1)	636 (26_124_2)
BFIsoil	0.54 (26_4149_1)	0.59 (various)
SAAR (mm)	1442 (26_124_2)	1482 (26_4149_1)
FARL	0.76 (various)	0.77 (various)
DRAIND	1.27 (various)	1.31 (26_4149_1)
S1085 (m/km)	1.5 (26_124_2)	2.5 (26_4149_1)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0.1 (all)	0.1 (all)

Table A1.7 Reach 3 Catchment Descriptor Range

Reach 4		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1290 (26_3561_1)	2779 (26_4162_2)
BFIsoil	0.67 (all)	0.67 (all)
SAAR (mm)	1136 (various)	1283 (various)
FARL	0.68 (various)	0.74 (various)
DRAIND	0.97 (various)	1.08 (26_4069_2)
S1085 (m/km)	0.37 (26_4162_1)	0.67 (various)
ARTDRAIN2 (%)	9 (various)	18 (various)
URBEXT (%)	0.3 (various)	0.4 (various)

Table A1.8 Reach 4 Catchment Descriptor Range

Reach 5		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	497 (26_3914_1)	654 (26_133_2)
BFIsoil	0.67 (26_133_2)	0.70 (various)
SAAR (mm)	1129 (26_133_2)	1140 (26_3914_1)
FARL	0.68 (26_133_2)	0.83 (various)
DRAIND	0.88 (various)	0.91 (various)
S1085 (m/km)	0.3 (various)	0.7 (various)
ARTDRAIN2 (%)	45 (26_133_2)	53 (various)
URBEXT (%)	0.3 (various)	0.5 (various)

Table A1.9 Reach 5 Catchment Descriptor Range

Reach 6		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	6.2 (26_2884_2)	10 (26_164_2)
BFIsoil	0.40 (all)	0.40 (all)
SAAR (mm)	1107 (26_2884_2)	1113 (26_164_2)
FARL	1.00 (all)	1.00 (all)
DRAIND	0.94 (26_2884_2)	1.20 (various)
S1085 (m/km)	22.0 (26_164_2)	34.5 (26_2884_2)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0 (all)	0 (all)

Table A1.10 Reach 6 Catchment Descriptor Range

Reach 7		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	3.0 (26_3489_1)	32 (26_3490_3)
BFIsoil	0.51 (various)	0.65 (26_3488_2)
SAAR (mm)	1109 (26_3488_2)	1139 (26_3489_1)
FARL	0.89 (various)	1.00 (various)
DRAIND	0.68 (26_3630_11)	1.83 (26_3489_3)
S1085 (m/km)	3.4 (26_3630_11)	5.6 (various)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0 (various)	0.9 (26_3490_3)

Table A1.11 Reach 7 Catchment Descriptor Range

Reach 8		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.0 (26_3603_1)	7.6 (26_1470_3)
BFIsoil	0.50 (various)	0.54 (26_1540_2)
SAAR (mm)	1032 (26_795_3)	1046 (26_3603_1)
FARL	0.95 (26_1503_2)	1.00 (various)
DRAIND	0.41 (26_3603_1)	2.21 (26_1540_2)
S1085 (m/km)	0.1 (26_3603_4)	10.1 (various)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0 (26_795_3)	34 (26_3554_2)

Table A1.12 Reach 8 Catchment Descriptor Range

Reach 9		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	51 (26_3074_4)	328 (26_3927_4)
BFIsoil	0.54 (various)	0.60 (various)
SAAR (mm)	919 (26_459_1)	1005 (various)
FARL	0.95 (various)	1.00 (various)
DRAIND	0.52 (various)	0.96 (various)
S1085 (m/km)	0.44 (26_3927_4)	2.91 (various)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0.1 (various)	1.4 (various)

Table A1.13 Reach 9 Catchment Descriptor Range

Reach 10		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.2 (26_2118_1)	5.3 (26_991_2)
BFIsoil	0.40 (various)	0.47 (26_643_1)
SAAR (mm)	934 (26_2118_3)	960 (26_3606_2)
FARL	1.00 (all)	1.00 (all)
DRAIND	0.15 (various)	1.49 (26_3606_2)
S1085 (m/km)	0.1 (various)	5.7 (26_3606_2)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0 (various)	21 (26_643_3)

Table A1.14 Reach 10 Catchment Descriptor Range

Reach 11		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	9.6 (26_813_17)	37 (26_4116_16)
BFIsoil	0.56 (various)	0.61 (26_813_17)
SAAR (mm)	936 (various)	970 (26_813_17)
FARL	1.00 (all)	1.00 (all)
DRAIND	0.75 (26_4116_13)	1.24 (26_813_17)
S1085 (m/km)	2.7 (26_4116_16)	6.0 (26_813_17)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0 (various)	0.4 (various)

Table A1.15 Reach 11 Catchment Descriptor Range

Reach 12		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	61 (26_2726_8)	61 (26_2726_8)
BFIsoil	0.60 (26_2726_8)	0.60 (26_2726_8)
SAAR (mm)	919 (26_2726_8)	919 (26_2726_8)
FARL	1.00 (26_2726_8)	1.00 (26_2726_8)
DRAIND	0.50 (26_2726_8)	0.50 (26_2726_8)
S1085 (m/km)	2.6 (26_2726_8)	2.6 (26_2726_8)
ARTDRAIN2 (%)	0 (26_2726_8)	0 (26_2726_8)
URBEXT (%)	0.3 (26_2726_8)	0.3 (26_2726_8)
Note: Reach 12 only has one HEP node with FSU catchment descriptors		

Table A1.16 Reach 12 Catchment Descriptor Range

Reach 13		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.9 (26_2239_1)	22 (various)
BFIsoil	0.45 (various)	0.48 (various)
SAAR (mm)	1021 (26_1220_3)	1049 (26_2307_4)
FARL	0.97 (various)	1.00 (various)
DRAIND	0.69 (26_2307_4)	1.26 (26_2239_4)
S1085 (m/km)	2.7 (26_1220_3)	8.7 (26_2239_4)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	1.4 (26_2239_1)	9.4 (26_2307_7)

Table A1.17 Reach 13 Catchment Descriptor Range

Reach 14		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	165 (26_2666_1)	299 (26_3711_5)
BFIsoil	0.61 (various)	0.64 (various)
SAAR (mm)	1033 (26_3711_5)	1050 (26_2666_1)
FARL	0.80 (various)	0.86 (various)
DRAIND	1.07 (26_3711_5)	1.23 (26_2666_1)
S1085 (m/km)	0.9 (26_3711_5)	1.1 (various)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0.2 (26_3711_5)	0.4 (various)

Table A1.18 Reach 14 Catchment Descriptor Range

Reach 15		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	165 (26_2666_1)	299 (26_3711_5)
BFIsoil	0.61 (various)	0.64 (various)
SAAR (mm)	1033 (26_3711_5)	1050 (26_2666_1)
FARL	0.80 (26_2666_1)	0.86 (various)
DRAIND	1.07 (26_3711_5)	1.23 (26_2666_1)
S1085 (m/km)	0.9 (26_3711_5)	1.1 (various)
ARTDRAIN2 (%)	0 (all)	0 (all)
URBEXT (%)	0.2 (26_3711_5)	0.4 (various)

Table A1.19 Reach 15 Catchment Descriptor Range

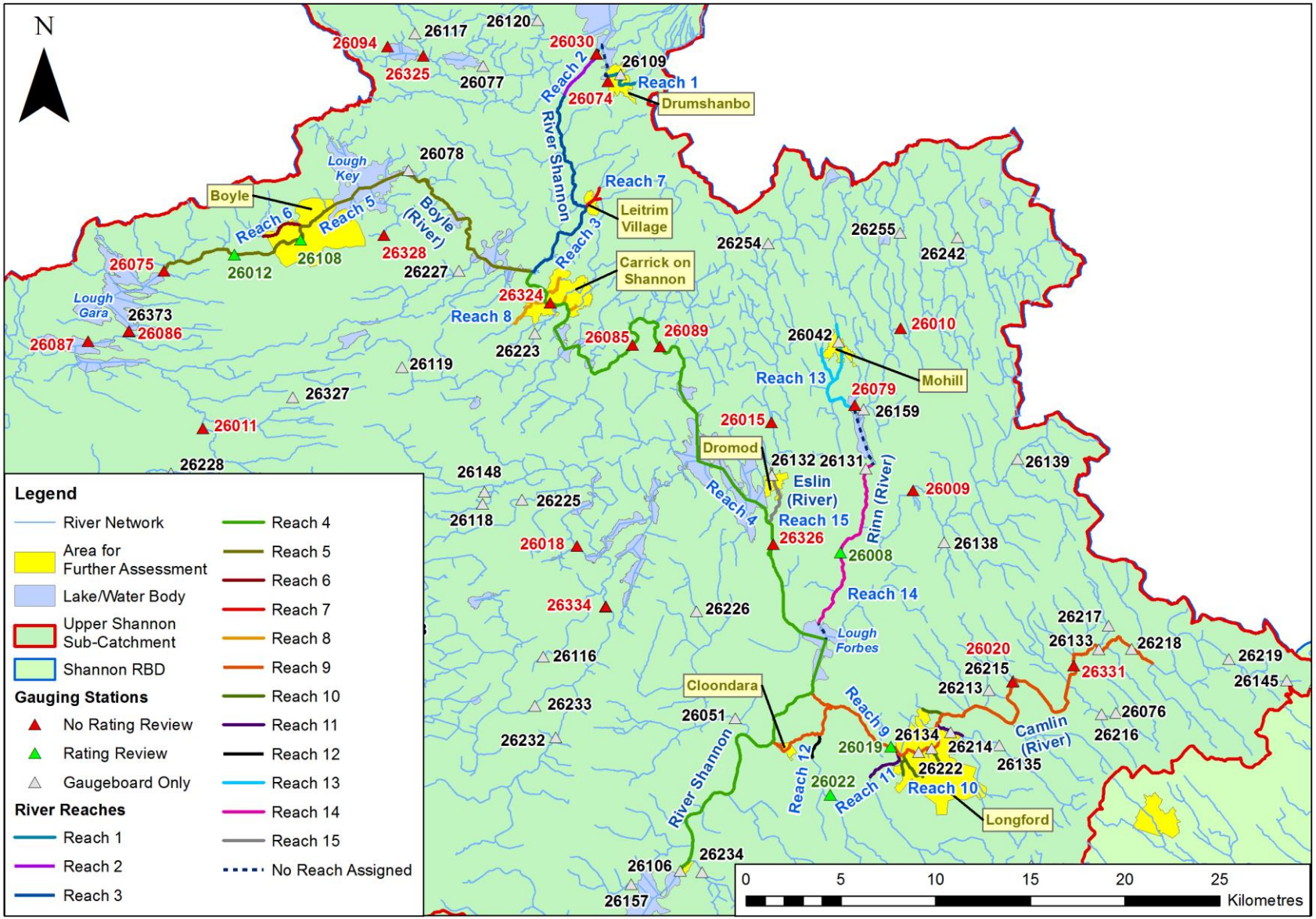


Figure A1.2 Upper Shannon Catchment River Reaches

A1.4 QMED Adjustment Factors

Table A1.20 below gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED.

Reach	Gauging Station Number	QMED Observed (m^3/s)	QMED (urban) Synthetic (m^3/s)	Adjustment Factor (-)	Model Extent	Note
2	26030	30.6	64.1	0.48	N01	1
5	26012	49.1	36.8	1.33	N01	2
	26108	41.6	35.6	1.17	N01	3
	26014	39.1	44.0	0.89	N01	
9	26019	21.2	26.5	0.80	N02	4
	26020	11.1	14.7	0.76	N02	
12	26022	6.4	5.7	1.13	N02	5
14	26008	22.9	24.9	0.92	N02	6
15	26015	6.3	6.8	0.92	N02	7

Table A1.20 Available QMED Adjustment Factors in each reach

Notes:

1. AMAX series only available from 2001 to 2011. Flows at this location (d/s of Lough Allen) affected by Lough storage and sluice operation.
2. AMAX available from 1993 to present (drainage works 1982-1992 resulting in a step change in flows), AMAX trends post-1992 to present. No high-flow check gaugings. Data from Station 26108 downstream should be used in preference to this site for QMED adjustment and flood frequency analysis.
3. AMAX available from 1990 to present. Several high-flow check gaugings available. OPW rating reviewed and unchanged.
4. Some scatter evident in check gaugings. Unexplained change evident in flows around 1990. AMAX 1953 – 1989 used to derive QMED adjustment factor. Similar to the adjustment factor at Station 26020.
5. Scatter evident in check gaugings, as a result it is recommended that flows are used with caution. However, 2009 gauging fits well to rating and as the only gauging station on the River Fallon it is deemed appropriate for QMED adjustment along the reach.
6. Slight upward trend in AMAX flows from 1955, but no evidence of any catchment change. Trend not considered significant to QMED, therefore entire AMAX series appropriate for QMED adjustment.
7. Upward trend in flows until around 1986/87 after which scatter in high flow check gaugings is lessened. AMAX from 1986 appropriate for QMED adjustment.
8. Station 26022 upstream of Reach 12 is suitable for QMED estimation but not for flood frequency analysis as there is insufficient confidence in the accuracy of flows above QMED.

The QMED adjustment factors for the ungauged reaches (or reaches with inadequate high flow monitoring) in the catchment were estimated using multiple pivotal sites in the absence of an adequate single pivotal site. The adjustment factors were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A1.21 to A1.28), with the exception of Reach 4 (HEP node 26_3935_4), where only four suitable pivotal sites were identified. The use of a single pivotal site was considered but no suitable station was found that was hydrologically similar and sufficiently near to the subject site. The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: Π (Adjustment Factor^{Weight}).

To obtain a QMED adjustment factor for Reach 4, the main River Shannon from the Boyle confluence to Lough Ree, pivotal sites were initially used due to a lack of flow gauges on the River Shannon between Lough Allen and Lough Ree. Four pivotal sites were initially selected to provide a group from which to calculate the geometric mean of QMED adjustment factors for HEP node 26_3935_4 (8.5 km upstream of Lough Ree). The number of stations selected was four instead of the usual five because only four stations were considered to be potentially suitable candidate pivotal sites with similarly high AREA and low FARL descriptors. Table A1.23 summarises the resulting candidate QMED adjustment factor.

However doubts were expressed as to the appropriateness of using multiple pivotal sites given the unique character of the main River Shannon in Reach 4. Also, the combined adjustment factor from four pivotal sites (1.10) was found to give very low 2-year return period water levels, as well as very low 100/1000-year water levels (when a suitable growth curve was applied) in comparison with the November 2009 flood. Refer to Section A1.5 for more information on the growth curve and a comparison with the 2009 flood.

Station 25017 (Banagher) is situated on the same watercourse, downstream of Reach 4. Its catchment is only three times larger than that of the subject reach at HEP 26_3935_4 and it has a similar FARL value (0.79 instead of 0.73). Also the SAAR, S1085, and BFIsoil values are similar, and both have essentially rural catchments. See Table A1.20a below for a comparison of the key catchment descriptors.

Catchment Descriptor	Reach 4 (HEP 26_3935_4)	Banagher (25017)
AREA (km^2)	2678	7980
BFIsoil (-)	0.67	0.65
SAAR (mm)	1144	1024
FARL (-)	0.73	0.79
DRAIND (km^{-1})	0.99	0.81
S1085 (m/km)	0.41	0.25
ARTDRAIN2 (%)	9.4	20.9
URBEXT (%)	0.4	0.8

Table A1.20a Catchment descriptor comparison Reach 4 with Pivotal Station 25017

Consequently Station 25017 (Banagher) was judged to offer a better means of providing a QMED adjustment. Wary of possible historic water level management changes to Lough Ree the QMED adjustment factor was based on the most recent 20-year period (1990 – 2009) giving a QMED adjustment of 1.36. Had the longer period 1972 to 2009 been used the adjustment factor was calculated to be little different at 1.32. The uniqueness of the ungauged Reach 4 is judged likely to introduce a greater degree of uncertainty into the final QMED estimate than is typical elsewhere.

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
36031	CAVAN	1	1.994	0.211	0.62
34024	POLLAGH	2	1.999	0.210	0.79
7033	VIRGINIA HATCHERY	3	2.157	0.195	0.82
34011	GNEEVE BRIDGE	4	2.171	0.194	0.90
3051	FAULKLAND	5	2.210	0.190	1.01
Weighted Geometric Mean					**0.81**

Table A1.21 QMED Adjustment Factor for Reach 1 based on multiple pivotal sites (Target location HEP 26_59_3)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
36027	BELLAHEADY	1	0.737	0.214	0.50
16007	KILLARDRY	2	0.771	0.205	1.39
27002	BALLYCOREY	3	0.792	0.199	1.22
35005	BALLYSADARE	4	0.812	0.194	0.89
20002	CURRANURE	5	0.842	0.187	1.12
Weighted Geometric Mean					**0.97**

Table A1.22 QMED Adjustment Factor for Reach 3 based on multiple pivotal sites (Target location HEP 26_3487_3)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
34001	RAHANS	1	0.910	0.277	1.00
25017	BANAGHER	2	1.013	0.249	1.29
34003	MOY	3	1.044	0.241	1.01
36019	BELTURBET	4	1.081	0.233	1.12
Weighted Geometric Mean					**1.10**

Table A1.23 The candidate QMED Adjustment Factor for Reach 4 based on multiple pivotal sites (Target location HEP 26_3935_4) *[Note: this initial value was not favoured, and an adjustment factor of 1.36 was preferred based on the last 20 years of data at the downstream Shannon gauging station at Banagher (25017), as discussed above. The multiple pivotal estimate is provided here only for completeness]*

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.463	0.493	2.32
23012	BALLYMULLEN	2	1.691	0.135	0.58
14033	OWENASS	3	1.764	0.129	1.17
24022	MAHORE	4	1.805	0.126	1.30
8012	BALLYBOGHIL	5	1.957	0.117	0.93
Weighted Geometric Mean					**1.47**

Table A1.24 QMED Adjustment Factor for Reach 6 based on multiple pivotal sites (Target location HEP 26_164_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
26010	RIVERSTOWN	1	0.943	0.246	1.12
26009	BELLANTRA BR.	2	1.131	0.205	0.93
36071	L. Scur	3	1.136	0.204	0.50
34024	POLLAGH	4	1.343	0.173	0.79
34011	GNEEVE BRIDGE	5	1.356	0.171	0.90
Weighted Geometric Mean					**0.83**

Table A1.25 QMED Adjustment Factor for Reach 7 based on multiple pivotal sites (Target location HEP 26_3488_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.750	0.350	2.32
24022	MAHORE	2	1.498	0.176	1.30
8012	BALLYBOGHIL	3	1.532	0.172	0.93
6031	FLURRY	4	1.643	0.160	2.05
8002	NAUL	5	1.844	0.143	1.39
Weighted Geometric Mean					**1.63**

Table A1.26 QMED Adjustment Factor for Reach 8 based on multiple pivotal sites (Target location HEP 26_1470_1)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.530	0.389	2.32
24022	MAHORE	2	1.225	0.168	1.30
8012	BALLYBOGHIL	3	1.356	0.152	0.93
6031	FLURRY	4	1.414	0.146	2.05
10022	CABINTEELY	5	1.430	0.144	1.62
Weighted Geometric Mean					**1.71**

Table A1.27 QMED Adjustment Factor for Reach 10, 13 based on multiple pivotal sites (Target location HEP 26_695_1)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6031	FLURRY	1	0.372	0.244	2.05
25040	BUNOW	2	0.414	0.220	0.55
26022	KILMORE	3	0.472	0.192	1.02
24022	MAHORE	4	0.527	0.172	1.30
16051	CLOBANNA	5	0.528	0.172	0.73
Weighted Geometric Mean					**1.04**

Table A1.28 QMED Adjustment Factor for Reach 11 based on multiple pivotal sites (Target location HEP 26_4116_16)

Table A1.29 shows the final QMED adjustment factor applied to each reach in the catchment, each with a justification for selection.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	0.81	26_59_3	No gauging station upstream of Lough Allen. Adjustment factor estimated using multiple pivotal sites.
2	0.48	26030	Only flow gauging station in reach. QMED adjustment considered appropriate until significant inflows from tributary (Feorish River).
3	0.97	26_3487_3	Adjustment factor estimated using multiple pivotal sites.
4	1.36	26_3935_4	Adjustment factor estimated using a single pivotal site (25017).
5	1.17	26108	Following rating review, Boyle Abbey (26108) is used in preference over Tinacarra (26012). Reliable for QMED estimation.
6	1.47	26_164_2	Adjustment factor estimated using multiple pivotal sites.
7	0.83	26_3488_2	Adjustment factor estimated using multiple pivotal sites.
8	1.63	26_1470_1	Adjustment factor estimated using multiple pivotal sites.
9	0.83	26019	Adjustment factors derived from 26019 and 26020 were similar, but 26019 (d/s of Longford) was selected as it is considered the most reliable gauge in the reach.
10, 13	1.71	26_695_1	Small urban tributaries to River Camlin, but hydrologically similar to River Cappagh. Not considered appropriate to use 26019 or 26020 on Camlin as both large rural catchments. Adjustment factor estimated using multiple pivotal sites.

11	1.04	26_4116_16	Small rural tributaries to River Camlin. Gauging stations 26019 and 26020 on Camlin not considered appropriate for QMED adjustment due to their considerably larger catchment areas and difference in slope. Adjustment factor estimated using multiple pivotal sites.
12	1.13	26022	Upstream gauge used to derive QMED adjustment factor, reliable for QMED adjustment.
14	0.92	26008	Only flow gauging station in reach. Considered reliable for QMED estimation.
15	0.92	26015	Only flow gauging station in reach. Considered reliable for QMED estimation.

Table A1.29 Final QMED Adjustment Factors Applied to Each Reach

A1.5 Flood Frequency Curves

Gauging Station Flood Frequency Curves

Three stations suitable for flood frequency analysis were identified in the catchment: 26108 (Boyle Abbey Bridge), 26019 (Mullagh) and 26008 (Johnston's Bridge). The flood frequency curves (or growth curves) are plotted in Figures A1.3 to A1.5 below. The flood frequency curve plots for all relevant stations are included in Appendix E. The figures below show the at-site AMAX series (made dimensionless by dividing the flows by QMED, and plotting positions based on the Gringorten formula), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate and an AEP scale.

In addition, 25017 (Banagher) was also identified as potentially offering a useful guide for the main River Shannon down to Lough Ree (Reaches 2, 3 and 4) as it is situated along the same river, downstream of the subject reaches, and given the similarly strong influence of lakes. The similarity of the catchment to this pivotal gauge with the catchment to Reach 4 is discussed in Section A1.4 below. The Banagher flood frequency curve is plotted in Figure A1.6.

a) Boyle Abbey Bridge Gauging Station (26108)

The River Boyle at Boyle Abbey Bridge has 20 years of AMAX data (from 1990 to 2009). A rating review undertaken by Jacobs identified that the OPW and modelled ratings were similar for flows up to 90 m^3/s (> 2xQMED) and recommended retaining the OPW rating. There is some scatter in the rating at high flows, which could be the result of hysteresis, but further gaugings would be needed to confirm this. A summary of the rating review is given in Appendix C.

Boyle Abbey Bridge was selected for growth curve estimation in preference to Tinnacarra, located 4 km upstream, due to evidence of an upward trend in the flow record at Tinacarra and the higher and more frequent check gaugings available at Boyle Abbey Bridge. The Boyle Abbey Bridge at-site and pooled growth curves are shown on Figure A1.3 below.

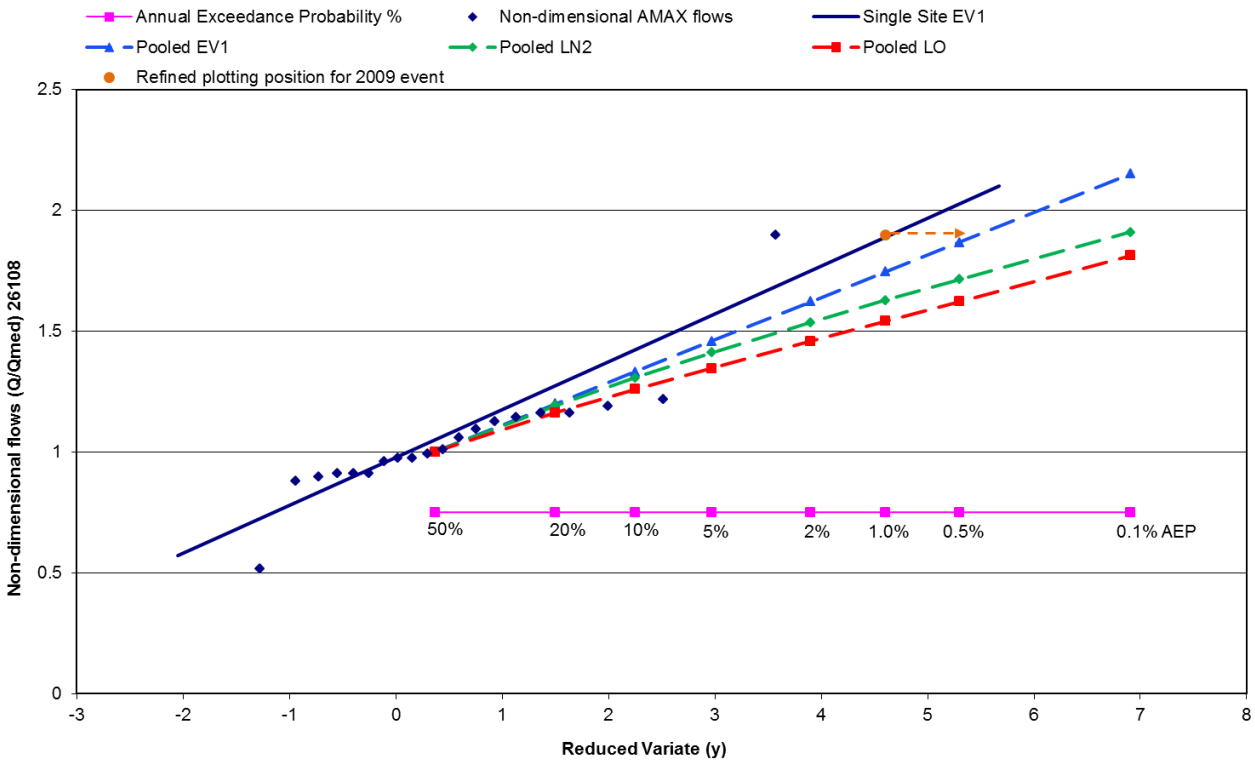


Figure A1.3 26108 Boyle Abbey Bridge – Flood Frequency Curves *(Refined plotting position of the largest annual maximum event [2009] comes from the event's rank within the longer Tinacarra series recorded upstream)*

The length of the AMAX series suggests single site analysis offers only reasonably robust estimates up to return periods of 10 years i.e. AEP = 10% (based on ½N with N=20). For lower AEPs (higher return periods) it is considered more appropriate to use pooled data, consequently the pooled growth curve is adopted. In Figure A1.3 the highest monitored event (2009 flood) has had its Gringorten plotting position revised. The presence of the Tinacarra gauge immediately upstream with an annual maximum series stretching back to 1957 confirms that the 2009 event is almost certainly the largest event on the river during this longer time period. This permits the return period of the event to be re-calculated as approximately 100 years. It is not possible to indicate a precise rarity. Based upon this information it is not straightforward to select the "best" growth curve to use. However the Pooled EV1 distribution has been taken forward to provide design flow estimates. This suggests the 2009 flood event has a return period slightly higher than 200 years, though with an appreciable degree of uncertainty. (Had the LN2 distribution been selected it would suggest a return period higher than 1000 years).

b) Mullagh Gauging Station (26019)

A rating review was commenced for Mullagh, but not completed following difficulties with model calibration, subsequently explained by the significant channel works that took place at the gauging station in October 2010. The hydraulic model developed for the site was based on river survey data collected in June 2012, at which time it is unlikely the channel would have stabilised post-channel works. Furthermore any model developed post-October 2012 would not be representative of the stage-discharge relationship pre-October 2012.

A review of the daily mean flow series identified a break in the flow record in 1990 and a step change down in peak flows. There is no record of any local or catchment change to explain this. Further analysis of the rating identified a reduction in scatter of the check gaugings around the rating when gaugings post-1990 are excluded, and confirmed the recommendation for use of AMAX data from 1953 to 1989 only. It is recognised that the exclusion of more recent AMAX flows (from 1990 to 2009) does raise uncertainty as to the representativeness of the AMAX series to current flows.

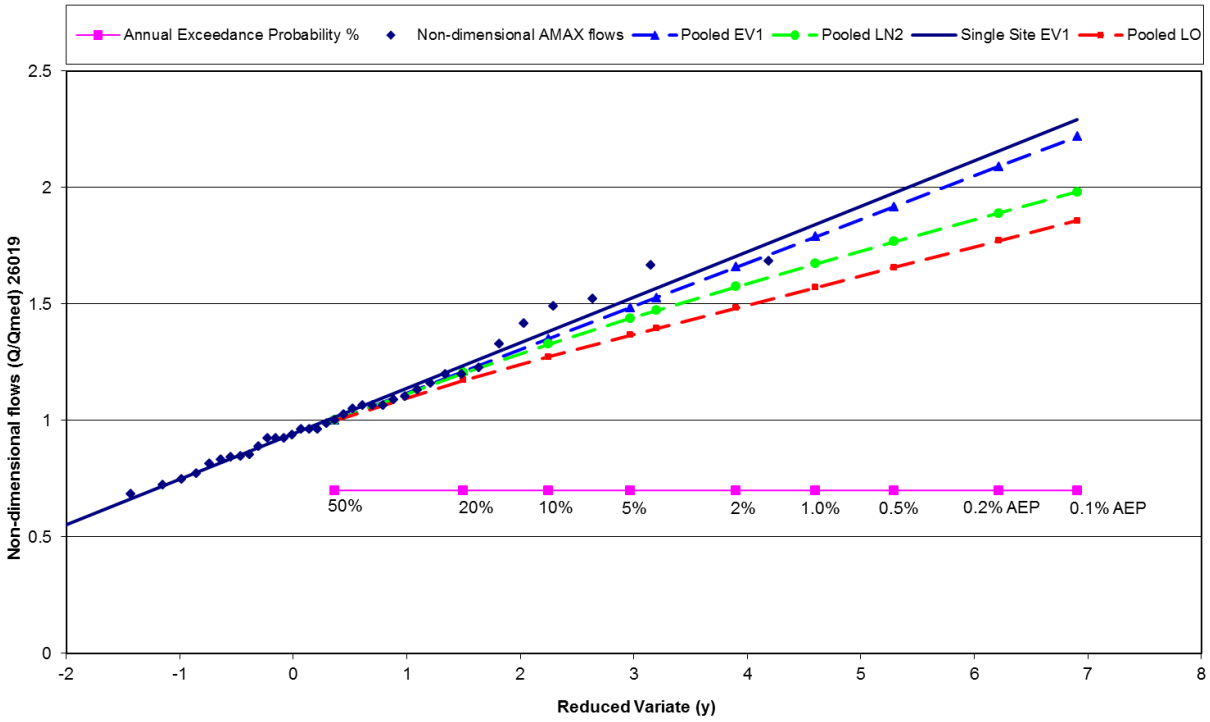


Figure A1.4 26019 Mullagh – Flood Frequency Curves

The length of the AMAX series suggests single site analysis offers reasonably robust estimates up to return periods of about 19 years i.e. AEP = 5 % (based on ½N with N=37). For lower AEPs (higher return periods) it may be more appropriate to use pooled data. Both the single site EV1 and the pooled EV1 growth curves appear reasonable. Due to the apparently slightly better representation of the local data at the 5% AEP the single site EV1 growth curve was selected.

c) Johnston's Bridge (26008)

The River Rinn at Johnston's Bridge has 55 years of AMAX data (from 1955 to 2009). A rating review was commenced for Johnston's Bridge, but it was not completed following difficulties calibrating the hydraulic model within an acceptable parameter range; it is believed that the river survey failed to capture a local control. Therefore, it was recommended the OPW rating be retained.

There is slight scatter in the check gaugings, but a good fit to the highest gauging in November 2009 indicates that the rating is reliable up to 1.5xQMED. A slight gradual upward trend in the flow and level series is not thought to significantly impact the AMAX series and the entire series is considered appropriate for flood frequency analysis.

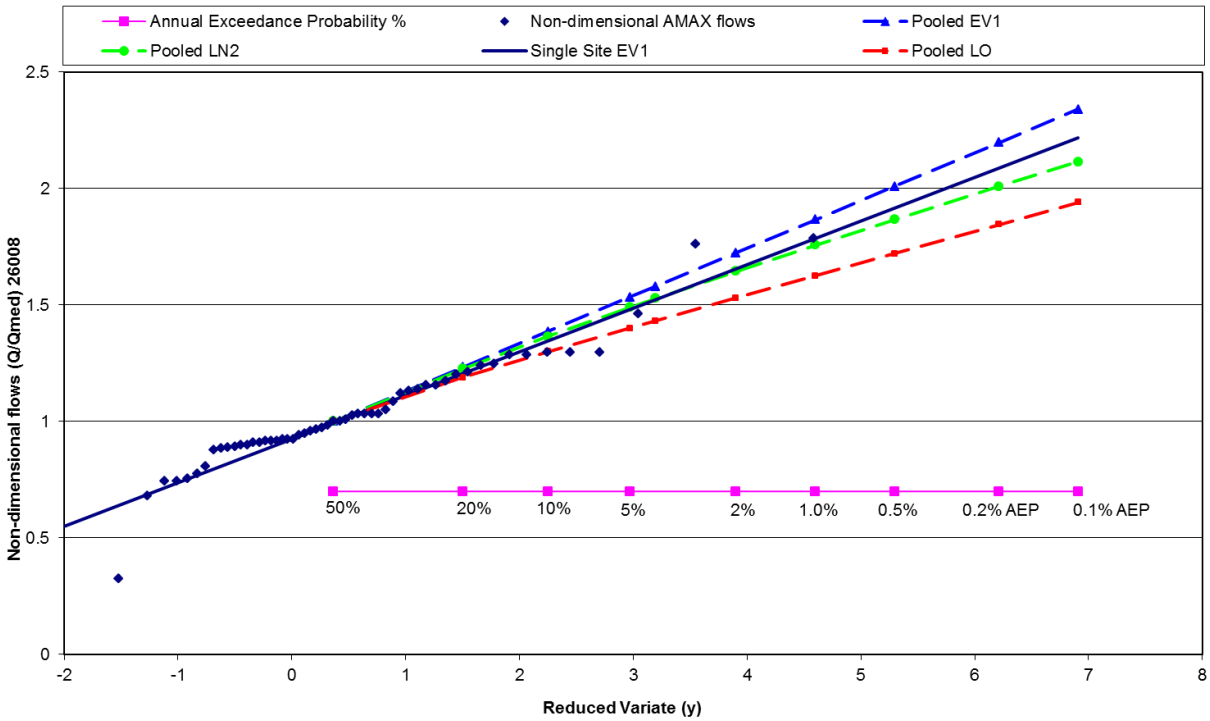


Figure A1.5 26008 Johnston's Bridge – Flood Frequency Curves

The length of the AMAX series suggests single site analysis offers reasonably robust estimates up to return periods of 25 years i.e. AEP = 4 % (based on ½N with N=55). For lower AEPs (higher return periods) it is considered more appropriate to use pooled data. As the at-site data does not provide evidence that the pooled distributions are inappropriate at Johnston's Bridge, the pooled growth curve is adopted. To acknowledge the importance of local observations, the pooled EV1 distribution is chosen.

d) Banagher (25016)

60 years of acceptable AMAX data suggests single site analysis offers reasonably robust estimates up to return periods of 30 years i.e. AEP = 3.33% (based on ½N with N=60).

Although there is a slight rising trend in the AMAX series, it is not considered strong enough to dismiss any of the AMAX data for flood frequency analysis.

Pooled analysis is considered inappropriate for this site, due to the size of the catchment and the relatively large effect of lakes in the Shannon catchment. The single site (EV1) growth curve in, and a comparison with hydraulic modelling results is discussed in the River Reach Flood Frequency section below.

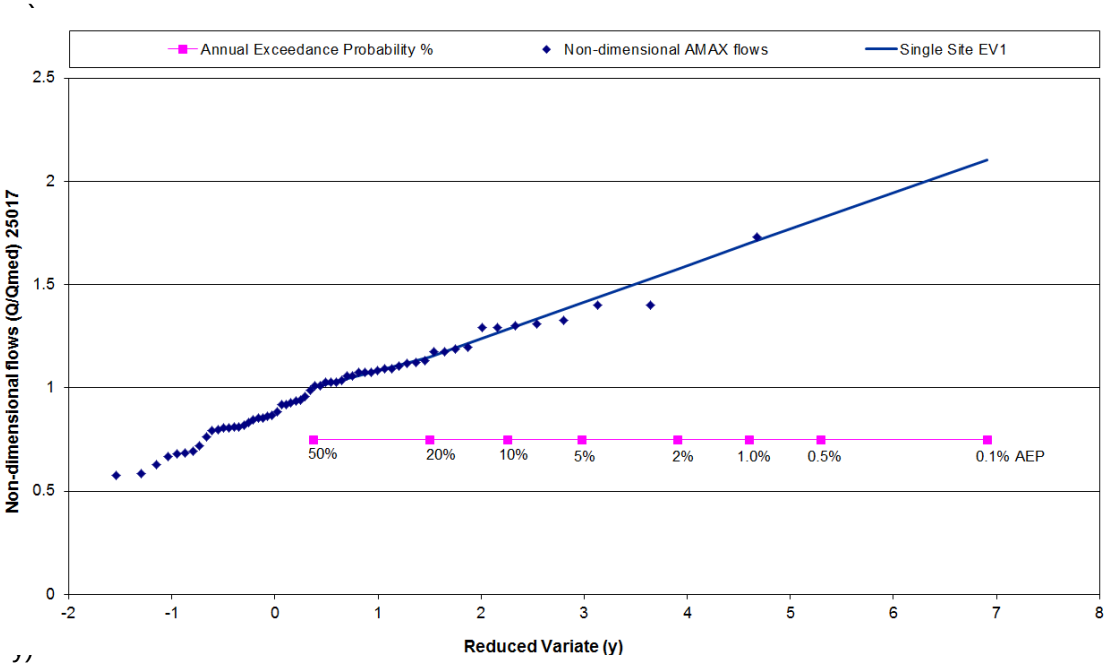


Figure A 1.6 25017 Banagher – Flood Frequency Curve

River Reach Flood Frequency

The source of growth curve distributions applied to the relevant reaches are shown in Table A1.30. The growth factors generated for a range of AEPs are given in Table A1.31a. Further detail on the derivation of flood frequency curves can be found in Section 2.5 of the Main Report.

As Station 25017 (Banagher) is situated downstream on the same river as Reaches 2, 3, and 4 its flood frequency curve was adopted these reaches.

Although the growth curve from Station 25017 was adopted for the main stem (Reaches 2, 3 and 4) a modification was required. In an iterative process between the hydraulic modelling and the hydrological estimation it became evident that the design flows based on the at-site growth curve at Banagher were insufficient to result in flooding along Reach 4 that would resemble the flooding that was experienced during the 2009 flood, even for the 1000-year (0.1% AEP) event. This is despite the adoption of a relatively high QMED adjustment factor in Reach 4 (1.36). This feedback/reality check was used to refine the hydrology and a modification to the original growth curve was introduced. An average of the Banagher and Flood Studies Report (FSR) growth curves provided a good fit to the flooding experienced on the Shannon and increased the 100-year (1% AEP) growth factor from 1.70 to 1.88. Table A1.31a compares the growth factors with those at other points along the model extents. This shows that the growth curve for Reaches 2, 3 and 4 is steeper than that for the other reaches with the exception of a few small tributaries (Reaches 8, 10 and 13). The calculation of the growth curve for Reaches 2, 3 and 4 from the Station 25017 Single Site growth curve and the FSR growth curve is shown in Table A1.31b.

Although many catchment descriptors for the Upper River Shannon are not dissimilar from those at Banagher (including the indicator for the presence of lakes

in the catchment, FARL, which is around 0.77 in Reach 3 and 0.79 at Banagher), it is speculated that the growth curve at Banagher may be so much flatter than that on the upper Shannon because of significant flood storage in the Callows, the low-lying area on the banks of the River Shannon between Lough Ree and Banagher. This area may add a significant storage volume for high return period floods which is not represented in the FARL catchment descriptor.

Reach	Station or HEP	Single Site or Pooled	Selected distribution
1	26_59_3	Pooled	EV1
2, 3, 4	25017	Modified Single Site	EV1
5, 6	26108	Pooled	EV1
7	26_3488_2	Pooled	EV1
8	26_1470_1	Pooled	EV1
9, 11, 12	26019	Pooled	EV1
10, 13	26_695_1	Pooled	EV1
14	26008	Pooled	EV1
15	26_4022_8	Pooled	EV1

Table A1.30 Final Growth Curves Selected

Annual Exceedance Probability (%)	Growth Factors Reach 1	Growth Factors Reaches 2, 3, 4	Growth Factors Reaches 5, 6	Growth Factors Reach 7	Growth Factors Reach 8	Growth Factors Reaches 9, 11, 12	Growth Factors Reaches 10, 13	Growth Factors Reach 14	Growth Factors Reach 15
50%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20%	1.22	1.21	1.20	1.23	1.31	1.21	1.37	1.23	1.21
10%	1.37	1.36	1.33	1.38	1.51	1.35	1.61	1.39	1.35
5%	1.51	1.55	1.46	1.52	1.70	1.49	1.85	1.53	1.49
2%	1.70	1.72	1.62	1.71	1.96	1.66	2.15	1.72	1.66
1%	1.84	1.88	1.74	1.84	2.14	1.79	2.37	1.87	1.79
0.5%	1.97	2.04	1.87	1.98	2.33	1.92	2.60	2.01	1.92
0.1%	2.29	2.42	2.15	2.30	2.77	2.22	3.12	2.34	2.22

Table A1.31a Final Growth Factors Applied to the Upper Shannon Catchment

Annual Exceedance Probability (%)	Growth Factors 25017 (Single Site EV1)	Growth Factors FSR (related to QMED instead of Qbar)	Average (Reaches 2, 3, 4)
50%	1.00	1.00	1.00
20%	1.15	1.26	1.21
10%	1.28	1.44	1.36
5%	1.41	1.68	1.55
2%	1.57	1.86	1.72
1%	1.70	2.06	1.88
0.5%	1.82	2.25	2.04
0.1%	2.10	2.74	2.42

Table A1.31b Growth Factor Calculation for the Main Shannon (Reaches 2, 3 and 4)

A1.6 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

Table A1.32 summarises the gauging stations used to produce the typical flood hydrograph shapes for the catchment reaches.

Reach	Gauging Station / HEP Node
1	26_59_3 (Hydrograph shape generator used – pivotal site 36021)
2	26030 – L. Allen d/s
3	26_3487_3 (hydrograph shape generator used – pivotal site 27002)
4	26_3935_4 (hydrograph shape generator used – pivotal site 36019)
5	26108 – Boyle Abbey Bridge
6	26_164_2 (hydrograph shape generator used – pivotal site 36021)
7	26_3490_3 (hydrograph shape generator used – pivotal site 26009)
8	26_1470_1 (hydrograph shape generator used – pivotal site 14033)
9, 10, 11, 12	26019 – Mullagh
13,14	26008 – Johnston's Bridge
15	26015 - Corrascoffy

Table A1.32 Gauging Stations used to Derive the Typical Hydrograph Shape in each Reach

Tables A1.33–A1.37 and Figures A1.6–A.10 identify the highest flood events chosen for comparison at the gauges. The figures present the hydrographs in a non-dimensional manner by dividing flows by their respective flood peaks. The hydrograph that best represents a typical/median flood response has then been selected as the representative design hydrograph shape.

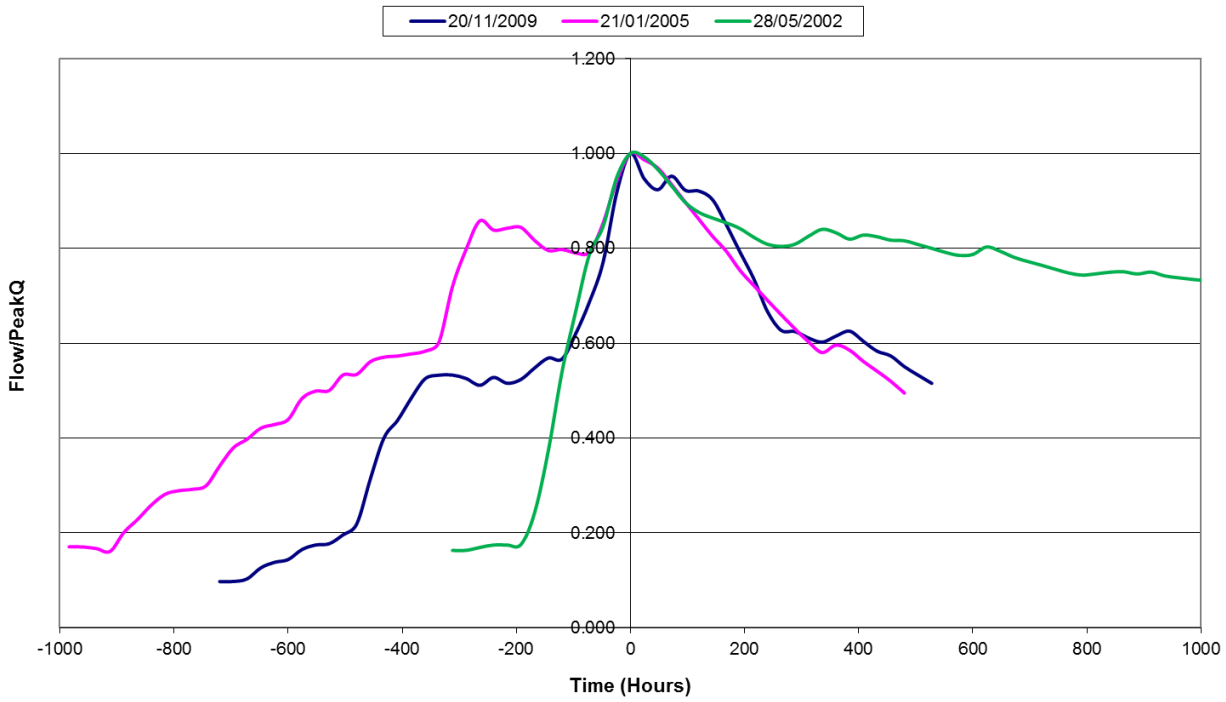


Figure A1.7 Non-dimensional Hydrographs for Gauging Station 26030 (Reach 2)

Date	Peak Flow (m^3/s)	Comments
21/05/2005	86.4	Selected for hydrograph shape
20/11/2009	59.0	
28/05/2002	36.4	

Table A1.33 Highest Flood Peaks for Gauging Station 26030

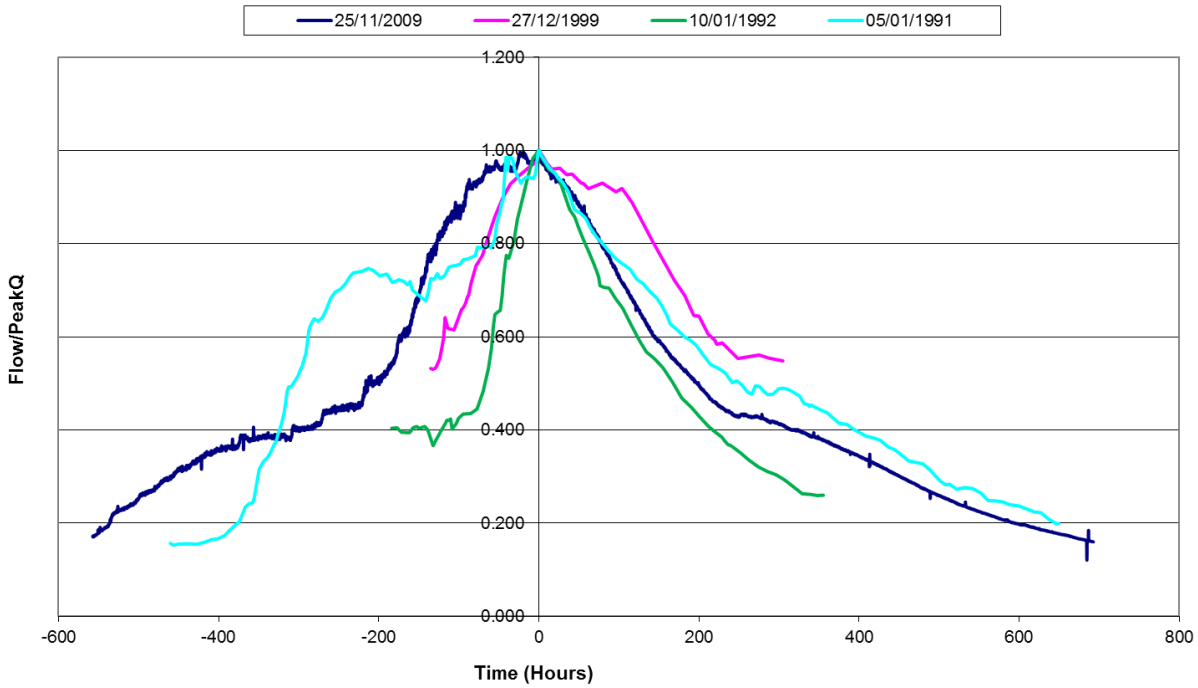


Figure A1.8 Non-dimensional Hydrographs for Gauging Station 26108 (Reach 5)

Date	Peak Flow (m^3/s)	Comments
25/11/2009	81.7	Selected for hydrograph shape
10/01/1992	47.2	
27/12/1999	50.6	
05/01/1991	55.1	

Table A1.34 Highest Flood Peaks for Gauging Station 26108

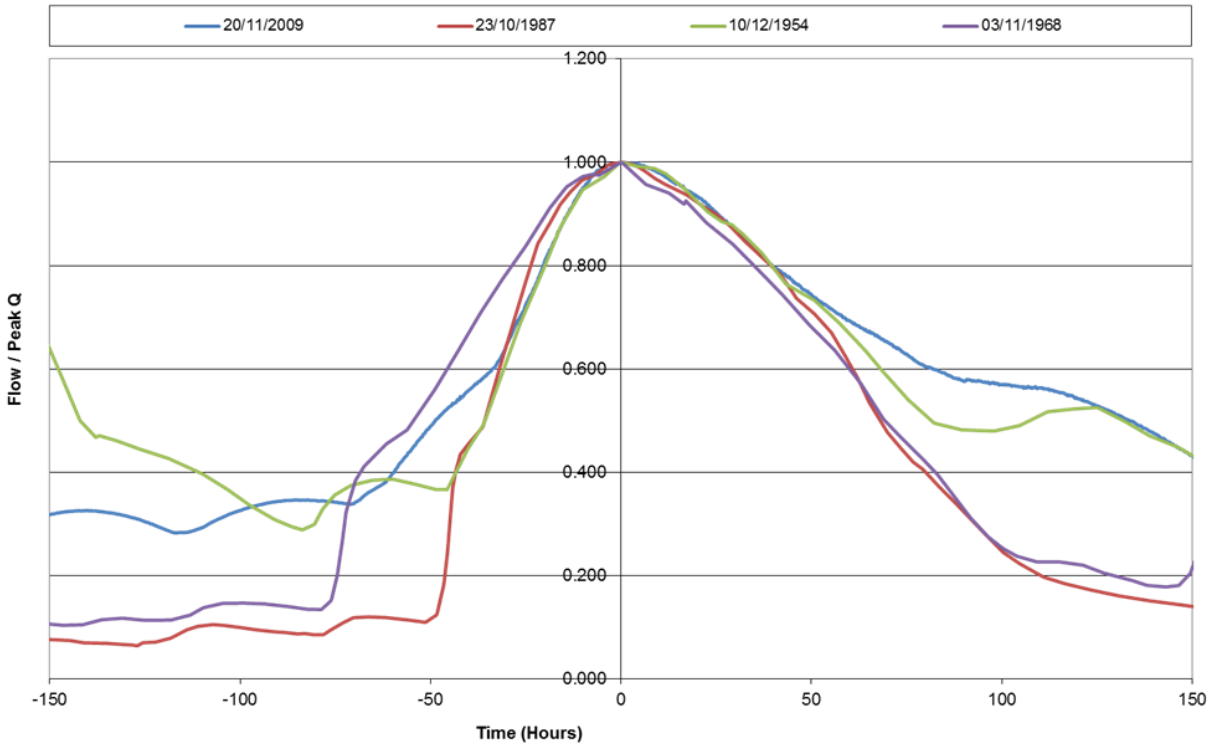


Figure A1.9 Non-dimensional Hydrographs for Gauging Station 26019 (Reaches 9, 10, 11 and 12)

Date	Peak Flow (m^3/s)	Comments
20/11/2009	49.2	
23/10/1987	37.9	Selected for hydrograph shape
10/12/1954	38.5	
03/11/1968	38.3	

Table A1.35 Highest Flood Peaks for Gauging Station 26019

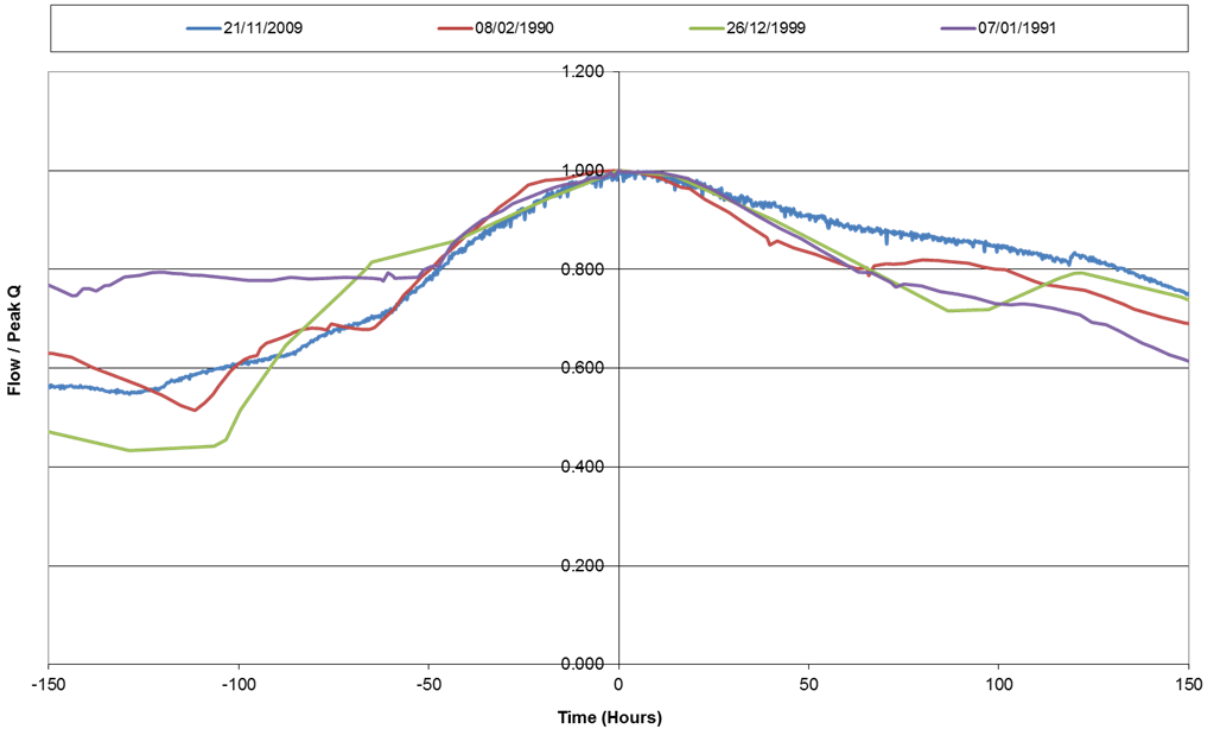


Figure A1.10 Non-dimensional Hydrographs for Gauging Station 26008 (Reaches 13 and 14)

Date	Peak Flow (m^3/s)	Comments
21/11/2009	40.4	Selected for hydrograph shape
08/02/1990	30.0	
26/12/1999	29.8	
07/01/1991	30.3	

Table A1.36 Highest Flood Peaks for Gauging Station 26008

It is noted that the observed flood hydrographs from Station 26008 are more suitable for Reach 14 (along which Station 26008 is situated) than for Reach 13, which has a smaller catchment. Therefore a sensitivity test was undertaken for Reach 13 with a shorter duration hydrograph. This hydrograph was determined using pivotal station 8008, with gauged shape parameters n, Tr and C (with Tr~14 hours). The reduction in the resulting flood depths was negligible in and around the Mohill AFA which confirms that flooding is dominated by the flood peak, not the volume.

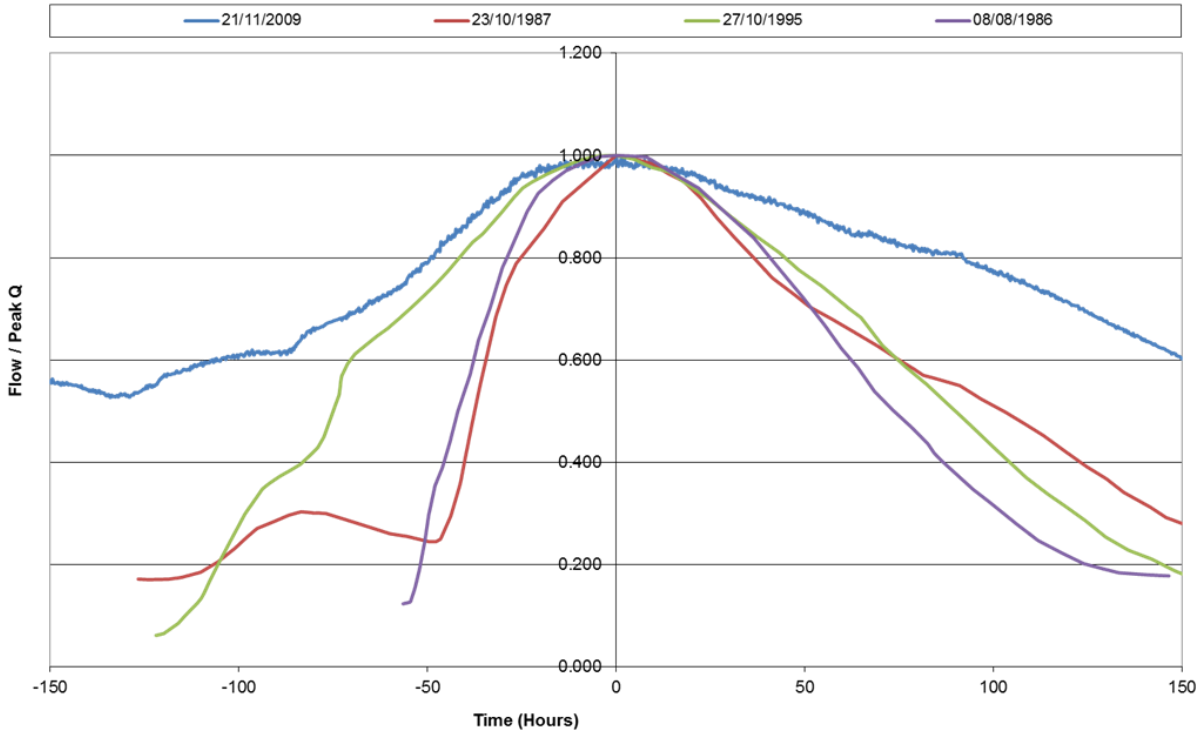


Figure A1.11 Non-dimensional Hydrographs for Gauging Station 26015 (Reach 15)

Date	Peak Flow (m^3/s)	Comments
21/11/2009	11.3	
23/10/1987	8.9	
27/10/1995	8.3	Selected for hydrograph shape
08/08/1986	8.2	

Table A1.37 Highest Flood Peaks for Gauging Station 26015

Where insufficient flow gauging exists to derive a typical flow response, one of two approaches was taken. Initially, attempts were made to select an appropriate hydrograph shape from a gauged pivotal site. However, where no suitable pivotal site was available, the FSU WP3.1 method was employed and a regression equation used to derive a synthetic hydrograph shape. Refer to Main Report Section 2.6 for further details. These hydrographs are presented in Figures A1.11 to A1.15.

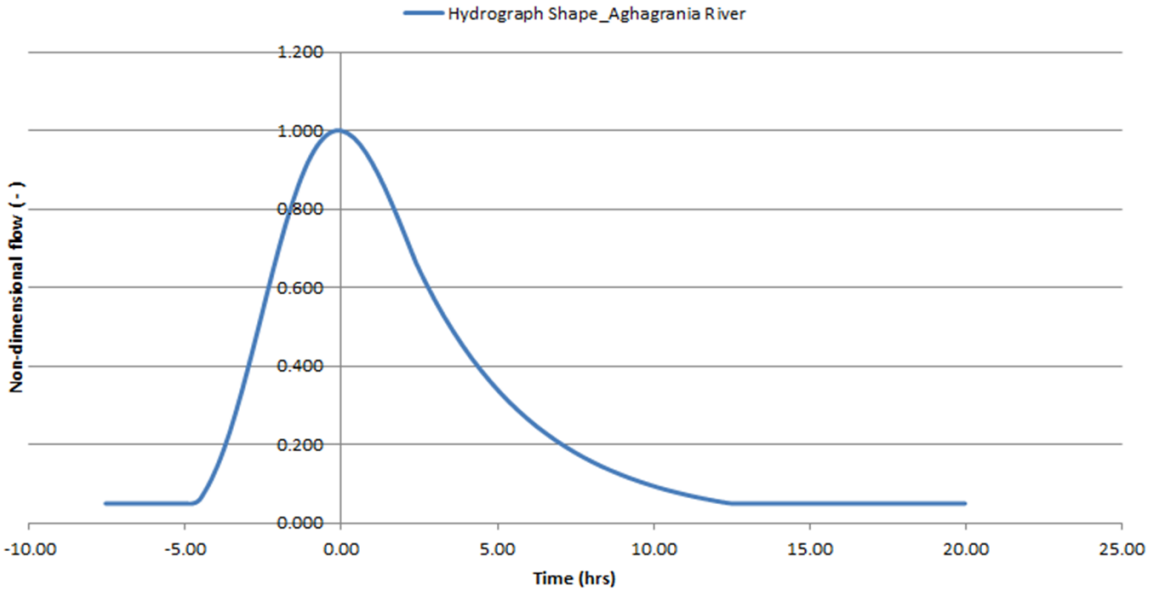


Figure A1.12 Non-dimensional Hydrograph for Reach 1 (HEP 26_59_3)

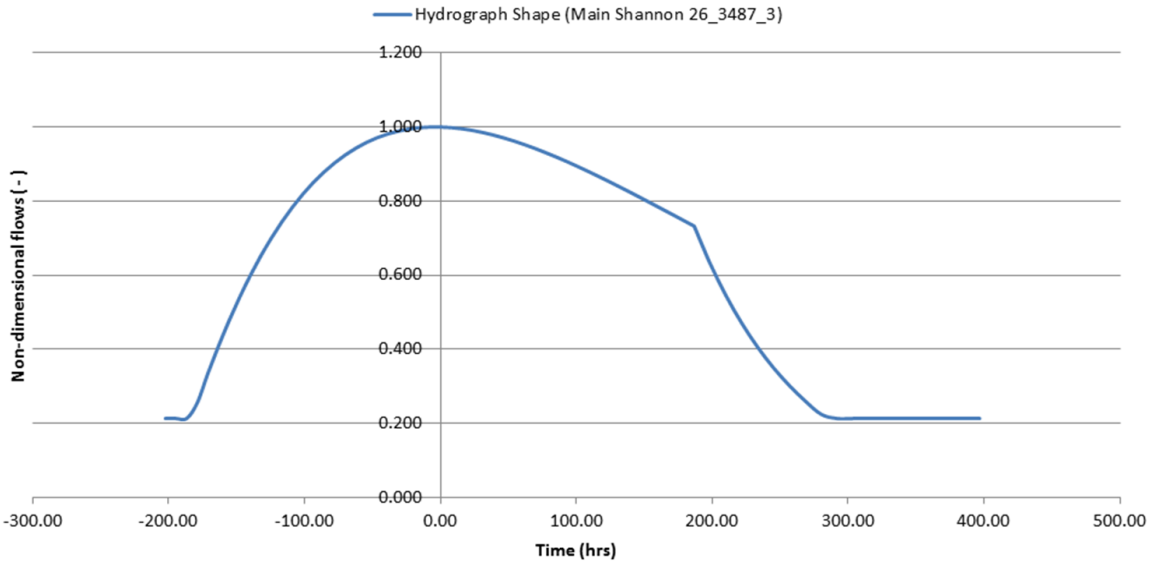


Figure A1.13 Non-dimensional Hydrograph for Reach 3 (HEP 26_3487_3)

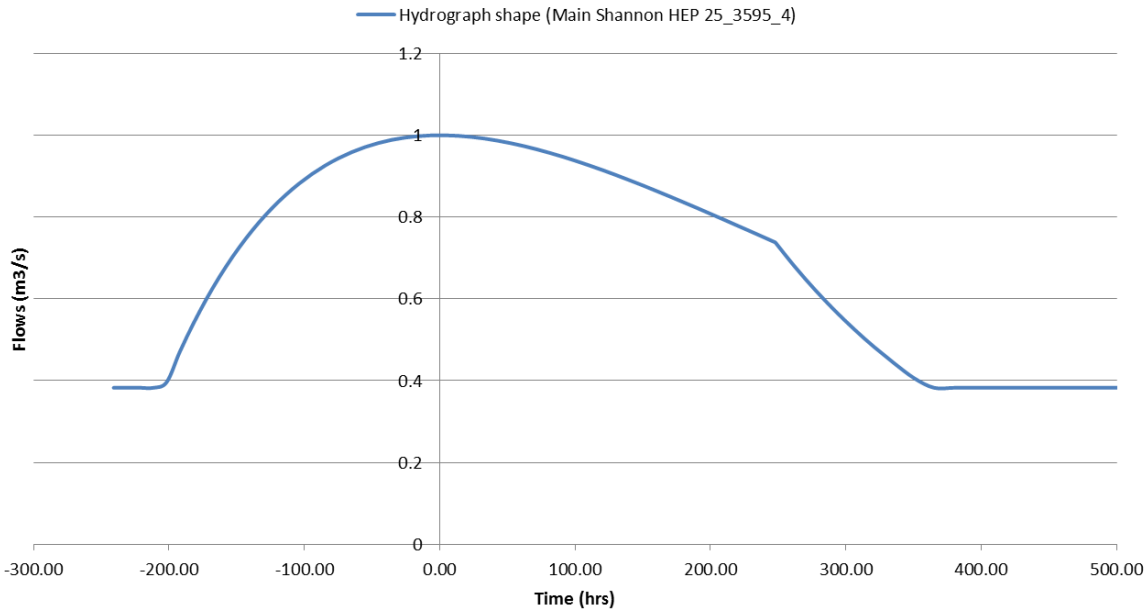


Figure A1.14 Non-dimensional Hydrograph for Reach 4 (HEP 26_3595_4)

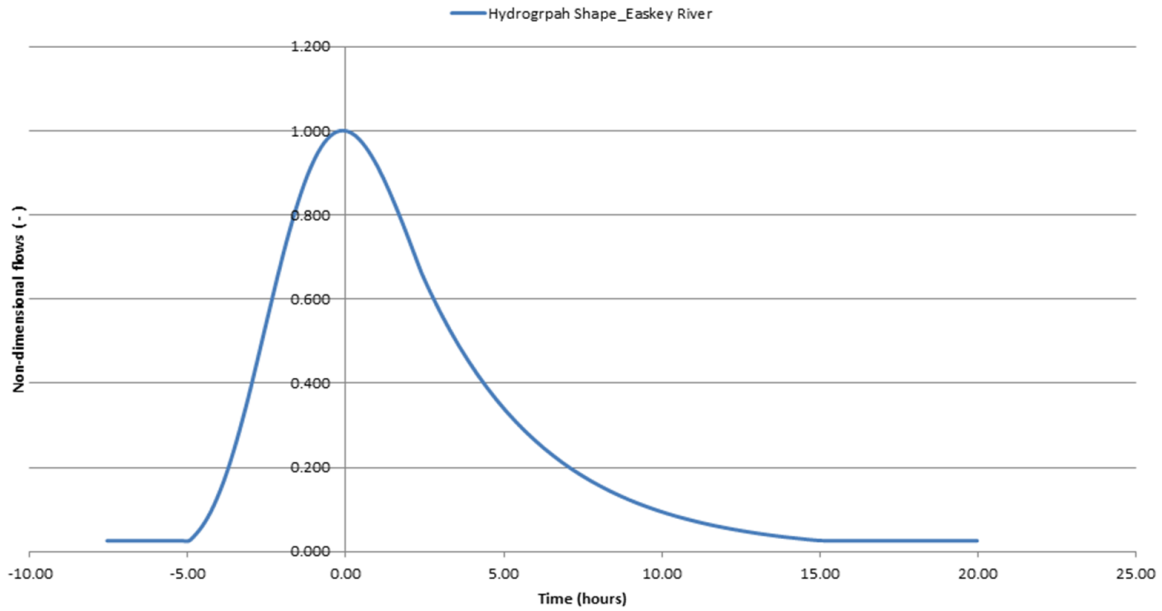


Figure A1.15 Non-dimensional Hydrograph for Reach 6 (HEP 26_164_2)

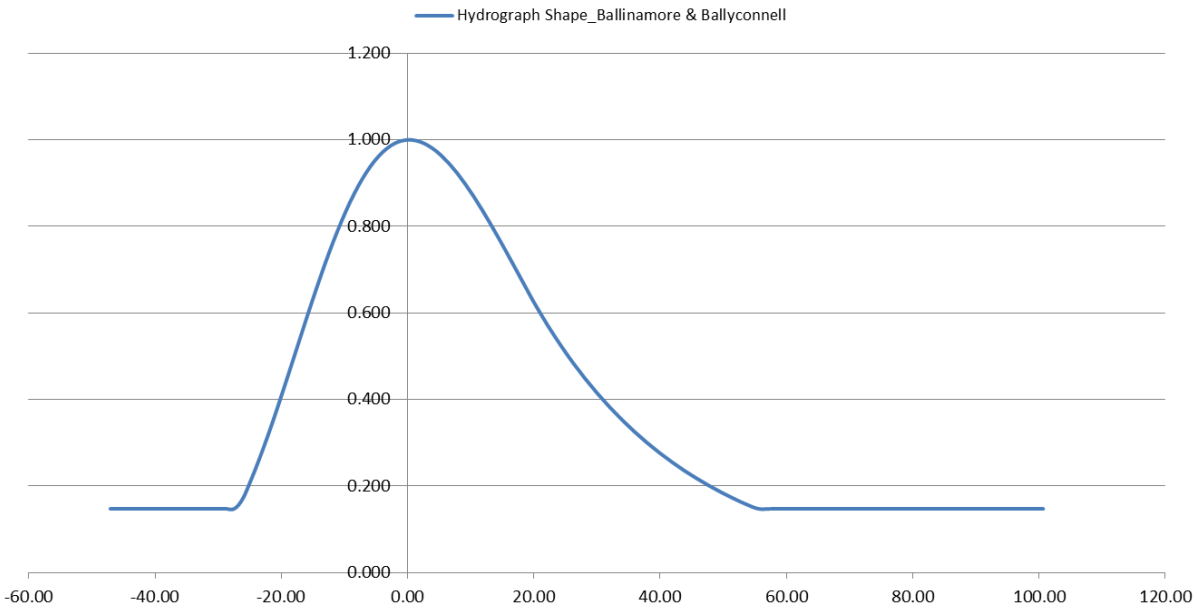


Figure A1.16 Non-dimensional Hydrograph for Reach 7 (HEP 26_3490_3)

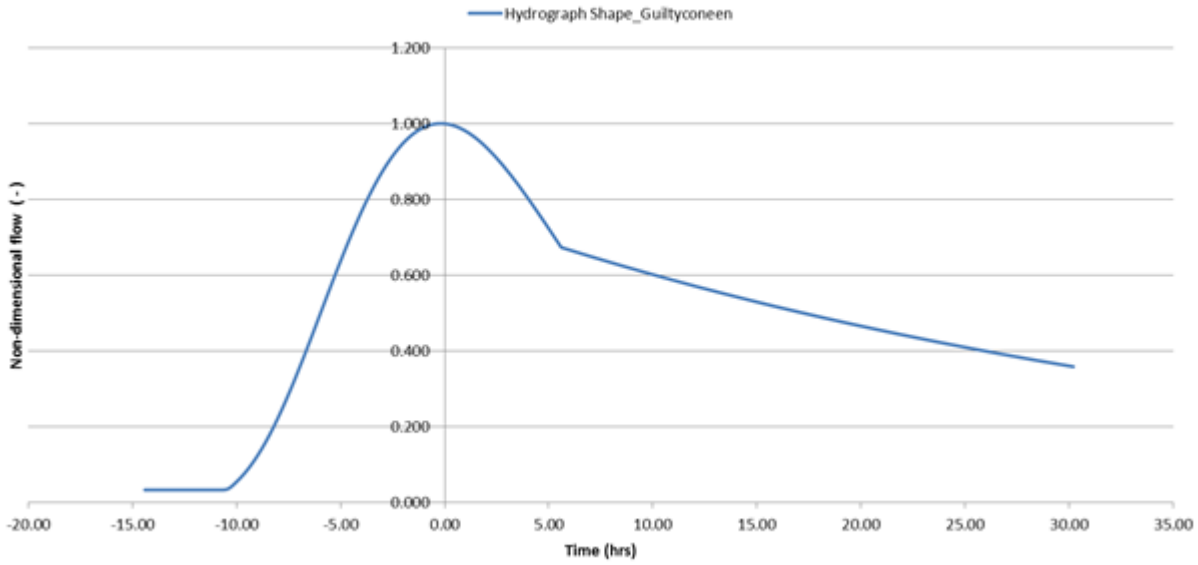


Figure A1.17 Non-dimensional Hydrograph for Reach 8 (HEP 26_1470_1)

A1.7 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for each model is discussed in Appendices B1 and B2.

A1.8 Calibration

The calibration and verification of hydraulic models is discussed in Appendices B1 and B2.

A2 Inny Catchment

A2.1 Catchment Description

The Inny Catchment in UoM 25/26 is one of the main subcatchments of the River Shannon with a total catchment area of 1231 km2. The catchment is relatively flat. The River Inny broadly flows from the north-east to the south-west into Lough Ree. Refer to Figure A2.1 for an overview map.

The Inny Catchment is covered by the hydraulic model N03, and a small part of N10. The River Inny is modelled from approximately 1 km downstream of Ballinalack Bridge to the inflow of Lough Ree.

In addition to the River Inny, the major modelled rivers in the catchment are the River Black and its tributary the Ballindadny, flowing from north-west to south east before joining the main river, and the River Tipper and the River Keelbaun entering the lower Inny.

The AFAs in the catchment are Edgeworthstown, Abbeyshrule and Ballymahon in model N03. There are no IRRs in the catchment.

The BFIsoil values along the modelled extent of the River Inny vary insignificantly between 0.79 and 0.76. The BFIsoil values along the River Black and its tributary are approximately 0.60. The BFIsoil values along the River Tipper vary between 0.69 and 0.61, the values along the River Keelbaun are approximately 0.62.

The SAAR values along the modelled extents vary from 900 to 992 mm.

A2.2 Catchment Geology

The geology of the River Inny catchment consists predominantly of glacial and peat subsoils over Palaeozoic limestone and sandstone bedrock. The sandstone bedrock is limited to the far north of the catchment and is described as a poor aquifer. The limestone bedrock is described as a locally important aquifer and between Lough Sheelin and Lough Derravaragh as a regionally important karstified bedrock aquifer with karst features. Refer to the aquifer map (Figure 3.3) and soil map (Figure 3.4) in the main report.

Low to moderate permeability sandstone and chert tills occur in the north and west of the catchment, and to the south of Castlepollard there is a low lying area with outcropping bedrock. Extensive peat deposits occur within these tills to the west and along tributaries throughout the catchment; the peat deposits are of low to moderate permeability and the Peatland Map of Ireland (1978) indicates the peat to be typically between 1.2m and 2.5m in depth.

Limestone tills of moderate permeability cover the rest of the catchment within which isolated outcrops of glaciofluvial deposits occur. The glaciofluvial deposits are described as sand and gravel aquifers of high permeability.

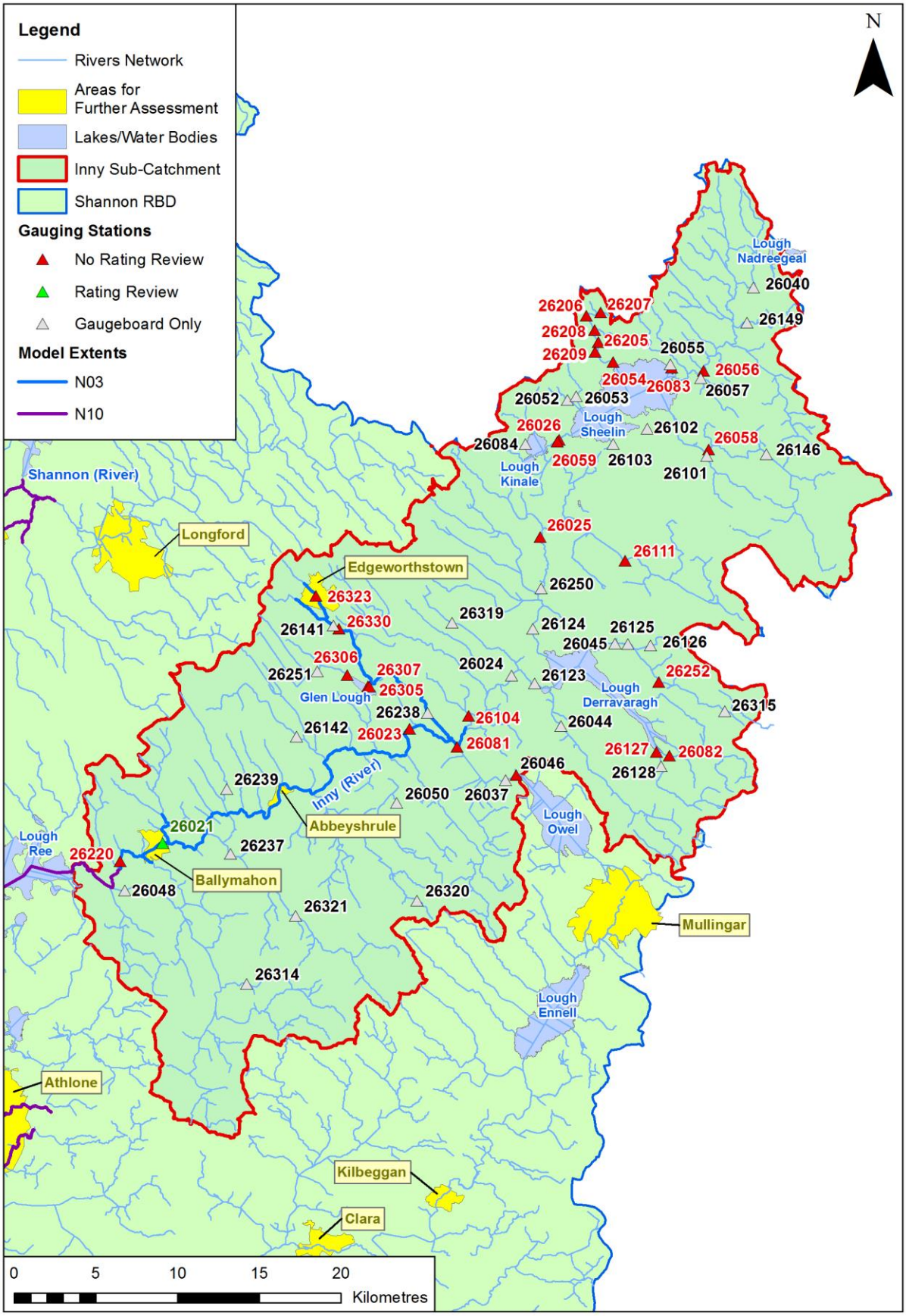
The General Soil Map of Ireland (1980) indicates the catchment is predominantly overlain by well drained dry mineral soils derived from the underlying till. Some

poorly drained gley soils occur over the sandstone tills in the far north and to a lesser extent in the far west of the catchment, south of Longford.

A2.3 Hydrometric Stations in the Inny Catchment

The gauging stations with a recorder in the catchment (on or near the model extents) are tabulated in Table A2.1. They are shown on Figure A2.1. Gauging stations located on tributaries that are not on the model extent, for example 26305, 26306 and 26307 were found to be unsuitable for flood estimation and have been excluded from Table A2.1.

In Table A2.1 the record data range refers to the range of AMAX data. HGF is the Highest Gauged Flow, i.e. the highest check gauging.



0 5 10 15 20 Kilometres

Figure A2.1 Inny Catchment Model Extent

Model	Gauging station	Name	Record data range	AMAX available	FSU quality class or HGF/QMED	CFRAMS rating review	Quality Comments
N03	26104	Ballinalack	1981 - 2009	Level	unknown	No	1
	26081	Iron	1952 - 1964	No	unknown	No	1
	26023	Ballycorkey	1952 - 1958	No	unknown	No	1
	26021	Ballymahon	1965 - 2009	Level and Flow	A2	Yes	2
	26220	Shrule Bridge	2009 - present	No	unknown	No	1,3
	26323	Edgeworthstown	2004 - 2007	Level and Flow	unknown	No	4
	26330	Barne	2008 - 2009	Level	unknown	No	4
N10	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table A2.1 Inny Catchment Gauging Stations

Table A2.1 Quality comments:

1. This site has no AMAX data available for this study.
2. This site is stable since 1965, as OPW confirmed. Revised rating produced a good fit with check gaugings and it is recommended that the whole revised AMAX series from 1975 is used for QMED estimation and single site analysis.
3. Station 26220 (Shrule Bridge) is a flow and level gauge with a record from Feb 2009, but as a low flow gauge the flows recorded here are not considered suitable for flood estimation.
4. Station 26323 Edgeworthstown was replaced by Station 26330 Barne in June 2008. There is no AMAX data available for 26330 due to the short period of record. The record for Station 26323 (3 years) was too short to be of use for peak flow estimation purposes, although it was decided to use gauged data from this station for the hydrograph shape, see Section A2.7 below.

A2.4 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A2.1 above. The river reaches are tabulated in Table A2.2 and shown on Figure A2.2 below. The variation in catchment descriptors for each reach is tabulated in Tables A2.4 to A2.8 below.

OPW confirmed that there was an issue of discontinuity in the DRAIND and ARTDRAIN2 catchment descriptors for the lower Black and their values are revised at the following nodes: 26_4028_2, 26_4028_9 and 26_4028_15. Table A2.3 below presents the original and revised catchment descriptors for the aforementioned nodes.

Reach	Description	Model Extent
1	River Inny (from 980m downstream of Ballinalack Bridge to Lough Ree)	N03, N10
2	River Black (tributary of River Inny)	N03
3	River Tipper (tributary of River Inny)	N03
4	River Keelbaun (tributary of River Inny)	N03
5	River Ballindadny (tributary of River Black)	N03

Table A2.2 River Reaches in the Catchment

HEP Node	Original Catchment Descriptors		Revised Catchment Descriptors	
	DRAIND (-)	ARTDRAIN2 (%)	DRAIND (-)	ARTDRAIN2 (%)
26_4028_2	0.02	10.1	0.81	51
26_4028_9	0.08	81.7	0.82	55
26_4028_15	0.13	81.6	0.84	65

Table A2.3 Lower River Black Original and Revised Catchment Descriptors

Reach 1			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	712 (26_1439_1)	1231 (26_883_8)
BFIsoil	-	0.76 (26_883_8)	0.79 (26_3662_1)
SAAR	mm	943 (26_883_8)	953 (26_3662_1)
FARL	-	0.72 (26_1439_1)	0.83 (26_883_8)
DRAIND	-	0.74 (26_1443_2)	0.78 (26_1439_1)
S1085	m/km	0.2 (26_940_2)	0.6 (26_1439_1)
ARTDRAIN2	%	61 (26_1439_1)	65 (26_883_8)
URBEXT	%	0.4 (26_940_2)	0.5 (26_3662_1)

Table A2.4 Reach 1 Catchment Descriptor Range

Reach 2			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	2.7 (26_3884_4)	54.7 (26_4028_15)
BFIsoil	-	0.57 (26_3884_4)	0.60 (26_4028_15)
SAAR	mm	975 (26_4028_15)	992 (26_3884_6)
FARL	-	1.00 (26_3884_4)	1.00 (26_4028_15)
DRAIND	-	0.75 (26_3884_6)	1.03 (26_3870_6)
S1085	m/km	0.7 (26_4028_9)	6.8 (26_3870_6)
ARTDRAIN2	%	51 (26_4028_2)	84 (26_3884_10)

URBEXT	%	0 (26_3884_4)	8.6 (26_3884_8)

Table A2.5 Reach 2 Catchment Descriptor Range

Reach 3			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	14.5 (26_4112_1)	20.6 (26_3975_3)
BFIsoil	-	0.61 (26_3975_3)	0.69 (26_4112_1)
SAAR	mm	903 (26_3975_3)	907 (26_4112_1)
FARL	-	1.00 (26_4112_1)	1.00 (26_3975_3)
DRAIND	-	0.90 (26_3975_3)	1.08 (26_4112_3)
S1085	m/km	5.8 (26_4112_1)	6.2 (26_3975_3)
ARTDRAIN2	%	46 (26_4112_1)	53 (26_3975_3)
URBEXT	%	0 (26_4112_1)	2.0 (26_3975_3)

Table A2.6 Reach 3 Catchment Descriptor Range

Reach 4			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	3.0 (26_917_6)	N/A
BFIsoil	-	0.62 (26_917_6)	N/A
SAAR	mm	900 (26_917_6)	N/A
FARL	-	1.00 (26_917_6)	N/A
DRAIND	-	1.01 (26_917_6)	N/A
S1085	m/km	5.4 (26_917_6)	N/A
ARTDRAIN2	%	92 (26_917_6)	N/A
URBEXT	%	0 (26_917_6)	N/A

Table A2.7 Reach 4 Catchment Descriptor (only 1 HEP available)

Reach 5			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	3.3 (26_2902_5)	4.7 (26_2902_9)
BFIsoil	-	0.58 (26_2902_5)	0.59 (26_2902_9)
SAAR	mm	985 (26_2902_5)	987 (26_2902_9)
FARL	-	1.00 (26_2902_5)	1.00 (26_2902_9)
DRAIND	-	0.96 (26_2902_5)	1.04 (26_2902_9)
S1085	m/km	5.2 (26_2902_5)	6.8 (26_2902_9)
ARTDRAIN2	%	36 (26_2902_5)	58 (26_2902_9)
URBEXT	%	0 (26_2902_5)	0 (26_2902_9)

Table A2.8 Reach 5 Catchment Descriptor Range

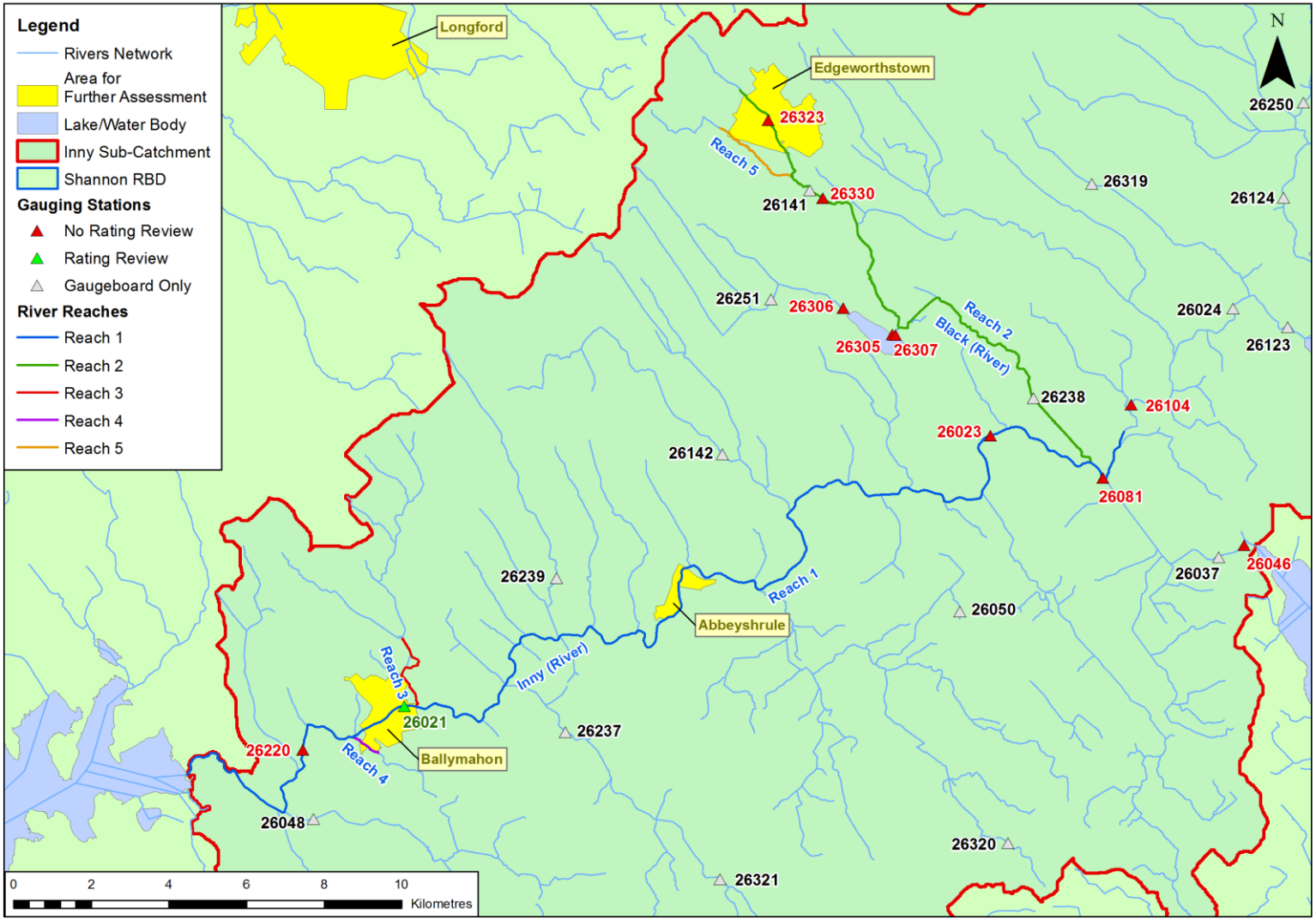


Figure A2.2 Inny Catchment River Reaches

The selection of the QMED adjustment factors, growth curves and hydrograph shapes for these reaches is detailed in Sections A2.5 to A2.7 below.

A2.5 QMED Adjustment Factors

Table A2.9 below gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED. Notes on the adjustment factor estimates are provided below the table.

Reach	Gauging station number	QMED observed (m^3/s)[1]	QMED (urban) synthetic (m^3/s)	Adjustment Factor (-)	Model Extent	Note
1	26021	71.3	42.6	1.67	N03	1
2	26323	11.0	1.08	10	N03	2

Table A2.9 QMED Adjustment Factors

1. AMAX series from 1975 are revised based on the CFRAM rating review
2. Station 26323 only has 3 years of flow data, which is too short to have any certainty with regard to estimating QMED (and higher return period design events). There are also indications that the flow estimates are unrealistically high: the three highest peaks are 12.8, 11.0 and 4.7 m^3/s, in a catchment with an area of 4.32 km^2. Even if the QMED was taken conservatively low as the average of the three measurements from POT analysis (effectively QBAR), with a QMED of 9.5 m^3/s this gives an 'observed' estimate of QMED 8.8 times higher than the synthetic estimate from the FSU regression equation, and a 2-year (50% AEP) runoff rate of 22 l/s/ha. When a significantly longer level record and more check gaugings are available the rating and AMAX flow estimates should be confirmed.

The QMED adjustment factors for the ungauged reaches (or reaches with discounted flow gauges) in the catchment (Reaches 2-5) were estimated using pivotal sites.

The adjustment factors for Reaches 2-5 were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A2.10-12). The use of a single pivotal site was considered but no suitable station was found that was hydrologically similar and sufficiently near to the subject site. The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: $\prod$ (Adjustment Factor^{Weight}).

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
9011	FRANKFORT	1	1.092	0.241	1.94

10022	CABINTEELY	2	1.204	0.219	1.62
25034	L. ENNELL TRIB	3	1.329	0.198	1.23
6030	BIG	4	1.515	0.174	2.32
25040	BUNOW	5	1.572	0.168	0.55
Weighted Geometric Mean					**1.42**

Table A2.10 QMED Adjustment Factor for 26323 / HEP 26_3884_6 (Reach 2 & 5)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
25040	BUNOW	1	0.525	0.234	0.55
10022	CABINTEELY	2	0.552	0.222	1.62
16051	CLOBANNA	3	0.629	0.195	0.94
8002	NAUL	4	0.689	0.178	1.39
10021	SHANGANAGH	5	0.718	0.171	1.49
Weighted Geometric Mean					**1.03**

Table A2.11 QMED Adjustment Factor for HEP 26_3975_3 (Reach 3)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
9011	FRANKFORT	1	0.890	0.293	1.94
10022	CABINTEELY	2	1.250	0.209	1.62
25034	L. ENNELL TRIB	3	1.403	0.186	1.23
8005	SLUICE	4	1.518	0.172	2.28
25040	BUNOW	5	1.868	0.140	0.55
Weighted Geometric Mean					**1.48**

Table A2.12 QMED Adjustment Factor for HEP 26_917_6 (Reach 4)

Table A2.13 shows the QMED adjustment factor applied to each reach in the catchment, with a justification for the selection of the gauging station.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	1.67	26021	Only flow gauging station with sufficient records of AMAX in the reach. Reliable for QMED estimation
2 / 5	1.42	26323 / 26_3884_6	Gauging Station has only 3 years of records with a suspect rating. QMED derived from geometric mean of adjustment factors at 5 pivotal sites.
3	1.03	26_3975_3	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
4	1.48	26_917_6	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.

Table A2.13 QMED Adjustment Factors Applied to Each Reach

HEP node 26_3884_8 with higher URBEXT, located downstream of the urban area (AFA Edgeworthstown) was also assessed and the resulting adjustment factor (1.40) was found to be similar to the value adopted for Reaches 2 and 5 (1.42).

A2.6 Flood Frequency Curves

Only one station, station 26021 (Ballymahon), was deemed potentially suitable for flood frequency analysis, see Table A2.1. The flood frequency curve (or growth curve) is plotted in Figures A2.3 below. The flood frequency curve plots for all relevant stations in the unit of management are shown in Appendix E.

The figure shows the at-site AMAX series (made dimensionless by dividing the flows by QMED), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate (on a Gringorten plot).

Ballymahon Gauging Station (26021)

A rating review has been undertaken for gauging station 26021 (Ballymahon). The model rating produced a good fit with the check gaugings and the revised AMAX flow series from 1975 is used for flood frequency analysis. Further details are shown in the rating review summary sheet for gauging station 26021 in Appendix C.

The Ballymahon at-site and pooled growth curves are compared to AMAX series, which is shown on Figure A2.3 below.

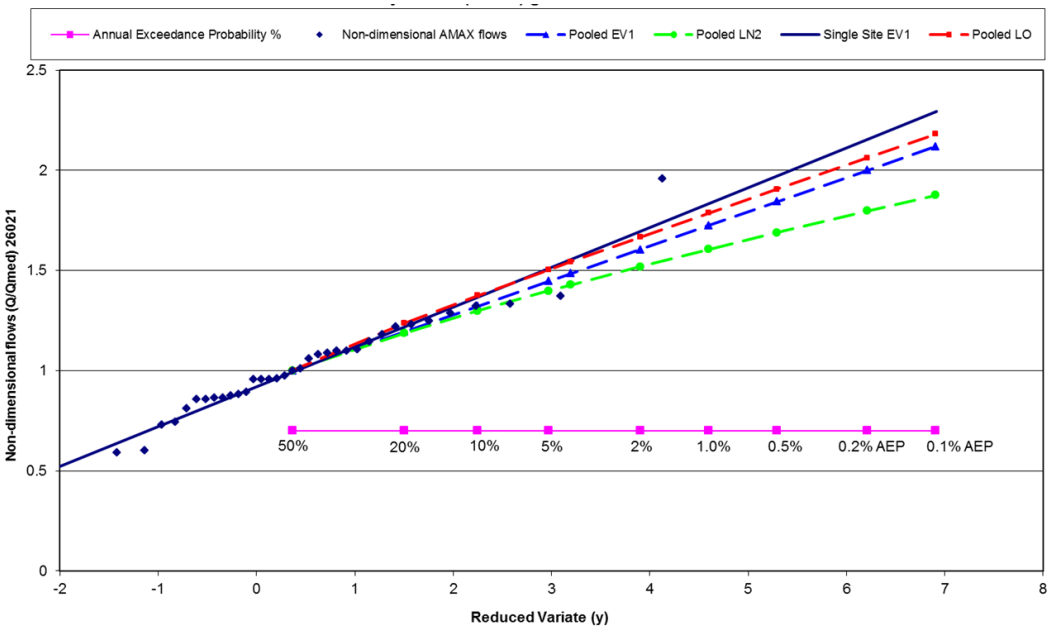


Figure A2.3 26021 Ballymahon – Flood Frequency Curves

The gauging station has an FSU quality rating of A2, which suggests it may not be very reliable at accurately recording flows in excess of QMED. Although the CFRAM rating review has provided a good rating for high flows based on a calibrated hydraulic model, with only 35 years of AMAX records single site analysis can only be used to reliably estimate growth factors for return periods up to approximately 18 years. A relatively homogeneous pooling group with 518 years of records was established for this station. Of all the pooled growth curves analysed, pooled LO fits well with the AMAX series and is the closest to the on-site EV1 curves. Therefore pooled LO was selected for flood flow estimation at this site.

River Reach Flood Frequency

(i) Flood Frequency Curve Reach 1

Station 26021 (Ballymahon) is the only reliable station with sufficient data to carry out flood frequency analysis within the reach for comparison with pooled analysis. Growth curves derived from the at-site and pooled analysis are shown in Figure A2.3. Based on its fit with the AMAX data (plotted on the Gringorten plot) and the EV1 at-site curve through the AMAX data, the pooled LO distribution was adopted for the River Inny, Reach 1.

(ii) Flood Frequency Curve Reach 2 and 5

The stations along Reach 2, 26323 (Edgeworthstown) and 26330 (Barne), have insufficient data for flood frequency analysis. Instead, pooled analysis at HEP node 26_3870_1 was undertaken. A growth curve based on the EV1 distribution was found to give the best fit with the pooled station data in the L-Moment ratio diagram (see Section 2.5.3 in the main report). The resulting growth factors were adopted for the River Black and its own tributary, Reaches 2 and 5.

(iii) Flood Frequency Curves Reach 3 and 4

There is no gauging station for flood frequency analysis within Reaches 3 and 4. Instead, pooled analysis at HEP node 26_3975_3 was undertaken. A growth curve based on the EV1 distribution was found to give the best fit with the pooled station data in the L-Moment ratio diagram (see Section 2.5.3 in the main report). The resulting growth factors were adopted for Reaches 3 and 4 as the two reaches are hydrologically similar for the catchment descriptors that are considered to affect growth curves. The two reaches only significantly vary on ARTDRAIN2, which affects QMED but in FSU is not considered to be an important factor for the growth curve.

(iv) Conclusion

The growth curve distributions applied to the relevant reaches are shown in Table A2.14. Growth factors generated for a range of AEPs have been detailed in Table A2.15. Looking at Table A2.15 it is observed that the growth factors for Reach 2 and Reach 5 are quite different to those for Reach 1. This can be attributed to the fact that Reach 1 is a much larger and flatter (less steep) catchment than its tributaries, Reach 2 and Reach 5. Comparison of the catchment descriptor data in Tables A2.4, A2.5 and A2.8 in Section 2.4 illustrate the differences in catchment area, slope and flow attenuation (i.e. FARL) between Reach 1, Reach 2 and Reach 5 respectively.

Reach	Station	Single Site or Pooled	Selected distribution
1	26021 – Ballymahon	Pooled	LO
2, 5	26_3870_1	Pooled	EV1
3, 4	26_3975_3	Pooled	EV1

Table A2.14 Growth Curves Selected

Annual Exceedance Probability (%)	Growth Factors Reach 1	Growth Factors Reach 2, 5	Growth Factors Reach 3, 4
50%	1.00	1.00	1.00
20%	1.24	1.40	1.28
10%	1.38	1.67	1.46
5%	1.50	1.93	1.64
2%	1.67	2.26	1.86
1%	1.79	2.51	2.03
0.5%	1.91	2.76	2.20
0.1%	2.18	3.33	2.60

Table A2.15 Growth Factors Applied to the Inny Catchment

A2.7 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

Station 26021 Ballymahon is the logical choice for Reach 1 as it is the only reliable station within the reach and the closest to the AFA Ballymahon. Station 26220 (Shrule Bridge) with data from February 2009 onwards was also analysed and a similar hydrograph shape was achieved. Therefore, the hydrograph derived from the station 26021 is applied to Reach 1. The same shape was applied to Reaches 3 and 4 as it was considered that the peak of the flow hydrograph is critical on these reaches, not the hydrograph width, and it constitutes a conservative approach.

Station 26323, located within the AFA Edgeworthstown, is the only station available for Reach 2. It was decided to use local data in preference over a pivotal site, despite some concern about the rating as described in Section A2.5. The resulting hydrograph shape appears realistic for the small catchment to Edgeworthstown. The hydrograph derived from this site is also applied to Reach 5 as it is a suitable pivotal station.

Table A2.16 summarises the reaches distinguished for the design event hydrograph shape selection and the flow gauging station used for each reach.

Reach	Gauging Station
1, 3, 4	26021 – Ballymahon
2, 5	26323 – Edgeworthstown

Table A2.16 Hydrograph Shape Sub-Reaches – Gauging Stations

Tables A2.17–18 and Figures A2.4–5 show the highest flood events chosen for comparison at stations 26021 and 26323. The hydrographs presented in Figures A2.4-5 are in a non-dimensional manner by dividing flows by their respective flood peaks. The hydrograph that best represents a typical or median storm duration has then been selected as the representative design hydrograph shape.

Date	Peak Flow (m^3/s)	Comments
20/11/2009	120.89	
11/12/2006	91.79	
27/12/1978	89.88	
08/01/2005	84.83	Selected for hydrograph shape

Table A2.17 Highest Flood Peaks for Gauging Station 26021

Date	Peak Flow (m^3/s)	Comments
07/01/2005	12.76	Selected for hydrograph shape
03/12/2006	11.04	
25/10/2006	4.67	
31/03/2006	4.56	(Ignored as record length shorter than 10 years, see Section 2.6 of the main report)

Table A2.87 Highest Flood Peaks for Gauging Station 26323

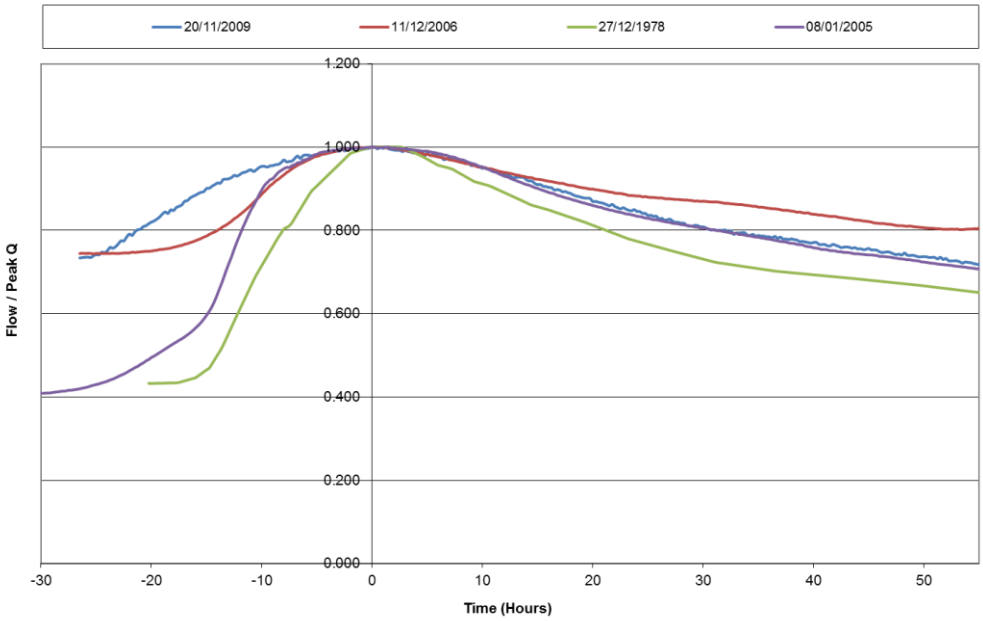


Figure A2.4 Non-dimensional Hydrographs for Gauging Station 26021 (Reaches 1, 3 and 4)

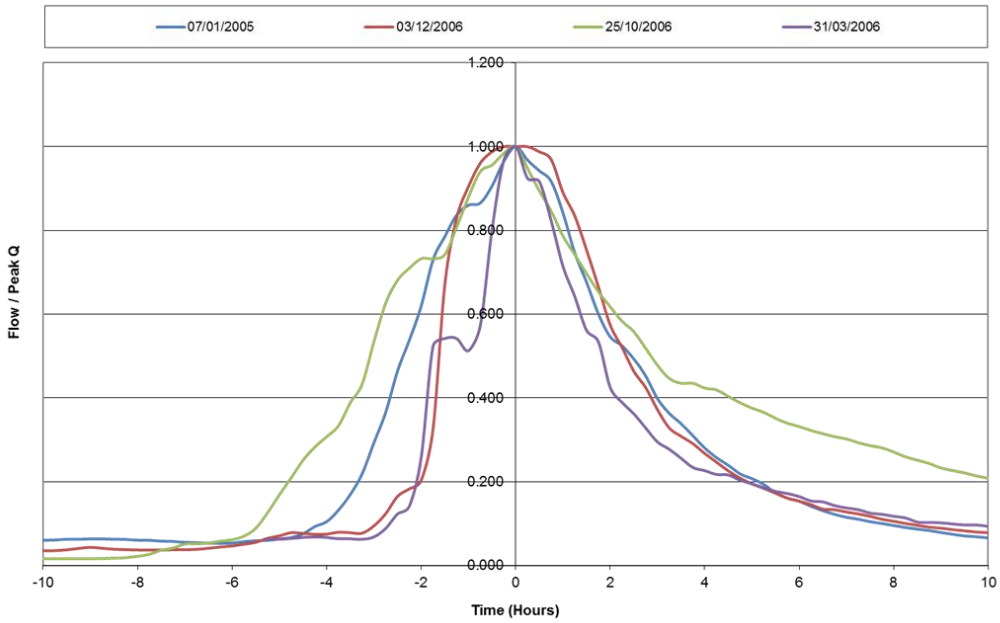


Figure A2.5 Non-dimensional Hydrographs for Gauging Station 26323 (Reaches 2 and 5)

A2.8 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for each model is discussed in Appendix B.

A2.9 Calibration

The calibration and verification of hydraulic models is discussed in Appendix B.

A3 Hind Catchment

A3.1 Catchment Description

The Hind Catchment lies within UoM 25/26, with the River Hind flowing into Lough Ree. The catchment area of the Hind to its entry into Lough Ree is approximately 78 km^2. Roscommon is the only Area for Further Assessment (AFA) in the catchment. The main watercourses in the catchment are the River Hind and the River Jiggy in addition to its tributaries, the Rivers Ballinagard and Loughnaneane. The Ballinagard and Loughnaneane tributaries flow into the River Jiggy just to the east of Roscommon town centre, and the Jiggy flows into the River Hind to the south of the town.

The Hind catchment is covered by two model extents, namely the N04 and a part of N10 model extent. Roscommon AFA is situated within model N04. Figure A3.1 shows the model extents within the Hind catchment. The hydrological analysis documented in this appendix covers the design hydrology for model N04 as well as the section of the River Hind within model N10. The model specific details are provided in Appendix B4 and Appendix B10 for the N04 and N10 model extents respectively.

There are no Individual Risk Receptors (IRRs) in the catchment.

The BFIsoil value along the River Hind varies from 0.70 at its upstream end to 0.60 at the downstream end entering Lough Ree. On the River Jiggy, the BFIsoil value ranges from 0.71 at its upstream end to 0.61 at its confluence with the Loughnaneane tributary and 0.69 at its confluence with the River Hind. On the Loughnaneane tributary the BFIsoil value at the downstream end is 0.58. At the downstream end of the Ballinagard tributary the BFIsoil value is 0.69.

The catchment features a significant number of karstic features (springs, sinkholes and turloughs) as shown on Figure 3.3 in Chapter 3. The figure includes a karstic feature layer provided to Jacobs by The Geological Survey Ireland (GSI) in 2012. The main karstic feature is Loughnaneane, which is a relatively large turlough in the catchment, just to the west of Roscommon. A turlough is a depression or lake from which water drains into the porous subsoil. In times of flood the turlough may fill up and spill over and contribute to flooding. It is noted that the relatively high BFIsoil values in the catchment reflects the permeable nature of the karst geology, although the BFIsoil value in the Loughnaneane tributary (0.58) is lower than the BFIsoil in the other watercourses, which is indicative of the fact that BFIsoil does not take account of the turlough specifically.

The SAAR values within the modelled sections vary insignificantly from 980mm to 1027mm.

The URBEXT values vary greatly within the Hind catchment. The catchment can be classed as heavily urbanised in some places. The upstream portion of the River Jiggy to its confluence with the Loughnaneane tributary has low URBEXT values up to approximately 1%. The Loughnaneane tributary itself has very high URBEXT values, up to 18%. This contributes to an URBEXT value of 14% on the River Jiggy downstream of its confluence with the Loughnaneane tributary which increases to 16% close to the River Jiggys confluence with the Ballinagard tributary.

From there the URBEXT values reduce in the downstream direction, with a value of 6.5% on the River Hind downstream of its confluence with the River Jiggy. In Figure A3.1 the Roscommon AFA appears large in comparison to the catchment size. Further inspection of the town size in Figure B4.1 (Appendix B4) shows that the actual town is small in comparison to the AFA extent.

A3.2 Catchment Geology

The geology of the Hind catchment consists of Quaternary subsoils over predominantly Carboniferous limestone bedrock from which much of the overlying glacial deposits are derived. The other predominant subsoil within the catchment is peat.

Glaciolacustrine deposits also occur within the Hind catchment but are limited to two isolated areas immediately to the west and to the south of Roscommon. The Geological Survey of Ireland (GSI) online National Groundwater Recharge map describes the glaciofluvial deposits as moderately permeable, overlain by poorly drained soils.

The peat deposits are predominantly underlain by the Carboniferous Marine shelf facies and are most extensive along the current route of the River Hind. The GSI online National Groundwater Recharge map describes the peat as low permeability subsoil over regionally and locally important bedrock aquifers. The Peatland Map of Ireland (An Foras Taluntais, 1978) indicates the peat within the Hind catchment to range between 1.2m and 7.0m average depth.

Limestone till deposits occur across the entire catchment area and are predominantly underlain by the karstified Marine shelf facies with the exception of the north east edge of the catchment, east of Roscommon, where the tills are underlain by the pale grey massive limestone of the Waulsortian mudbank and the dark grey, argillaceous, bioclastic limestone and shale of the Marine shelf and ramp facies (Courceyan limestone). The GSI online National Groundwater Recharge map describes the limestone till as moderately permeable subsoil overlain in some areas by well-drained soil but principally by poorly drained gley soil (blue grey clay soil that forms in heavily waterlogged areas).

Elsewhere, predominantly within the city boundaries of Roscommon, subsoils appear to be largely absent with Made Ground lying directly over the karstified Marine shelf facies. North of Roscommon limited alluvial deposits occur along a small stretch (approximately 2.5 km) of the River Hind overlying the Marine shelf facies to the west and the Marine shelf and ramp facies to the east.

The majority of the catchment area is underlain by the cherty limestone and calcareous shale of the karstified Marine shelf facies which also occurs as significant surface outcrops along the far southern edge of the catchment and in isolated outcrops within the limestone till around Roscommon. The Marine shelf facies is designated as a regionally important aquifer of low to extreme vulnerability (Geological Survey of Ireland National Draft Bedrock Aquifer and Groundwater Vulnerability map). In the far northeast of the catchment the bedrock is Waulsortian mudbank and Marine shelf and ramp facies, both designated locally important aquifers.

A3.3 Hydrometric Stations in the Hind Catchment

Details of the gauging stations in the Hind catchment are tabulated in Table A3.1. They are also shown on Figure A3.1.

Model	Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments
N04	26016	Ballymurray	1972 to date	Level	N/A	Yes (HGF/QMED ~0.6	1
	26110	Moate Park	N/A	N/A	N/A	No	2
	26147	Jiggy	N/A	N/A	N/A	No	2
	26204	Ballymartin	2003 to date	N/A	N/A	No	3
	26211	Ballygalda	N/A	N/A	N/A	No	2
	26224	Cloonybeirne	N/A	N/A	N/A	No	2
	26235	Cloonabrackna	N/A	N/A	N/A	No	2
	26312	Ballinagard	2001-2003	Level	N/A	No	4
N10	26210	Cloonsellan Bridge	N/A	N/A	N/A	No	2

Table A3.1 Hind Catchment Gauging Stations

Table A3.1 Hydrometric Data Quality Comments:

1. No AMAX flows available before the CFRAM rating review for this station. AMAX flow data (as derived from the rating established by the CFRAM rating review) from 1972 used only due to drainage works (See CFRAM rating review summary sheet in Appendix C). The rating is subject to some uncertainty as the check gaugings show considerable scatter and are lower than QMED.
2. Staff gauge only (no recorder).
3. Station 26204 is a low flow gauging station and has a poor stage discharge relationship. Based on the adjusted synthetic QMED (i.e. the synthetic estimate of QMED multiplied by an adjustment factor found at station 26016 to obtain a best estimate of QMED at station 26204, see Table A3.4 below) the highest gauged flow is approximately 0.6xQMED.
4. Station 26312 was only active for little over six years between the 09/11/2001 and 12/02/2008. The data is of poor quality as there is a lot of missing data, flat lining of the flow record and unrealistic flow peaks. OPW have confirmed that this was found to be a poor flow gauging site and it was only active for a short period for that reason.

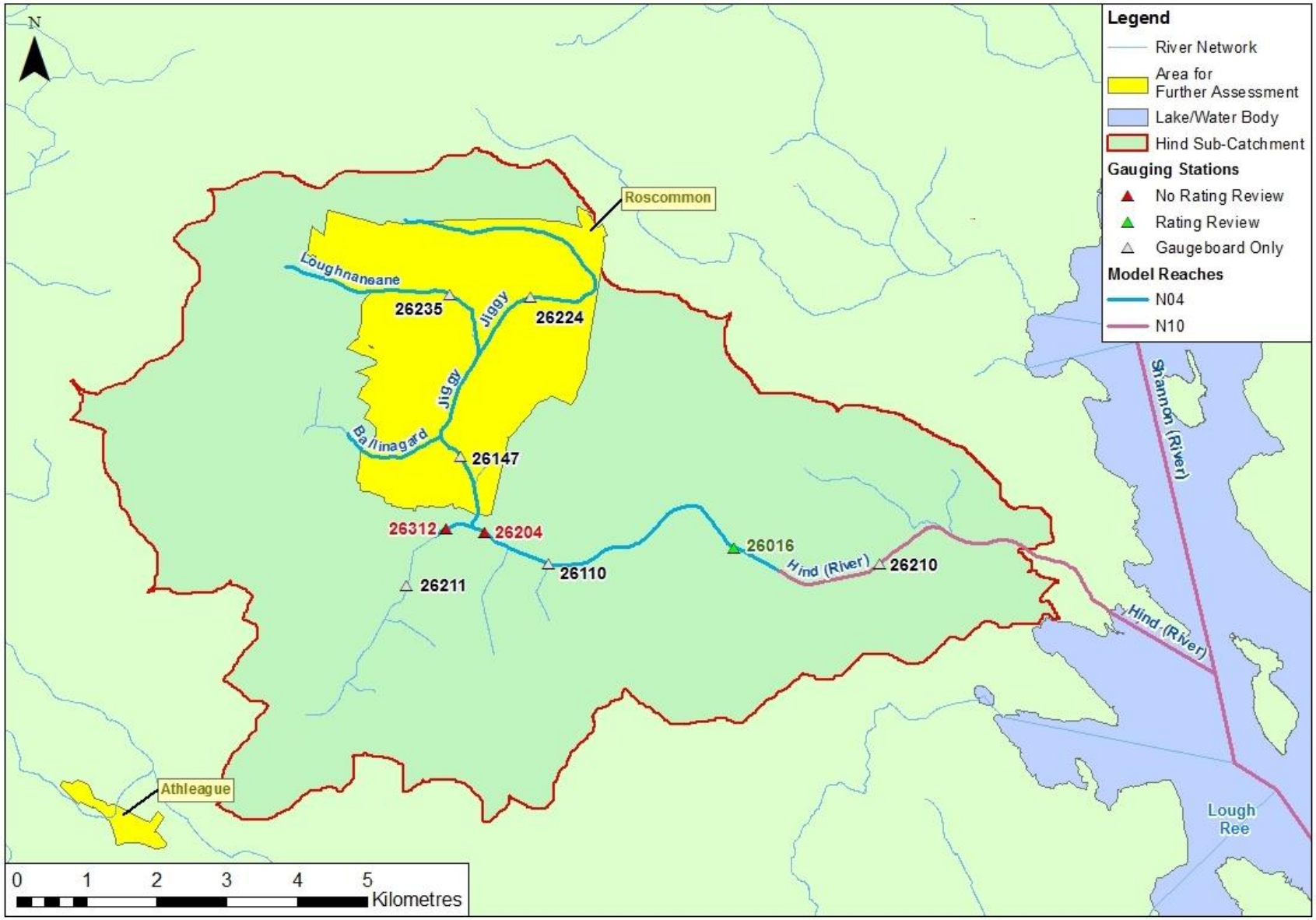


Figure A3.1 Hind Catchment Model Extent

A3.4 Catchment River Reaches

River reaches are defined in the context of the Shannon CFRAM design hydrology analysis as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and the quality of data at the gauging stations listed in Table A3.1 above.

There is a considerable variation in catchment area, urban extent (URBEXT) and slope (S1085) throughout the modelled extent. However, as there is only one reliable gauging station within the Hind catchment, and there is only a small variation in the BFIsoil and SAAR parameters, it was considered appropriate to use the local gauge as a pivotal site for the rest of the modelled extent and define one reach only. The reach is defined in Table A3.2 while the limits of the catchment descriptors within the model are shown in Table A3.3 below.

Reach	Description
Entire modelled extent in the Hind Catchment	Entire N04 model extent and a portion of the N10 model extent from HEP 26_3598_7 to the entry point of the River Hind into Lough Ree (refer to Appendices B4 and B10 for the HEP node numbering).

Table A3.2 River Reach in the Catchment

Reach 1 (entire modelled extent in the Hind catchment)		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.5 (26_728_1)	78 (26_2995_5)
BFIsoil	0.58 (26_3147_2)	0.70 (26_728_1)
SAAR (mm)	980 (26_3585_4)	1027 (26_728_11)
FARL	1.00 (26_728_1)	1.00 (26_3598_7)
DRAIND	0.21 (26_2111_2)	0.80 (26_728_11)
S1085 (m/km)	0.3 (26_2111_2)	8.1 (26_3147_2)
ARTDRAIN2 (%)	0.0 (26_728_1)	0.0 (26_3598_7)
URBEXT (%)	0.0 (26_211_2)	18.6 (26_3147_2)

Table A3.3 Catchment Descriptor Range for the Hind Catchment

A3.5 QMED Adjustment Factors

The QMED has been calculated for gauging station 26016 (Ballymurray) both from recorded annual maximum data and synthetically. The ratio of these two values gives an adjustment factor to refine the QMED estimate at ungauged locations in the same reach. Table A3.4 below gives the QMED adjustment factor at the only useable flow gauging station in the catchment.

Reach	Gauging Station Number	Catchment Area (km^2)	QMED Observed (m^3/s)	QMED (urban) Synthetic (m^3/s)	Adjustment Factor (-)
1	26016	62.7	8.9	6.7	1.34

Table A3.4 QMED Adjustment Factor for Hind Catchment

The rating review summary sheet in Appendix C confirms that the gauged flows at Station 26016 are subject to some uncertainty as the check gaugings show considerable scatter and the gauged flows only go up to about 0.6xQMED. However, the higher gauged QMED was considered an improvement over the synthetic estimate and was therefore adopted.

The QMED adjustment factor of 1.34 has been applied to the entire catchment.

A3.6 Flood Frequency Curves

One station was identified to be suitable for flood frequency analysis in the catchment, gauging station 26016 (Ballymurray). The flood frequency curve is plotted in Figure A3.2 below. Figure A3.2 shows the at-site AMAX series (made dimensionless by dividing the flows by QMED), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate (on a Gringorten plot).

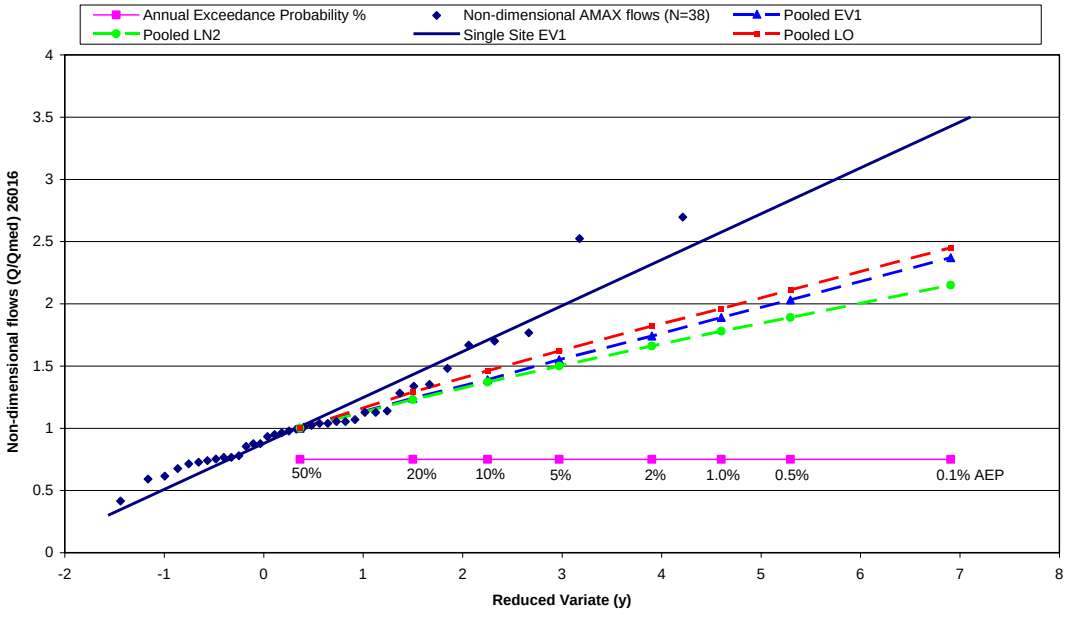


Figure A3.2 26016 Ballymurray - Growth Curves

A rating review has been undertaken for gauging station 26016 (Ballymurray) as part of the Shannon CFRAM Study. A high flow rating was established using a detailed hydraulic model at the gauge. The model rating showed a reasonable fit with the highest check gaugings, although it was noted that the highest check gaugings are considerably lower than QMED. Refer to Appendix C for the rating

review summary sheet for gauging station 26016. The model rating was used to establish an AMAX flow series from recorded annual maximum water levels.

There are 38 years of AMAX data at gauging station 26016. This data can be used to directly estimate growth factors with reasonable confidence for return periods up to approximately 19 years (1/2 N with N=38), i.e. the approximate 5% AEP flood. Figure A3.2 above shows that the at-site growth curve is steeper than the pooled growth curves for the lower return periods. Also the figure shows that had the pooled growth curve been selected, the 1% (1 in 100) AEP and even the 0.1% (1 in 1000) AEP peak flows would have been exceeded twice in the period from 1972 to 2010. This suggests that the pooled growth curves may not be appropriate at this site.

In addition, the site is affected by karst geology thereby making pooled analysis less appropriate as karstic catchments are under-represented in the database of gauging stations for pooling. Also, karstic catchments are subject to a large variability in hydrological response. The single site analysis was therefore considered more appropriate and the resulting single site growth factors were adopted for the entire Hind catchment.

Two large storms were identified in August 2009 and November 2009, which lie above the EV1 distribution fitted through the at-site AMAX series in Figure A3.2. Further analysis was undertaken to ensure these two events were not anomalies by comparing the hydrograph response recorded at gauging station 26016 (Ballymurray) to the hydrograph response at gauging station 26204 (Ballymartin), approximately 4.2 km upstream of gauging station 26016 in the 2007 to 2010 time period. This analysis showed good consistency between the peak flows for these storms at both sites.

The EV1 distribution is considered a good fit with the AMAX data, especially as it is considered that the highest AMAX values are subject to the greatest uncertainty (in flow and particularly in reduced variate).

The applied distribution and resulting growth factors for a range of AEPs are shown in Table A3.5 and Table A3.6 respectively.

Reach	Station	Single Site or Pooled	Selected Distribution
1	26016 – Ballymurray	Single Site	EV1

Table A3.5 Growth Curve Selected

Annual Exceedance Probability (%)	Growth Factors
50%	1.00
20%	1.43
10%	1.71
5%	1.97
2%	2.32

1%	2.58
0.5%	2.83
0.1%	3.43

Table A3.6 Growth Factors Applied to the Hind Catchment

A3.7 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. Gauged data from station 26016 was used to select the design hydrograph shape for the entire modelled extent in the Hind catchment. No flow gauges are available on the River Jiggy.

Gauging station 26016 is located approximately centrally between the Roscommon AFA boundary and the entry point of the River Hind into Lough Ree. Table A3.7 and Figure A3.3 show the four largest flood events recorded at station 26016. Figure A3.3 presents the hydrographs in a non-dimensional manner by dividing flows by their respective flood peak. For comparison the figure also shows the synthetic hydrograph derived from catchment descriptors. The hydrograph that best represents the median or typical storm duration has then been selected as the representative design hydrograph shape.

Date	Peak Flow (m^3/s)	Comments
05/08/1986	16.42	
19/09/1999	15.38	
18/08/2009	23.16	
17/11/2009	24.86	Selected for hydrograph shape

Table A3.7 Highest Flood Peaks for Gauging Station 26016

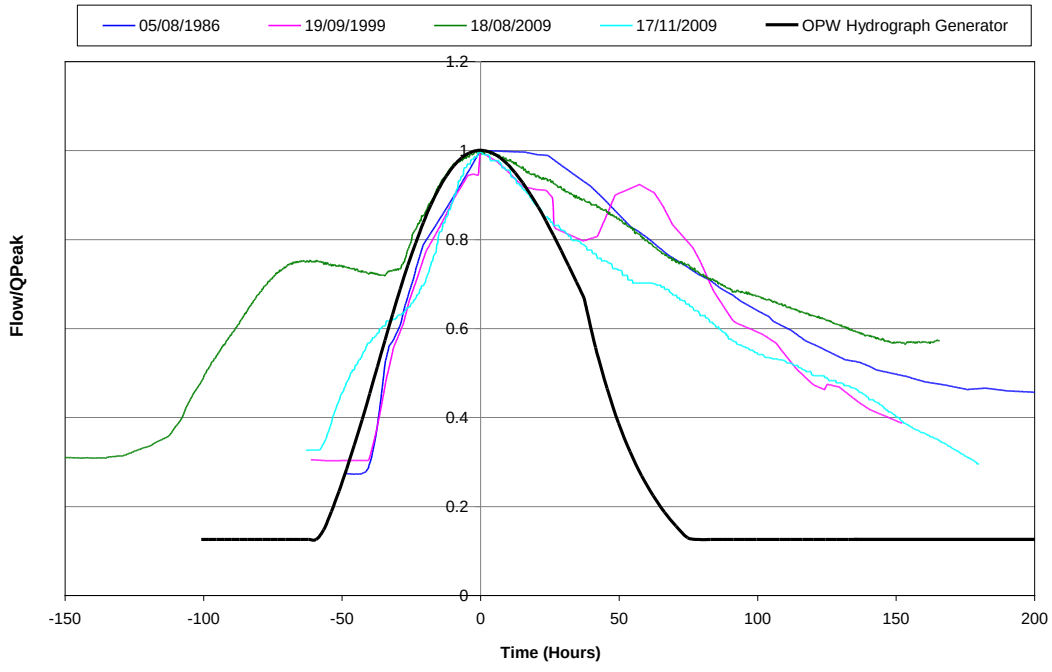


Figure A3.3 Non-dimensional Hydrographs for Gauging Station 26016

The 17/11/2009 historic flood hydrograph was selected at gauging station 26016 as an appropriate shape for the design hydrographs. Of the four historic hydrographs shown in Figure A3.3, the duration of the 17/11/2009 event appears to be typical. It is therefore considered to be a good estimate of the median hydrograph. It is also noted that a longer design hydrograph would not seem realistic for the high priority watercourse (HPW) through the Roscommon AFA.

A3.8 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for each model is discussed in Appendix B4.

A3.9 Calibration

The calibration and verification of hydraulic models is discussed in Appendix B4.

A4 Brosna Catchment

A4.1 Catchment Description

The Brosna Catchment in UoM 25/26 is one of the largest sub-catchments of the River Shannon with a total catchment area of 1247 km^2. The catchment is predominantly flat except for some undulations caused by glacial deposits. Most of the catchment is covered by grassland with underlying carboniferous limestone. The River Brosna broadly flows from the north-east to the south-west into the River Shannon (refer to Figure A4.1 for an overview map).

The Brosna Catchment is covered by four hydraulic models, viz. N05, N06, N07 and a part of N10.

In addition to the River Brosna, the principal rivers in the catchment are the Sheever in model N05, the Silver in model N06 and the Clodiagh, Gorragh and Tullamore in model N07.

The AFAs in the catchment are Mullingar in model N05, Kilbeggan, Clara, Pollagh in model N06 and Clonaslee and Rahan in Model N07. There are no IRRs in the catchment.

The primary urban areas within the Brosna catchment are discussed in relation to each model. In the N05 model the main urban area is Mullingar located between Lough Owel and Lough Ennell in the upper reaches of the catchment. URBEXT along the N05 model ranges from 0.00 in the upper catchment to 9.50 immediately downstream of Mullingar town. In the N06 model the main urban areas are Kilbeggan, Clara and Pollagh. Kilbeggan and Clara are located approximately midway along the River Brosna while Pollagh is located approximately three kilometres downstream of the confluence between the River Brosna and River Clodiagh. URBEXT along the N06 model ranges from 0.00 on rural tributaries to the River Brosna to 3.13 immediately downstream of Kilbeggan. In the N07 model the main urban areas are Rahan and Conlaslee. Clonalsee is located in the upper catchment of N07 while Rahan is approximately five kilometres upstream of the River Brosna/River Clodiagh confluence. URBEXT along the N07 model range from 0.00 immediately upstream of Clonaslee to 4.59 immediately downstream of Tullamore town (not on the N07 model extent but immediately upstream of it). The impact of increased paved areas and consequently higher URBEXT values would be to increase the volume of runoff and a reduction in the time to peak of the hydrograph from the catchment (e.g. a more “flashy” catchment response). Concerning the wider River Brosna the catchment response would be expected to be dominated by the predominately rural catchment. However, on a localised basis in the vicinity of urban areas there is likely to be a more rapid response from the immediate catchment thereby increasing flows in the receiving watercourse(s) and potentially increasing flood risk to nearby areas.

Two large lakes (Lough Owel and Lough Ennell) dominate the catchment response along the Brosna’s upper and middle reaches, with FARL values as low as 0.61 downstream of Lough Owel and 0.78 downstream of Lough Ennell. The effect of the lakes diminishes moving downstream along the Brosna, with a FARL value of 0.95 at Gauging Station 25006 (Ferbane).

The BFIsoil values along the River Brosna increase from 0.67 at the upstream end of the model extent to a very high 0.84 downstream at the confluence with the River Gageborough (just downstream of the Clara AFA), and then decreases to 0.71 at the confluence with the River Shannon. The BFIsoil values along the River Clodiagh range from a very low 0.31 at the upstream end of the model extent to 0.67 at the confluence with the River Brosna.

Central to the catchment is a permeable aquifer overlain by well drained soils (see Section A4.2 and Figures 3.3-3.5 in the main report). There are some karst features in the east of the catchment (see Figure 3.5 in the main report), which may have an effect on the hydrological response locally, e.g. in the Rivers Tullamore and Clodiagh.

The catchment SAAR values along the River Brosna increase mildly from 930 mm at the upstream end of the model extent to 958 mm downstream of Lough Ennell, and then decrease to 928 mm at the confluence with the River Shannon. The catchment SAAR values along the River Clodiagh range from a very high 1460 mm at the upstream end of the model extent to 923 mm near the downstream end.

The variation in BFIsoil and catchment SAAR on the River Clodiagh suggests that the hydrological response may be very different to that of the River Brosna.

A4.2 Catchment Geology

The geology of the River Brosna catchment is dominated by Quaternary deposits (subsoils) over Carboniferous limestone bedrock, from which much of the overlying deposits are formed. Within the Brosna catchment the Quaternary deposits are predominantly glacial tills. Peat, which is poorly draining, similarly represents a significant Quaternary deposit within the Brosna catchment, particularly in the south west.

Limestone tills are generally overconsolidated, poorly sorted and undifferentiated with their properties being a product of the regional topography and the depositional environment in which they were formed. As a result tills can vary widely in composition and exhibit a range of permeabilities over a relatively small area, although they are generally considered to be well draining in the Brosna catchment.

About ¾ of the catchment is underlain by locally important aquifers, which are described as bedrock which is moderately productive only in local zones. The remaining ¼ of the catchment is described as a karstified regionally important aquifer with diffuse flow, and is situated in a relatively narrow band through the centre of the catchment. This can be expected to be moderately to highly permeable.

In the southwest corner of the Brosna catchment isolated outcrops of limestone tills lie within extensive peat deposits which drain poorly, while in the southeast, north and east peat is less extensive and the dominant subsoil is limestone till of low to moderate permeability.

Figure 3.5 in the main report shows that karst features are present in some areas of the catchment, in particular centrally and in the catchment of the River Clodiagh around –and to the east of– Rahan.

Around Clara the glaciofluvial deposits overlie the massive limestone of the Waulsortian mudbank. The National Recharge map describes the glaciofluvial deposits as a highly permeable, locally important gravel aquifer overlain by well drained soils.

A particular characteristic of limestone is an irregular bedrock surface and on this basis the thickness of the overlying subsoils may be expected to vary considerably over the catchment area.

For further supporting information refer to Section 3.5 and Figures 3.3 – 3.5 of the main report

A4.3 Hydrometric Stations in the Brosna Catchment

The gauging stations with a recorder in the catchment (on or near the model extents) are tabulated in Table A4.1. They are shown on Figure A4.1.

In Table A4.1 the record data range refers to the range of AMAX data. HGF is the Highest Gauged Flow, i.e. the highest check gauging.

Gauges that were found to be irrelevant for flood estimation along the model extent have been omitted from Table A4.1.

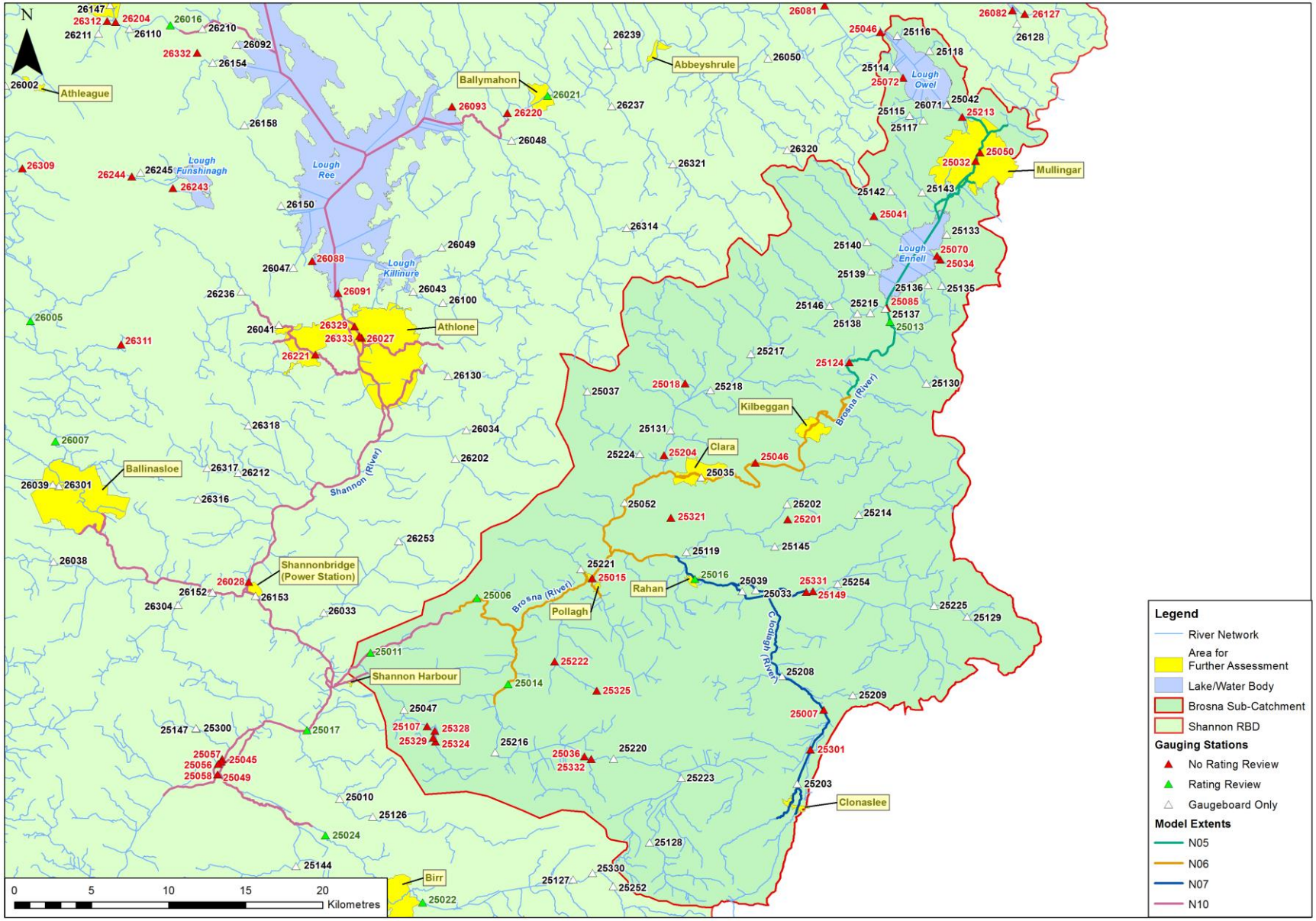


Figure A4.1 Brosna Catchment Model Extent

Model	Gauging station	Name	Record data range	AMAX available	FSU quality class or HGF/QMED	CFRAMS rating review	Quality Comments
N05	25213	Culleen Fish Farm	1957 - 2009	No	HGF/QMED ~ 0.3	No	1
	25050	Mullingar Pump House	1977 - 2009	Level and Flow	HGF/QMED ~ 0.5	No	
	25032	Mullingar	1975 - 1985	No	N/A	No	2
	25085	Clonsingle	1954 - 2009	Level	N/A	No	3
	25013	Newell's Bridge	1973 - 2009	Level and Flow	N/A	Yes	4
	25124	Ballynagore	1986 - 2011	Level and Flow	A2 (HGF/QMED) ~ 1.0)	No	5
N06	25046	Lismoyny	2009 - 2011	No	N/A	No	6
	25006	Ferbane	1953 - 2009	Level and Flow	A1	Yes	7
	25014	Millbrook	1951 - 2009	Level and Flow	A1	Yes	8
	25015	Pollagh	1972 - 2010	Level	N/A	Yes	9
	25204	Ballyboughlin	1990 - 2009	No	N/A	No	10
	25321	Clara Bog	1972 - 2010	No	N/A	No	11
N07	25016	Rahan	1963 - 2009	Level and Flow	A2/B	Yes	12
	25007	Gorteen	1954 - 2009	Level	HGF/QMED ~ 0.5	No	13
	25149	Tullamore	2001 - 2009	Level and Flow	HGF/QMED ~ 1.6	No	
	25331	Tullamore Weir	2006 - 2011	Level and Flow	HGF/QMED ~ 1.1	No	14
	25301	Bracknagh Bridge	2002 - 2010	None	HGF/QMED ~ 0.1	No	15
N10	25011	Moystown	1954 - 2009	Level and Flow	B	Yes	16

Table A4.1 Brosna Catchment Gauging Stations

The quality comments for Table A4.1 are shown on the next page.

Table A4.1 Quality comments:

1. Culleen Fish Farm is used to regulate discharge from the local fish farm. No AMAX available.
2. Mullingar is a level gauge only, with no AMAX series.
3. Clonsingle is the Lough Ennell outflow control structure (sluice) without rating.
4. AMAX flows only available since the Jacobs rating review. The check gaugings at Newell's Bridge show extensive scatter, and medium and high flows cannot be confidently confirmed. This station should not be used for flood estimation. See Jacobs rating review summary sheet (station 25013) for more details.
5. Ballynagore only has AMAX available from 1986 to 2004. EPA state 'Rating is Good', but there is considerable scatter evident in the check gaugings.
6. Lismoyny is a level only site. EPA state that the rating is under development.
7. Reliable rating and AMAX series. AMAX data from 1972 used only (for QMED estimation) due to a step change in AMAX data. Data from 1958 used for growth curve estimation. Section A4.6.1 contains a discussion of the use of different AMAX ranges for QMED and growth curve estimation. See Jacobs rating review (station 25006) for more details.
8. Millbrook – the outcome of the rating review is that the revised rating has been applied to the AMAX series dating back to the completion of drainage works within the catchment in 1952 (there is no evidence of a significant catchment change since this year).
9. This site was reviewed by Jacobs but the model rating produced as part of the review shows a poor match with the check gauging. This site is not to be used for hydrology and is included here for reference only.
10. Ballyboughlin is a site with level only and has no rating.
11. Clara Bog is a level only site with the rating currently under development.
12. Rahan – outcome of the rating review is that the rating revision based on the hydraulic modelling is recommended to be applied to the data from 1963 onwards, and that this can be used for both QMED estimation and flood frequency analysis.
13. Gorteen has level data but data since 1999 has not yet been digitised.
14. Tullamore Weir has a short AMAX series.
15. Bracknagh Bridge has no rating. No AMAX series available. Highest gauging has a flow of 2.44 m^3/s.
16. Check gaugings show considerable scatter, possibly due to backwater effects from the River Shannon. Ferbane was used for QMED estimation and flood frequency analysis in this reach, and the results compared with this station.

A4.4 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A4.1 above. The river reaches are tabulated in Table A4.2 and shown on Figure A4.2 below. The variation in catchment descriptors for each reach is tabulated in Tables A4.3 to A4.10 below.

The HEP nodes referred to below are shown on the model extent maps in Appendix B.

Reach	Description	Model Extent
1	Brosna upstream of Lough Ennell (including lough)	N05
2	Brosna downstream of Lough Ennell (excluding lough)	N05, N06, N10
3	River Silver (West of Pollagh)	N06
4	River Straduff (tributary of Brosna)	N06
5	River Killooly (tributary of Brosna)	N06
6	River Clodiagh from upstream model extent to confluence with the River Gorragh (through Clonaslee AFA)	N07
7	River Gorragh (through Clonaslee AFA)	N07
8	River Clodiagh from confluence with the Gorragh to the confluence with the Tullamore	N07
9	River Tullamore (tributary of Clodiagh)	N07
10	River Clodiagh from the River Tullamore confluence to the downstream confluence with the River Brosna	N06, N07

Table A4.2 River Reaches in the Catchment

Reach 1			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	3.3 (26_2668_1)	60 (25_2938_1)
BFIsoil	-	0.68 (25_3912_1)	0.76 (25_2938_1)
SAAR	mm	930 (25_3912_1)	945 (25_3125_2)
FARL	-	0.61 (25_3912_1)	0.99 (25_2938_2)
DRAIND	-	0.04 (25_3912_1)	1.22 (26_2668_1)
S1085	m/km	2.5 (25_3912_1)	13.2 (25_3125_2)
ARTDRAIN2	%	18.6 (25_3125_2)	100 (25_3682_3)
URBEXT	%	0.0 (26_2668_1)	9.5 (25_2938_2)

Table A4.3 Reach 1 Catchment Descriptor Range

Reach 2			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	176 (25_3639_4)	1247 (25_681_1)
BFIsoil	-	0.67 (25_545_3)	0.84 (25_562_3)
SAAR	mm	923 (25_612_5)	958 (25_3639_4)
FARL	-	0.78 (25_545_3)	0.96 (25_316_5)
DRAIND	-	0.55 (25_545_3)	0.71 (25_608_1)
S1085	m/km	0.5 (25_559_7)	5.0 (25_3639_4)
ARTDRAIN2	%	44.2 (25_3639_4)	59.0 (25_545_3)
URBEXT	%	1.8 (25_3525_1)	4.2 (25_3639_4)

Table A4.4 Reach 2 Catchment Descriptor Range

Reach 3			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	133 (25_3701_1a)	178 (25_3701_2a)
BFIsoil	-	0.61 (25_3701_2a)	0.64 (25_3701_1a)
SAAR	mm	984 (25_3701_2a)	1032 (25_3701_1a)
FARL	-	1.00 (25_3701_1a)	1.00 (25_3701_2a)
DRAIND	-	0.93 (25_3701_2a)	1.03 (25_3701_1a)
S1085	m/km	4.8 (25_3701_2a)	7.2 (25_3701_1a)
ARTDRAIN2	%	36.9 (25_3701_1a)	37.4 (25_3701_2a)
URBEXT	%	0.4 (25_3701_2a)	0.6 (25_3701_1a)

Table A4.5 Reach 3 Catchment Descriptor Range

Reach 4			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	15.5 (25_3141_4)	16.1 (25_3141_6)
BFIsoil	-	0.44 (25_3141_6)	0.47 (25_3141_4)
SAAR	mm	869 (25_3141_6)	870 (25_3141_4)
FARL	-	1.00 (25_3141_4)	1.00 (25_3141_6)
DRAIND	-	0.55 (25_3141_4)	0.57 (25_3141_6)
S1085	m/km	0.7 (25_3141_4)	0.9 (25_3141_6)
ARTDRAIN2	%	26.6 (25_3141_4)	32.8 (25_3141_6)
URBEXT	%	0.0 (25_3141_4)	0.0 (25_3141_6)

Table A4.6 Reach 4 Catchment Descriptor Range

Reach 5			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	34.1 (25_709_2)	36.2 (25_709_4)
BFIsoil	-	0.54 (25_709_4)	0.55 (25_709_2)
SAAR	mm	864 (25_709_4)	864 (25_709_2)
FARL	-	1.00 (25_709_2)	1.00 (25_709_4)
DRAIND	-	0.65 (25_709_4)	0.67 (25_709_2)
S1085	m/km	1.97 (25_709_4)	1.98 (25_709_2)
ARTDRAIN2	%	36.0 (25_709_2)	38.5 (25_709_4)
URBEXT	%	0.0 (25_709_2)	0.0 (25_709_4)

Table A4.7 Reach 5 Catchment Descriptor Range

Reach 6			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	11.4 (25_570_12)	13.5 (25_570_18)
BFIsoil	-	0.34 (25_570_12)	0.42 (25_570_18)
SAAR	mm	1439 (25_570_18)	1460 (25_570_12)
FARL	-	1.00 (25_570_12)	1.00 (25_570_18)
DRAIND	-	0.71 (25_570_12)	0.81 (25_570_18)
S1085	m/km	25.8 (25_570_18)	32.4 (25_570_12)
ARTDRAIN2	%	0.0 (25_570_12)	5.6 (25_570_18)
URBEXT	%	0.0 (25_570_12)	1.3 (25_570_18)

Table A4.8 Reach 6 Catchment Descriptor Range

Reach 7			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	12.4 (25_582_5)	13.0 (25_582_9)
BFIsoil	-	0.31 (25_582_5)	0.31 (25_582_9)
SAAR	mm	1543 (25_582_9)	1554 (25_582_5)
FARL	-	1.00 (25_582_5)	1.00 (25_582_9)
DRAIND	-	0.88 (25_582_5)	0.99 (25_582_9)
S1085	m/km	29.4 (25_582_9)	37.1 (25_582_5)
ARTDRAIN2	%	0.0 (25_582_5)	13.0 (25_582_9)
URBEXT	%	0.0 (25_582_5)	0.9 (25_582_9)

Table A4.9 Reach 7 Catchment Descriptor Range

Reach 8			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	26.5 (25_583_1)	118 (25_550_4)
BFIsoil	-	0.34 (25_583_1)	0.60 (25_550_4)
SAAR	mm	1076 (25_550_4)	1490 (25_583_1)
FARL	-	0.99 (25_553_7)	1.00 (25_583_1)
DRAIND	-	0.76 (25_553_7)	1.03 (25_583_9)
S1085	m/km	6.8 (25_550_4)	25.8 (25_583_1)
ARTDRAIN2	%	9.6 (25_583_1)	50.3 (25_550_4)
URBEXT	%	0.7 (25_588_7)	1.1 (25_583_1)

Table A4.10 Reach 8 Catchment Descriptor Range

Reach 9			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	113 (25_3798_6)	131 (25_3798_17)
BFIsoil	-	0.63 (25_3798_6)	0.65 (25_3798_17)
SAAR	mm	845 (25_3798_17)	846 (25_3798_6)
FARL	-	1.00 (25_3798_6)	1.00 (25_3798_17)
DRAIND	-	0.63 (25_3798_17)	0.69 (25_3798_6)
S1085	m/km	0.8 (25_3798_6)	1.0 (25_3798_17)
ARTDRAIN2	%	51.8 (25_3798_6)	54.9 (25_3798_17)
URBEXT	%	4.6 (25_3798_6)	4.6 (25_3798_17)

Table A4.11 Reach 9 Catchment Descriptor Range

Reach 10			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	249 (25_3030_1)	379 (25_2952_4)
BFIsoil	-	0.62 (25_3612_1)	0.66 (25_2952_4)
SAAR	mm	923 (25_2952_4)	954 (25_3030_1)
FARL	-	0.99 (25_3030_1)	0.99 (25_2952_4)
DRAIND	-	0.69 (25_2952_4)	0.72 (25_2946_3)
S1085	m/km	4.2 (25_2952_4)	6.8 (25_3030_1)
ARTDRAIN2	%	52.5 (25_3030_1)	54.5 (25_2952_4)
URBEXT	%	2.1 (25_2952_4)	2.9 (25_3030_1)

Table A4.12 Reach 10 Catchment Descriptor Range

Reach 2 (from Lough Ennell to the downstream confluence with the River Shannon) is very long, with catchment areas varying from 176 km^2 to 1247 km^2. It was considered to split this reach up in two sections at the River Clodiagh inflow location. However, the section of the River Brosna between Lough Ennell and the Clodiagh does not have any gauging stations that are suitable for flood estimation. Furthermore Station 25006 (Ferbane) on the lower section was considered the best pivotal station due to its downstream position on the same watercourse. Due to the permeable nature of the geology (with BFIsoil values of 0.67 and higher), the amount of arterial drainage works (ARTDRAIN2 44% and higher) and the presence of the lakes no suitable alternative pivotal site was identified. It was therefore decided to apply the gauged data from Station 25006 to both sections, and combine them in one reach.

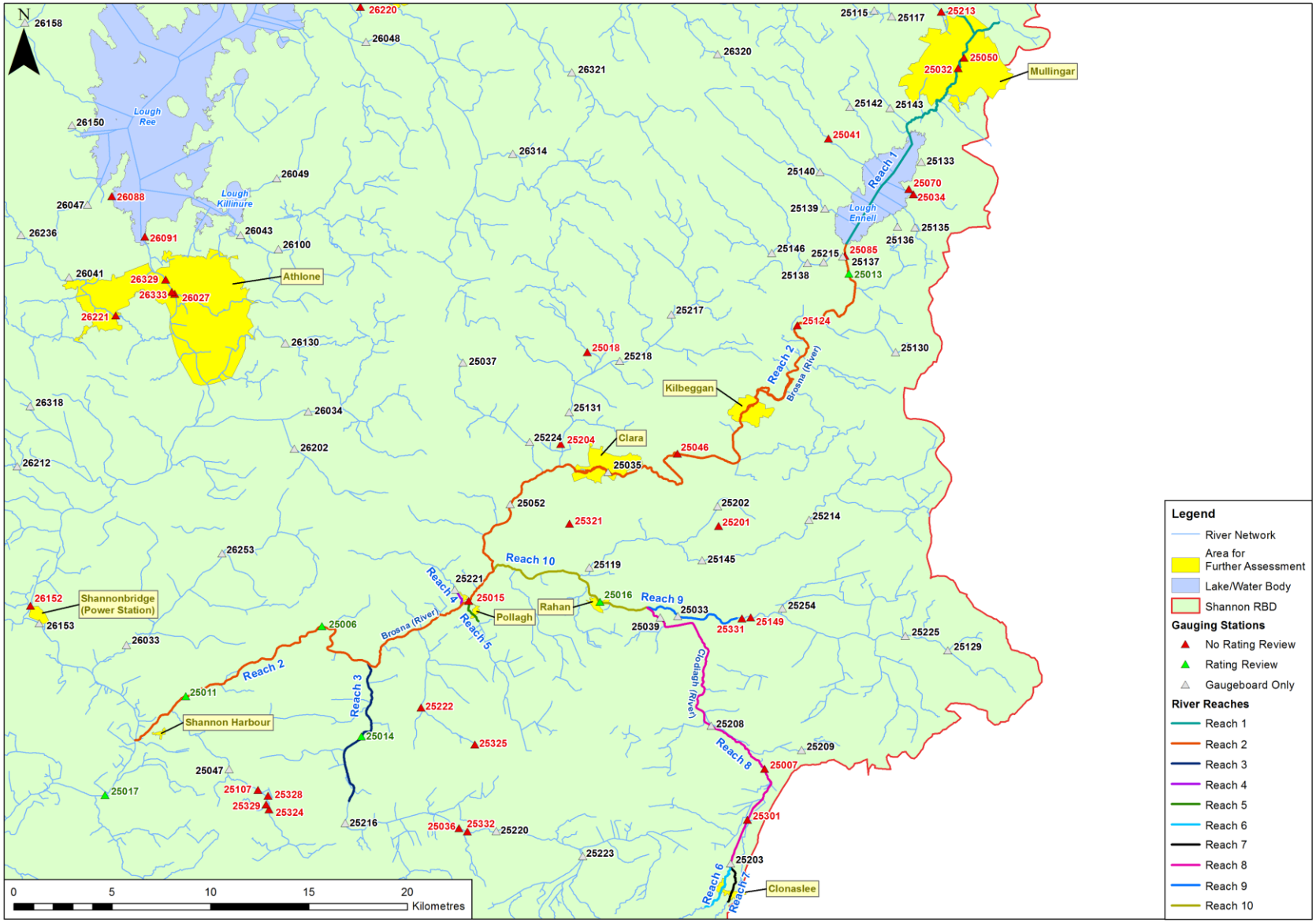


Figure A4.2 Brosna Catchment River Reaches

The selection of the QMED adjustment factors, growth curves and hydrograph shapes for these reaches is detailed in Sections A4.5 to A4.7 below.

A4.5 QMED Adjustment Factors

Table A4.13 gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED. Notes on the adjustment factor estimates are provided below the table.

Reach	Gauging station number	QMED observed (m^3/s)[1]	QMED (urban) synthetic (m^3/s)	Adjustment Factor (-)	Model Extent	Note
1	25050	4.18	1.05	3.98	N05	1
2	25013	13.1	11.5	1.14	N05	
	25124	13.7	12.2	1.12	N05	2
	25015	60	63.9	0.94	N06	3
	25006	79.0	89.0	0.89	N06	4
	25011	81.9	88.7	0.92	N10	
3	25014	20.2	26.7	0.76	N06	
9	25149	8.8	11.8	0.74	N07	5
	25331	10.1	11.4	0.89	N07	6
10	25016	23.4	40.2	0.58	N07	

Table A4.13 QMED Adjustment Factors

1. Rating is subject to uncertainty around QMED. FSU catchment descriptors AREA, FARL, S1085 and URBEXT were found to be inaccurate in this reach because the catchment area is delineated incorrectly. The catchment area has been improved using the IfSAR National Digital Height Model (NDHM). More appropriate values were determined as follows: AREA=53.3 km^2, FARL=0.61 (using the FSU FARL equation), S1085=2.50 m/km (measured from OSi mapping), URBEXT=5.4% (measured from OSi mapping). The revised synthetic QMED is 1.05 m^3/s, which shows a strong deviation from observed QMED. This is attributed to the presence of the large lake upstream of Mullingar in a relatively small catchment; the FSU regression equation is not expected to be reliable for such situations.
2. Currently AMAX series only available from 1986 to 2004. There is considerable scatter evident in the check gaugings.
3. The small amount of available check gaugings appear to give a reasonable estimate of the rating for medium flows up to approximately 51 m^3/s, so a preliminary rating curve drawn through the check gaugings was used for the observed QMED estimate in the table. Note that this curve had to be extrapolated beyond the check gaugings to obtain QMED. This site was reviewed by Jacobs but the model rating produced as part of the review shows a poor match with the check gaugings. OPW has confirmed that the site is unsuitable for flow derivation. This site is not to be used for flood estimation and is included here for reference only.

4. AMAX data from 1972 used only (for QMED estimation) due to a step change in AMAX data. Reliable rating and AMAX series. See Jacobs rating review (Appendix C, station 25006) for more details.
5. Short AMAX series 2001 to 2009. Although OPW has reported weed growth issues at this station, an inspection of the check gaugings and the AMAX series has not revealed any concerns, suggesting that the effects are small during floods. The entire AMAX series has been used to estimate QMED.
6. Short AMAX series 2006 to 2013.

The QMED adjustment factors for the ungauged reaches (or reaches with low flow gauges only) in the catchment (Reaches 4-8) were estimated using pivotal sites.

The adjustment factors for Reaches 4-8 in the N06 and N07 model extents were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A4.14 -18). The use of a single pivotal site was considered but no suitable station was found that was hydrologically similar and sufficiently near to the subject site. The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: $\prod$ (Adjustment Factor^{Weight}).

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
8007	BROADMEADOW	1	0.863	0.234	1.02
8012	BALLYBOGHILL STREAM	2	0.864	0.234	0.93
6033	WHITE (DEE)	3	1.104	0.183	1.52
24022	HOSPITAL	4	1.134	0.178	1.30
8005	KINSALEY HALL	5	1.182	0.171	2.28
Weighted Geometric Mean					1.29

Table A4.14 QMED Adjustment Factor for HEP 25_3141_6 (Reach 4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6031	CURRALHIR	1	0.384	0.237	2.05
24022	HOSPITAL	2	0.395	0.230	1.30
8012	BALLYBOGHILL STREAM	3	0.469	0.194	0.93
8002	DELVIN	4	0.531	0.171	1.39
6033	WHITE (DEE)	5	0.542	0.168	1.52
Weighted Geometric Mean					1.41

Table A4.15 QMED Adjustment Factor for HEP 25_709_4 (Reach 5)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.99	0.236	2.32
10004	GLENMACNASS	2	0.99	0.236	2.12
36021	KILTYBARDAN	3	1.19	0.196	1.22
1055	MOURNE BEG WEIR	4	1.39	0.169	0.72
23012	BALLYMULLEN	5	1.44	0.163	0.58
Weighted Geometric Mean					**1.31**

Table A4.16 QMED Adjustment Factor for HEP 25_570_16 (Reach 6)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
36021	KILTYBARDAN	1	0.575	0.374	1.22
27001	INCH BR.	2	1.158	0.185	0.66
39001	NEW MILLS	3	1.279	0.168	0.99
33001	GLENAMOY	4	1.537	0.140	1.10
32011	BUNOWEN	5	1.613	0.133	1.21
Weighted Geometric Mean					**1.03**

Table A4.17 QMED Adjustment Factor for HEP 25_582_6 (Reach 7)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
23012	BALLYMULLEN	1	0.238	0.356	0.58
14033	OWENASS	2	0.314	0.270	1.17
35002	BILLA BR.	3	0.626	0.135	1.42
34009	CURRAGHBONAUN	4	0.680	0.124	0.73
35004	BIG BRIDGE	5	0.739	0.115	0.82
Weighted Geometric Mean					**0.85**

Table A4.18 QMED Adjustment Factor for HEP 25_588_6 (Reach 8)

Table A4.19 shows the QMED adjustment factor applied to each reach in the catchment, with a justification for the selection of the gauging station.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	3.98	Station 25050	This is the only station with mid-flow rating in the reach. Rating is subject to uncertainty around QMED, but locally gauged data is preferred over synthetic/pivotal data because: (1) FSU catchment descriptors are inaccurate in this reach. They have been improved using the NDHM but are still uncertain; (2) there are no suitable pivotal sites due to the effect of the upstream lake (low FARL). Flood outlines for high design events based on the observed QMED estimates suggest that the synthetic QMED estimates are too low (see calibration in Section B5.1).
2	0.89	Station 25006	Stations 25013 and 25124 within the reach are unsuitable for flood estimation (large scatter in check gaugings for low and mid flows, no check gaugings for high flows). Stations 25015 and 25011 show large scatter in the check gaugings and appear to be affected by backwater effects. OPW confirmed that station 25015 was not suitable for design hydrology. Nearest reliable gauge downstream of Lough Ennell is Station 25006 (Ferbane). The adjustment factor at 25006 is similar to those at 25015 and 25011, although the latter two are considered less reliable.
3	0.76	Station 25014	Only flow gauging station in reach. Reliable for QMED estimation
4	1.29	25_3141_6	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
5	1.41	25_709_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
6	1.31	25_570_16	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
7	1.03	25_582_6	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
8	0.85	25_588_6	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
9	0.74	Station 25149	Flow gauging station just upstream of reach. Reliable for QMED estimation.
10	0.58	Station 25016	Station 25016 is the only active gauging station within the reach and has a reasonable reliability for flows around QMED. Station 25007 upstream of 25016 is unsuitable for QMED estimation.

Table A4.19 QMED Adjustment Factors Applied to Each Reach

Reach 1 has an unusually high adjustment factor, which is attributed to the inability of the FSU regression equation to accurately represent a small catchment with a large lake, as detailed in Note 1 below Figure A4.13. The adjustment factor for Reach 2 is based on a reliable rating for Station 25006, and is thought to be appropriate for the entire lower section of the Brosna from the Clodiagh confluence

to the Shannon. The adoption of the same adjustment factor for the part of Reach 2 upstream of the Clodiagh confluence is discussed in Section A4.4, and is subject to more uncertainty.

Relating the other adjustment factors in Table A4.19 to the locations of the reaches in Figure A4.2 and the geology/soil maps in the main report (Figures 3.3-3.5) shows that there is an apparent relationship between the adjustment factors and the permeability of the geology and soils (with higher adjustment factors for impermeable catchments). This explains the trend of decreasing adjustment factors when moving downstream the Clodiagh. The two small ungauged tributaries joining the Brosna at Pollagh (Reaches 4 and 5) have high adjustment factors (1.29-1.41), and drain catchments largely overlain by peat deposits. The permeability of the soils in the catchment to Reach 3 (with an adjustment factor of 0.76) is mixed, but the catchment upstream of the model extent is on a permeable aquifer with evidence of karst features (see Figure 3.5 in the main report).

A4.6 Flood Frequency Curves

Three stations suitable for flood frequency analysis were identified in the catchment: stations 25006 (Ferbane), 25016 (Rahan) and 25014 (Millbrook). The flood frequency curves (or growth curves) are plotted in Figures A4.3, A4.4 and A4.5 below. The flood frequency curve plots for all relevant stations are included in Appendix E.

The figures show the at-site AMAX series (made dimensionless by dividing the flows by QMED), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate (on a Gringorten plot).

25006 - Ferbane Gauging Station

The confidence in the AMAX data at Ferbane is high as there is little scatter in the check gaugings from 1958 onwards. High flow check gaugings before 1958 appear to be different to those taken later. It is speculated that the drainage works within the catchment during the period 1948-1955 may have influenced the rating. The modelled rating from the rating review that was carried out as part of the CFRAM study fits well with the check gaugings. Further details are shown in the rating review summary sheet for gauging station 25006 in Appendix C.

Ferbane has 52 years of AMAX data (from 1958 to 2009). Although only the 38 years from 1972 were used for QMED estimation (due to an apparent step change in the AMAX data from that year), the step change is considered sufficiently small to ignore it for growth curve estimation purposes, and the dataset from 1958 to 2009 was used for this (although compared to the growth curve from the shortened AMAX series from 1972 only, see below). This is on the basis that for growth curve estimation more years of data are required than for a reasonable estimate of QMED, and the data from the historic catchment with a catchment behaviour that is only mildly different from the existing condition may be preferable over the use of data from pivotal sites for low return periods. AMAX data from before 1958 is omitted. The Ferbane at-site and pooled growth curves are shown on Figure A4.3 below.

With 52 years of data the on-site data can be used directly to estimate growth factors for return periods up to approximately 26 years (½N with N=52). For lower AEPs (higher return periods) it may be more appropriate to use pooled data. As the at-site data does not provide evidence that the pooled distributions are inappropriate

at Ferbane, the pooled growth curve is adopted. To acknowledge the importance of local observations, the pooled distribution that is closest to the plotted AMAX data was chosen, which at Ferbane is the LN2 distribution (for the target return period of 100 years, i.e. the event with 1% AEP).

It is noted that the growth curve at Ferbane is relatively flat. This may be partly caused by some routing effect of the lakes in the catchment (FARL=0.95) and the relative permeability of the geology (observed BFI=0.71, BFIsoil=0.76).

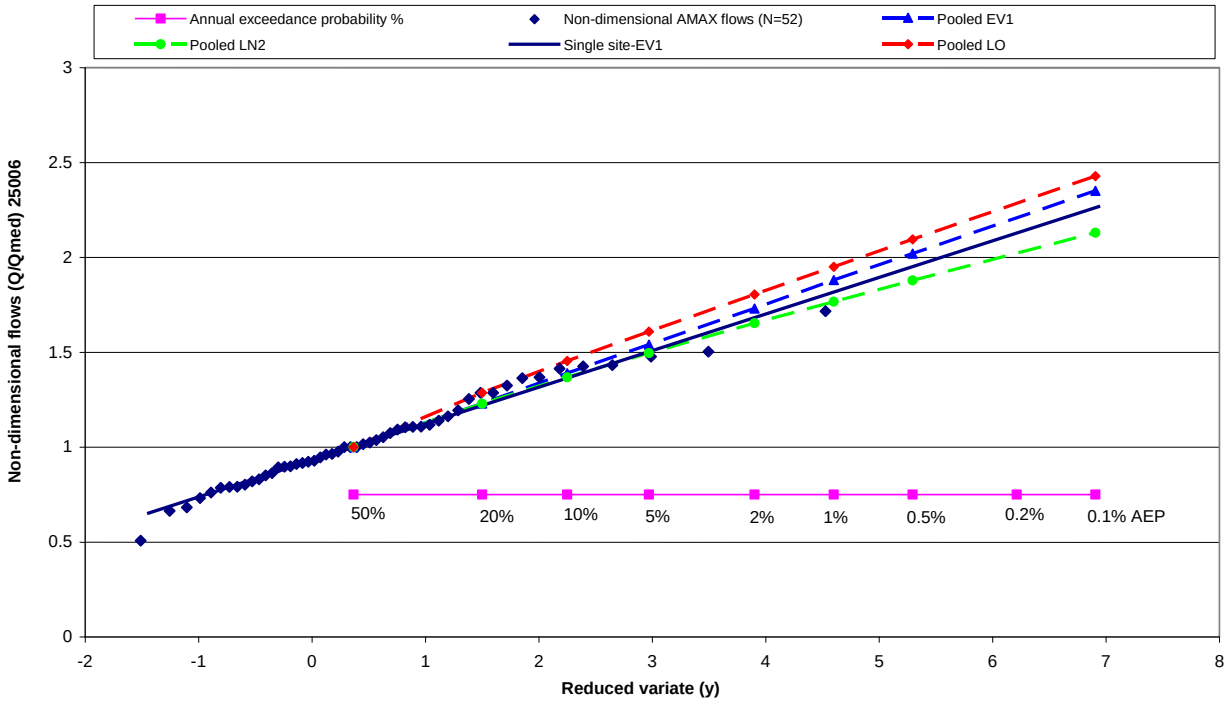


Figure A4.3 25006 Ferbane – Flood Frequency Curves

For comparison purposes the Ferbane at-site data was also employed to derive an at-site growth curve using the past 38 years of data only (from 1972 to 2009). This period shows more consistency in the AMAX flows (see also Section A4.5) as there appears to be a step change in the AMAX series in 1972. Although using fewer years would reduce the confidence of the resulting growth curve for low AEPs (high return periods), it is noted that this growth curve was found to be flatter (lower) than the at-site growth curve in Figure A4.3 based on 52 years of data, and slightly flatter (lower) than the LN2 pooled growth curve at Ferbane.

25016 - Rahan Gauging Station

A rating review has been undertaken for gauging station 25016 Rahan, details of which are provided in Appendix C. The historic OPW rating and modelled rating were compared to the check gaugings. The check gaugings show a shift in rating prior to 1963. There is minimum scatter in check gaugings after 1963 and the modelled rating shows a good fit with the check gaugings. Data prior to 1963 was not used for QMED estimation or flood frequency analysis due to the aforementioned change in flow regime.

There are 53 years of AMAX data of which 46 years is utilised for flood frequency analysis (due to the shift in flow regime prior in 1963). This data can be used to

directly estimate growth factors with reasonable confidence for return periods up to approximately 23 years (½N with N=46), i.e. the approximate 4% AEP flood. Figure A4.4 shows that the pooled LN2 growth curve is similar but slightly steeper than the curve for the at-site data. Given the plotting positions of the rarer events and consideration of these in light of the ½N rule: the pooled LN2 growth curve is judged appropriate for flood flow estimation at this site.

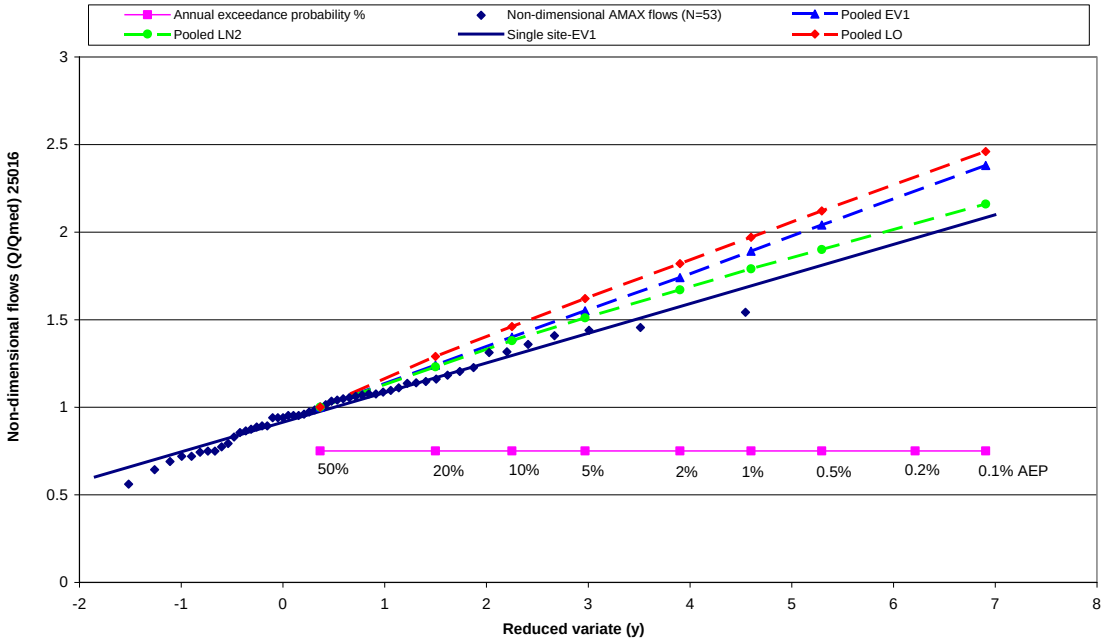


Figure A4.4 25016 Rahan – Flood Frequency Curves

25014 - Millbrook Gauging Station

A rating review has been undertaken for gauging station 25014 Millbrook, details of which are provided in Appendix C. The historic OPW rating and modelled rating were compared to the check gaugings. The modelled rating has a relatively good relationship with the majority of the check gaugings. There is some scatter but this seems to be situated evenly around the rating. The existing OPW rating lies significantly above the majority of the check gaugings. A high flow gauging was completed in December 1960 which lies close to the modelled rating but no high flows gaugings have been completed since the 1960's. Due to the age of this gauging it may not be representative for the current condition in the catchment. A new set of rating equations have been derived for high flows and applied to the AMAX series since 1952. This in part is due to the completion of drainage works in the catchment in 1951.

There are 59 years of AMAX data. This data can be used to directly estimate growth factors with reasonable confidence for return periods up to approximately 30 years (½N with N=59), i.e. the ~3.5% AEP flood. Figure A4.5 shows that the pooled LN2 growth curve agrees well with the at site growth curve up to 3.5% AEP and is judged the suitable for flood flow estimation at this site.

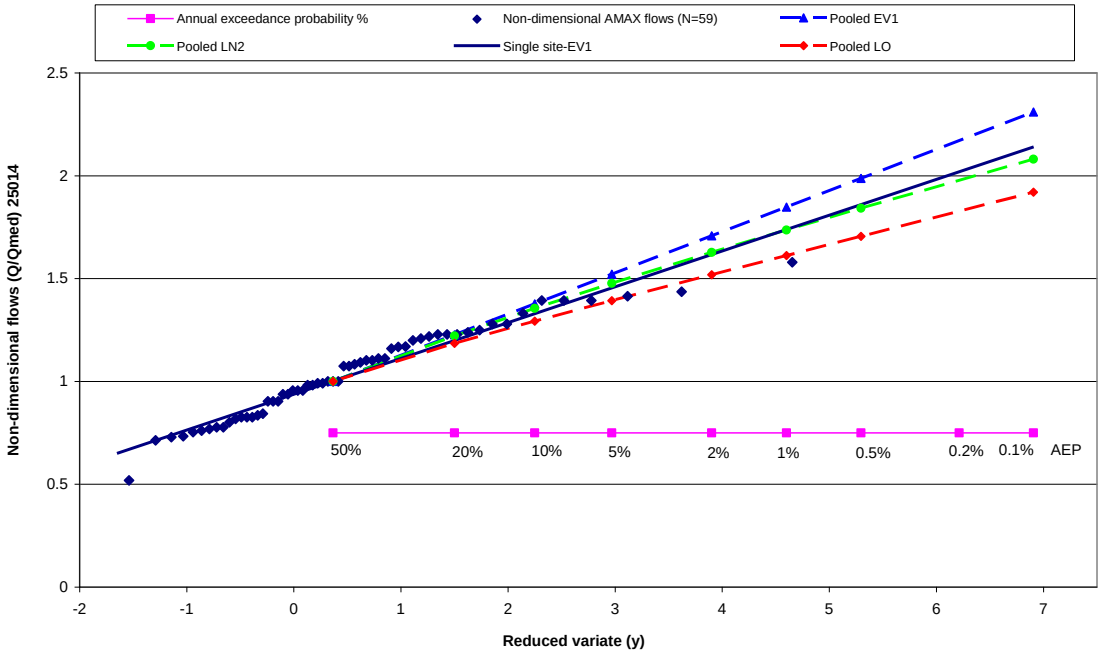


Figure A4.5 25014 Millbrook – Flood Frequency Curves

River Reach Flood Frequency

(i) Flood Frequency Curve Reach 1

For Reach 1 (upstream of Lough Ennell) several attempts were made to obtain a representative growth curve as there is no gauging station that is suitable for flood frequency analysis in this reach.

FSU catchment descriptors are inaccurate in this reach. They have been manually improved using the NDHM and 1:50,000 scale OSi mapping, but the synthetic QMED estimate based on the revised descriptors is much lower than estimates of the observed QMED (with an adjustment factor of nearly 4). Flood outlines for high design events based on the observed QMED estimates suggest that the synthetic QMED estimates are too low.

Pooling at the gauge location (without the subject site included in the pooling group) using improved catchment descriptors showed that there were insufficient representative sites with similar catchment descriptors. This is due to the low revised value of FARL (0.61), which reflects the lake immediately upstream of Mullingar (Lough Owel).

The use of a single pivotal site was also considered, but there are no gauged sites available that are suitable for flood frequency analysis and have FARL values as low as 0.61. Newell's Bridge (25013) appeared a reasonable compromise as it is on the same watercourse, downstream of the subject site, and has a reasonably low FARL (0.78) reflecting its location downstream of Lough Ennell. However the station's check gaugings show considerable scatter, indicating that the AMAX flows may be subject to considerable uncertainty. The pooling group for Newell's Bridge was heterogeneous with generally higher FARL values than Newell's Bridge. The single site and pooling analysis resulted in 1% AEP (100-year return period) growth factors of 1.67 (with on-site data) and 2.01 (pooled). The pooled estimate is not expected to represent the influence of the lakes in the catchment well. The growth factor of 1.77

for the 1% AEP event found from pooled analysis at Ferbane compares reasonably with the Newell's Bridge on-site growth factor of 1.67.

The pooled growth curve at Ferbane was adopted for Reach 1.

(ii) Flood Frequency Curve Reach 2

Station 25006 (Ferbane) has the most reliable data for flood frequency analysis on the reach. The stations upstream of Ferbane have been dismissed for the same reasons they were not used for QMED estimation, as specified in the comments for Tables A4.13 and A4.19. In addition, no gauging station upstream of Ferbane had sufficient check gaugings in the high flow range (with the highest check gauging at 25124-Ballynagore around 1.0xQMED, See Table A4.1). Pooling at Newell's Bridge was attempted and dismissed as discussed under Sub-section (i) above.

Station 25011 (Moystown) shows considerable scatter in the check gaugings and appears to be affected by backwater effects from the River Shannon.

Therefore the pooled growth curve at Ferbane was adopted for Reach 2.

(iii) Flood Frequency Curves Reaches 3, 4 and 5

Station 25014 (Millbrook) is the only gauging station with relatively reliable data for flood frequency analysis in Reach 3. The pooled growth curve at Millbrook has therefore been taken forward for this reach.

There are no suitable gauging stations within either Reach 4 or 5 and these reaches are not hydrologically similar to any nearby reaches with suitable gauging stations. As Reaches 4 and 5 are hydrologically similar to each other pooling has been undertaken to HEP node 25_709_4 in Reach 5. The growth curve produced from this analysis has then been taken forward for both reaches.

(iv) Flood Frequency Curve Reach 6, 7, 8, 9 and 10

Station 25016 (Rahan) is the only station with sufficiently reliable data for flood frequency analysis on these reaches.

Since the upper Clodiagh around the Clonaslee AFA is far upstream from station 25016 (Rahan), and could potentially have a different growth curve from that station, a check was done of the growth curve on the River Clodiagh at an ungauged site immediately downstream of the confluence with the Gorragh (HEP 25_583_1) near Clonaslee using pooling analysis. The results are shown in the pooling group audit trail in Appendix G.

A comparison of the pooled growth factors at node 25_583_1 with the growth factors at Rahan showed little difference (approximately a 7% difference for the 1% [1 in 100] AEP flood using the pooled EV1 distribution, and less using the LN2 distribution) and for consistency the Rahan growth curve was employed for the entire Clodiagh catchment.

(v) Conclusion

The growth curve distributions applied to the relevant reaches are shown in Table A4.20. Growth factors generated for a range of AEPs have been detailed in Table A4.21.

Reach	Station	Single Site or Pooled	Selected distribution
1	25006 – Ferbane	Pooled	LN2
2	25006 – Ferbane	Pooled	LN2
3	25014 – Millbrook	Pooled	LN2
4	25_709_4 (HEP node)	Pooled	LN2
5	25_709_4 (HEP node)	Pooled	LN2
6	25016 – Rahan	Pooled	LN2
7	25016 – Rahan	Pooled	LN2
8	25016 – Rahan	Pooled	LN2
9	25016 – Rahan	Pooled	LN2
10	25016 – Rahan	Pooled	LN2

Table A4.20 Final Growth Curves Selected

Annual Exceedance Probability (%)	Growth Factors Reaches 1, 2	Growth Factors Reach 3	Growth Factors Reaches 4, 5	Growth Factors Reaches 6, 7, 8, 9, 10
50%	1.00	1.00	1.00	1.00
20%	1.23	1.22	1.30	1.23
10%	1.37	1.36	1.49	1.38
5%	1.49	1.48	1.67	1.51
2%	1.65	1.63	1.89	1.67
1%	1.77	1.74	2.06	1.79
0.5%	1.88	1.84	2.23	1.90
0.1%	2.13	2.08	2.61	2.16

Table A4.21 Final Growth Factors Applied to the Brosna Catchment

A4.7 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

Mullingar Pump House (Station 25050) is the logical choice for Reach 1 (upstream of Lough Ennell) as it is situated within the AFA and is the most reliable flow gauge in the reach. Its rating is only confirmed to about 0.5xQMED and the accuracy of the hydrograph for high flows is therefore uncertain, but still considered better than one derived synthetically from catchment descriptors or from a pivotal station, given the presence of a large lake in the catchment.

As there are multiple gauging stations within Reach 2 that could be used for the hydrograph shape, sub-reaches have been defined for which different hydrograph shapes have been defined. Newell's Bridge is considered sufficiently reliable to produce a representative hydrograph shape for the section of Reach 2 that lies within the N05 model, downstream of Lough Ennell. Ferbane (station 25006) has been selected as the most appropriate gauge to use in order to obtain a representative hydrograph shape for the sections of Reach 2 within the N06 model.

Millbrook (Station 25014) was selected as appropriate to obtain a representative hydrograph shape for Reach 3. Millbrook has been assessed as sufficiently reliable to use for this purpose and is the only suitable gauge in the modelled reach.

Reaches 4 and 5 have a lack of suitable gauging stations to derive a hydrograph shape. As the reaches are hydrologically similar the synthetic hydrograph shape generator was used to derive a suitable hydrograph shape for both reaches. Catchment characteristics at HEP node 25_709_4 (in Reach 5) were selected for input into the hydrograph shape generator and pivotal site 24008 was selected as appropriate to use for hydrograph generation purposes
.
As there are no other suitable flow gauging stations on Reaches 6, 7, 8 and 10 (Rivers Clodiagh and Gorragh), Station 25016 (Rahan) was used to produce hydrographs for both rivers.

Station 25149 was considered suitable for hydrograph extraction for the River Tullamore (Reach 9).

Table A4.22 summarises the (sub-) reaches distinguished for the design event hydrograph shape selection and the flow gauging station used for each (sub-) reach.

Reach	Gauging Station
1	25050 – Mullingar Pump House
2 (sub-reach within N05)	25013 – Newell's Bridge
2 (sub-reach within N06)	25006 - Ferbane
3	25014 – Millbrook
4	Synthetic hydrograph shape generator to HEP node 25_709_4
5	Synthetic hydrograph shape generator to HEP node 25_709_4
6	25016 – Rahan
7	25016 – Rahan
8	25016 – Rahan
9	25149 – Tullamore
10	25016 – Rahan

Table A4.22 Hydrograph Shape Sub-Reaches – Gauging Stations

Tables A4.23–28 and Figures A4.6–11 show the highest flood events chosen for comparison at Stations 25050, 25013, 25006, 25014, 25016 and 25149. Figures A4.6-11 present the hydrographs in a non-dimensional manner by dividing flows by their respective flood peaks. The hydrograph that best represents a typical or average storm duration has then been selected as the representative design hydrograph shape.

Date	Peak Flow (m^3/s)	Comments
13/08/2008	9.15	Selected for hydrograph shape
29/01/1995	5.97	
26/01/1995	5.56	
08/02/1990	5.88	

Table A4.23 Highest Flood Peaks for Gauging Station 25050

Date	Peak Flow (m^3/s)	Comments
26/12/1978	14.8	Selected for hydrograph shape
18/08/2009	14.7	
14/08/2008	15.8	
30/01/1995	16.5	
30/11/1979	18. 9	

Table A4.24 Highest Flood Peaks for Gauging Station 25013

Date	Peak Flow (m^3/s)	Comments
06/12/1957	150	
27/02/1967	122	
20/12/1968	139	
09/02/1990	122	
29/01/1995	116	
21/11/2009	110	
01/02/2009	104	Selected for hydrograph shape
09/01/2005	100	

Table A4.25 Highest Flood Peaks for Gauging Station 25006

Date	Peak Flow (m^3/s)	Comments
18/08/1986	26.1	
05/02/1990	20.2	
29/01/1974	20. 5	
01/02/2009	22.2	Selected for hydrograph shape

Table A4.26 Highest Flood Peaks for Gauging Station 25014

Date	Peak Flow (m^3/s)	Comments
03/12/1960	34.0	
24/12/1968	39.3	Selected for hydrograph shape
08/02/1990	35.4	
29/01/1995	34.0	

Table A4.27 Highest Flood Peaks for Gauging Station 25016

Date	Peak Flow (m^3/s)	Comments
07/12/2006	9.56	
16/08/2008	16.1	Selected for hydrograph shape
17/11/2009	10.5	

Table A4.28 Highest Flood Peaks for Gauging Station 25149

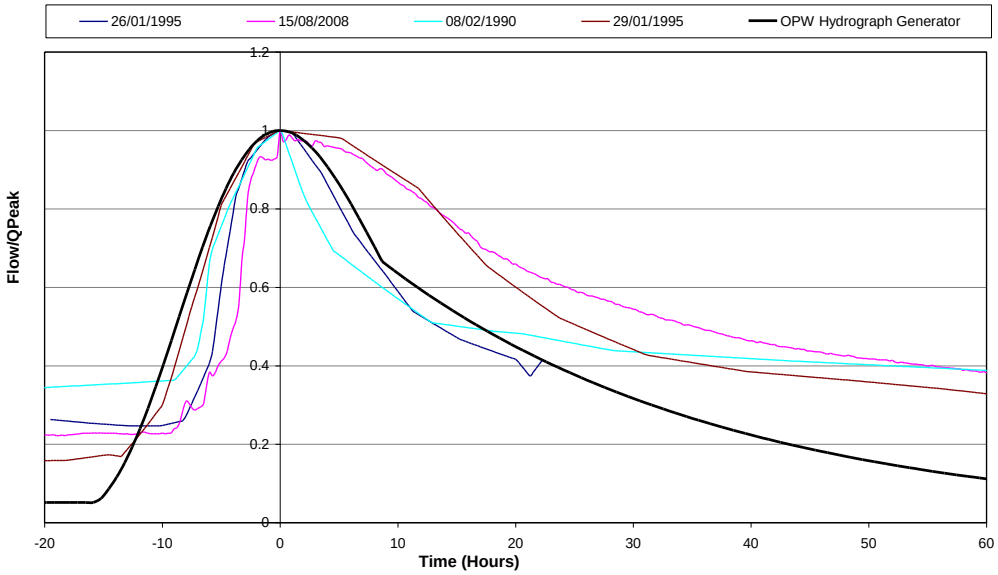


Figure A4.6 Non-dimensional Hydrographs for Gauging Station 25050

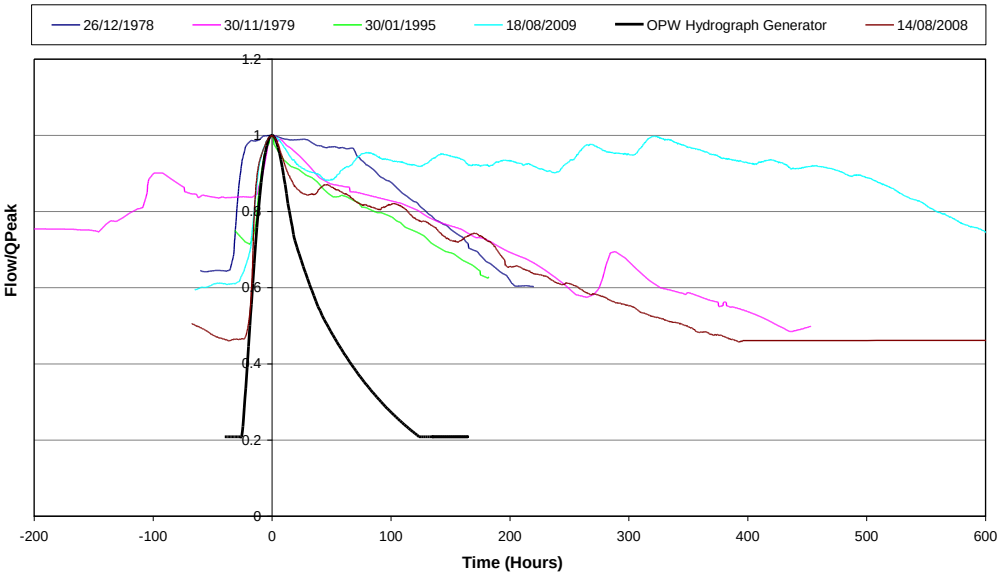


Figure A4.7 Non-dimensional Hydrographs for Gauging Station 25013

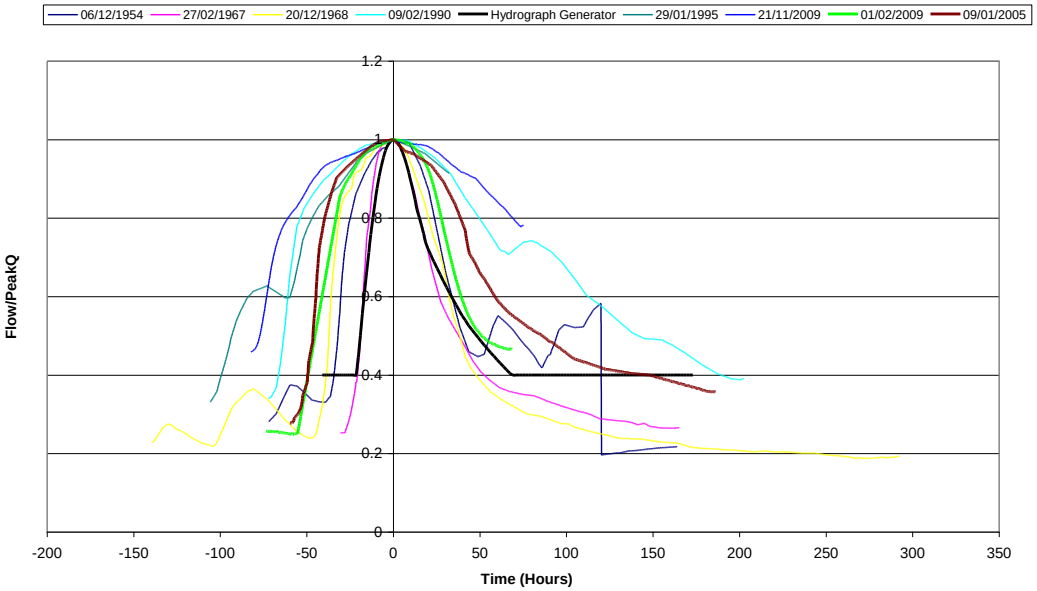


Figure A4.8 Non-dimensional Hydrographs for Gauging Station 25006

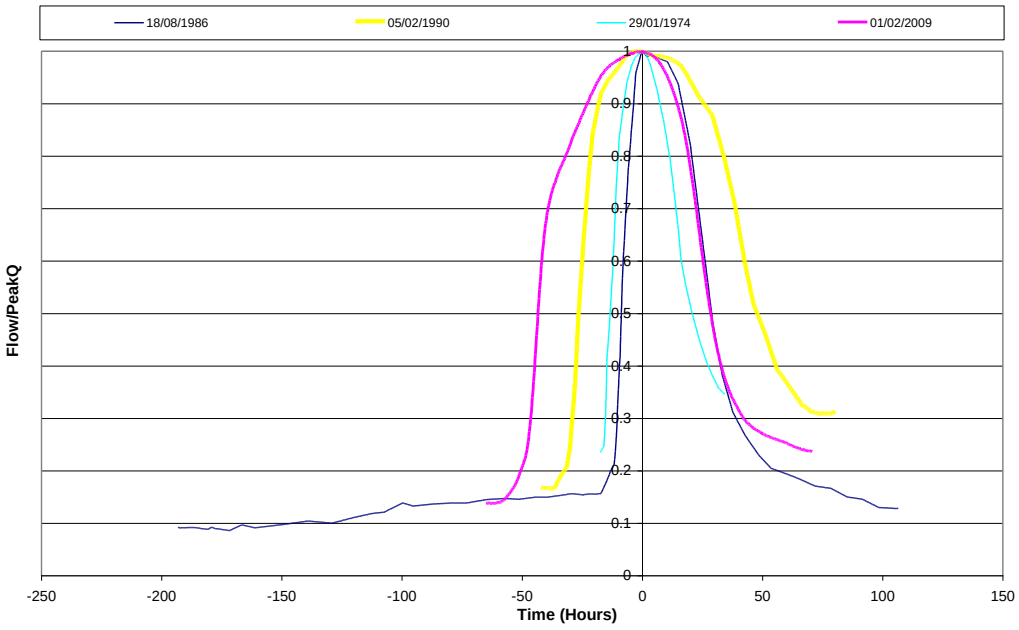


Figure A4.9 Non-dimensional Hydrographs for Gauging Station 25014

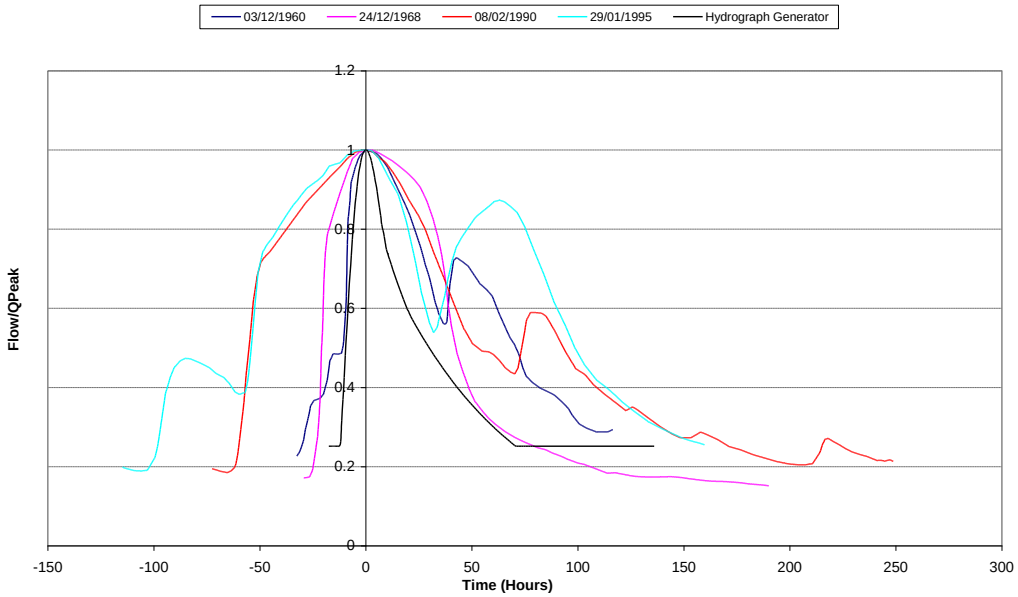


Figure A4.10 Non-dimensional Hydrographs for Gauging Station 25016

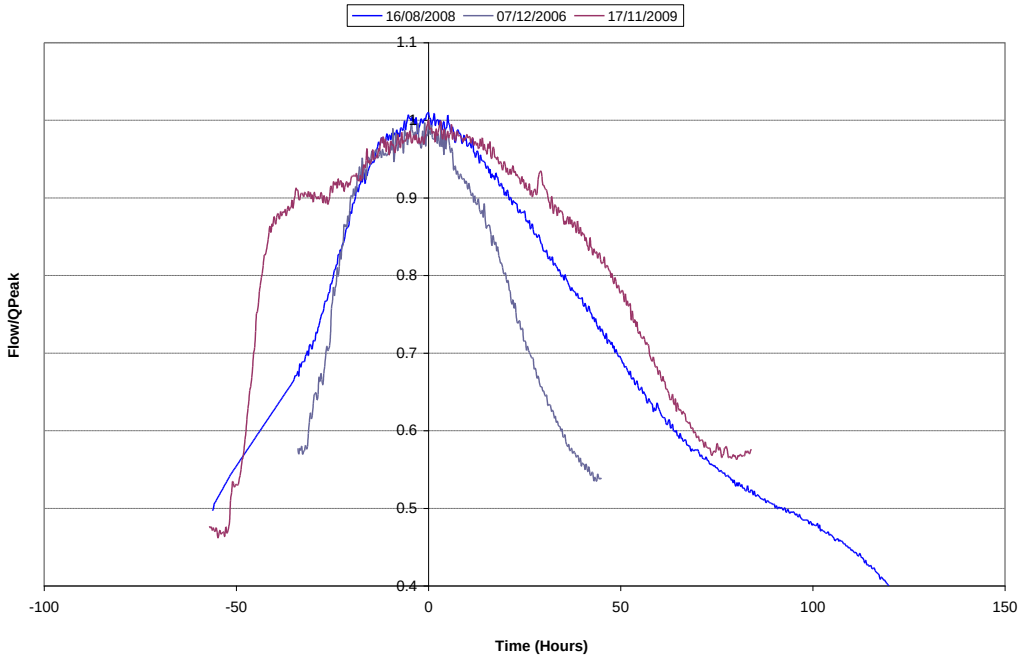


Figure A4.11 Non-dimensional Hydrographs for Gauging Station 25149

The 13/08/2008 historic flood hydrograph was selected for Station 25050. Figure A4.6 shows that of the four highest events the second longest hydrograph was selected (measured at 80% of the peak flow).

The 26/12/1978 historic flood hydrograph was selected for Station 25013. Of the five highest events the third longest (i.e. the median) hydrograph was selected (measured at 80% of the peak flow), see Figure A4.7.

The 01/02/2009 historic flood hydrograph was selected for Station 25006. This hydrograph shape is shown to be roughly the average shape of the events selected (see Figure A4.8).

The 01/02/2009 historic flood hydrograph was also selected for Station 25014. Figure A4.9 shows that this flood hydrograph has a typical shape and is representative of the group.

The 24/12/1968 historic flood hydrograph was selected at Station 25016 as an appropriate hydrograph shape for the design hydrographs. Figure A4.10 shows that of the four highest events the 1968 event has the approximate median duration and was therefore selected as the hydrograph shape at gauging Station 25016.

As shown in Figure A4.11 only the three highest flood events were considered for Station 25149 because of the very short gauged record (9 years). The fourth highest peak event would have a return period that is too low to be considered for the purpose of this flood study (refer to Section 2.6 of the main report). The 16/08/2008 historic flood hydrograph was selected for Station 25149. Of the three highest events it has the median duration.

The hydrograph shape generator was used to generate a hydrograph shape for Reaches 4 and 5. This occurred as no suitable gauged data was available for either reaches. Given the reaches have similar hydrological characteristics one hydrograph shape was generated for both reaches using the catchment characteristics from HEP node 25_709_4. The synthetic hydrograph shape generated is presented in Figure A4.12.

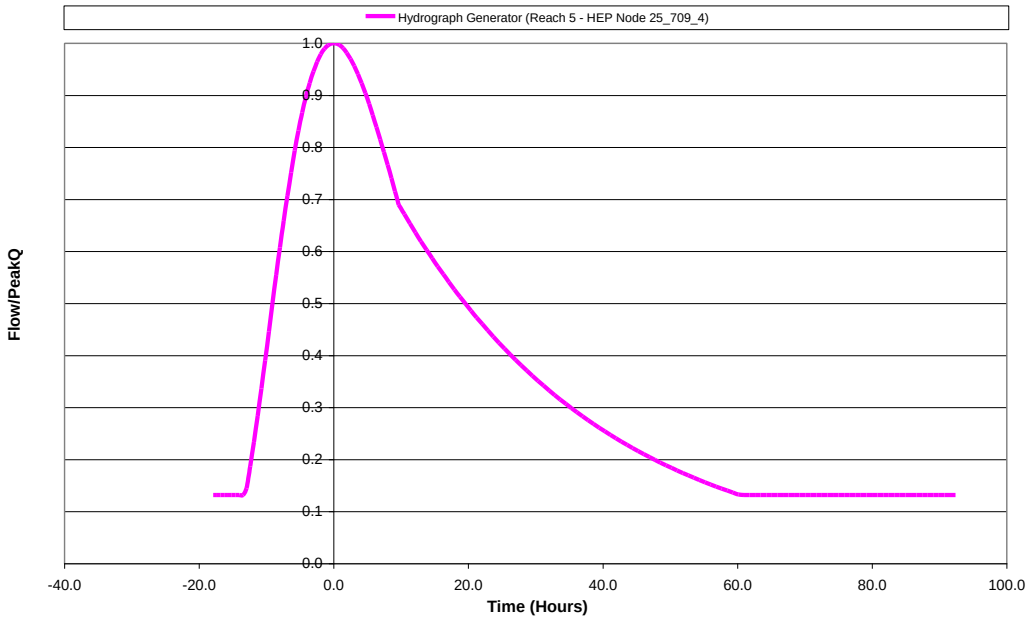


Figure A4.12 Non-dimensional Synthetic Hydrograph generated for HEP Node 25_709_4 (Applied to Reaches 4 and 5)

A4.8 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for each model is discussed in Appendix B.

A4.9 Calibration

The calibration and verification of hydraulic models is discussed in Appendix B.

A5 Suck Catchment

A5.1 Catchment Description

The Suck Catchment in UoM 25/26 is one of the main subcatchments of the River Shannon with a total catchment area of 1600 km^2. The catchment is predominantly shallow, mostly formed by glacial deposits derived from the underlying carboniferous limestone and sandstone bedrock. 65% of the catchment is covered by pasture. The River Suck broadly flows from the north-west to the south-east into the River Shannon (refer to Figure A5.1 for an overview map). There are large floodable areas along the River Suck.

The Suck Catchment is covered by three hydraulic models, N08, N09 and a part of N10.

In addition to the River Suck, the principal modelled rivers in the catchment are the Francis in model N08, the Bunowen and its tributary Ahascragh, the Deerpark, the Ballyhugh, and the Mackney in model N09.

The AFAs in the catchment are Castlerea and Athleague in model N08, and Ballinasloe in model N09. There are no IRRs in the catchment.

The BFIsoil values along the modelled reach of the River Suck vary from 0.48 in the AFA Castlerea to 0.65 at the AFA Athleague. The BFIsoil values along the River Francis are approximately 0.48, and 0.64 along the River Deerpark. The BFIsoil values along River Ahascragh and River Bunowen range from 0.59 to 0.64. The values along River Ballyhugh and River Mackney reach approximately 0.7. There are a large number of karstic features and karstified aquifers (with flow through conduits) in the catchment, especially in the upper catchments of the tributaries to the east of the River Suck (see Figure 3.3 in the main report), which may have a significant impact on flood flows in the catchment's main river network.

The SAAR values along the River Suck model extent decrease mildly from 1159 mm at the upstream end of the model extent to 1039 mm at the confluence with the River Shannon. The SAAR values along the River Francis are approximately 1109 mm, and 920 mm along the River Ballyhugh. The SAAR values along River Ahascragh and River Bunowen decrease from 1093 mm at the upstream end of the model extent to 1080mm near the downstream end, the values along River Deerpark vary between 1072 mm and 1064mm, and the values along River Mackney vary between 973 mm and 961 mm.

A5.2 Catchment Geology

An assessment of the geological and hydrogeological conditions anticipated within the catchment has been undertaken with reference to the following data sources (see full references in Chapter 6 of the main report):

- Geological Survey of Ireland GIS datasets public viewer
- Teagasc Soils and Subsoils Report
- EPA Envision website

The geology of the River Suck catchment consists of subsoils over predominantly Carboniferous limestone and locally over sandstone bedrock. Much of the overlying subsoils within the catchment are glacial deposits derived from the underlying bedrock. The other predominant subsoil within the catchment is peat.

The peat deposits are most extensive in the far northwest of the catchment and within the Suck tributary catchments. The peat consists of raised and fen peat but is predominantly described as Cutover peat which is defined as having been modified by man. North of Ballinasloe the peat deposits are predominantly underlain by the limestone and shale of the karstified Marine shelf facies while to the south of Ballinasloe the underlying bedrock is predominantly limestone of the Marine basinal facies (Visean basinal limestone or Calp). The GSI online National Groundwater Recharge map describes the peat deposits as low to moderate permeability subsoils over regionally and locally important bedrock aquifers. The Peatland Map of Ireland (1978) indicates that the peat within the Suck catchment is likely to range between 1.2m and 7.0m in depth.

Glacial subsoils occur across the entire catchment area. In the north of the catchment, north and east of Athleague, the glacial deposits comprise both limestone tills and sandstone tills underlain predominatly by the karstified limestone of the Marine basinal facies. However the sandstone tills are most likely derived from the sandstones, mudstones and conglomerates of the Shallow marine and coastal plain facies (Courceyan basal clastics) which occur as inliers to the west of Athleague and around Castlerea. The GSI online National Groundwater Recharge map describes the tills within the Suck catchment as low to moderately permeable subsoils underlain by locally and regionally important bedrock aquifers. The General Soil Map of Ireland (1980) shows the tills to be overlain by dry mineral soils and wet gley soils (mineral and organic clayey soils) derived from the underlying tills. The wet gley soils are described as dominantly influenced by groundwater, seepage and springs.

Isolated patches of glaciofluvial limestone sands and gravels overlie the Marine shelf facies around the water bodies east of Ballyhaunis. The Geological Survey of Ireland (GSI) online National Groundwater Recharge map describes the sands and gravels as highly permeable, overlain by poorly drained soils. South of Ballinasloe basic sands and gravels overlie the limestone and shale of the Marine basinal facies. The Geological Survey of Ireland (GSI) online National Gravel Aquifer map describes these sands and gravels as a highly permeable aquifer overlain by well drained soils.

Limited alluvial clay subsoils also occur within the catchment adjacent to current watercourses, particularly along the River Suck. The alluvial deposits are described as moderately permeable subsoils overlain by poorly drained soils.

Throughout the catchment the limestone and shale bedrock forms isolated surface outcrops within the surrounding till subsoils. To the east of the River Suck these outcrops are principally karstified limestone and shales of the Marine shelf facies.

The GSI online karst features map indicates caves, dry valley features, enclosed depressions, swallow holes and solution features, springs and turlough (periodic lakes formed during flooding) within the Suck catchment. These are associated with the underlying karstified limestone of the Marine shelf facies and occur throughout the catchment area.

A5.3 Hydrometric Stations in the Suck Catchment

The gauging stations with a recorder in the catchment (on or near the model extents) are tabulated in Table A5.1. They are shown on Figure A5.1.

In Table A5.1 the record data range refers to the range of AMAX data. HGF is the Highest Gauged Flow, i.e. the highest check gauging. Gauging Stations that appear in Figure A5.1 but not in Table A5.1 (e.g. 26310, 26336, 26337 and 26311) were found to be irrelevant for flood estimation in the model extent.

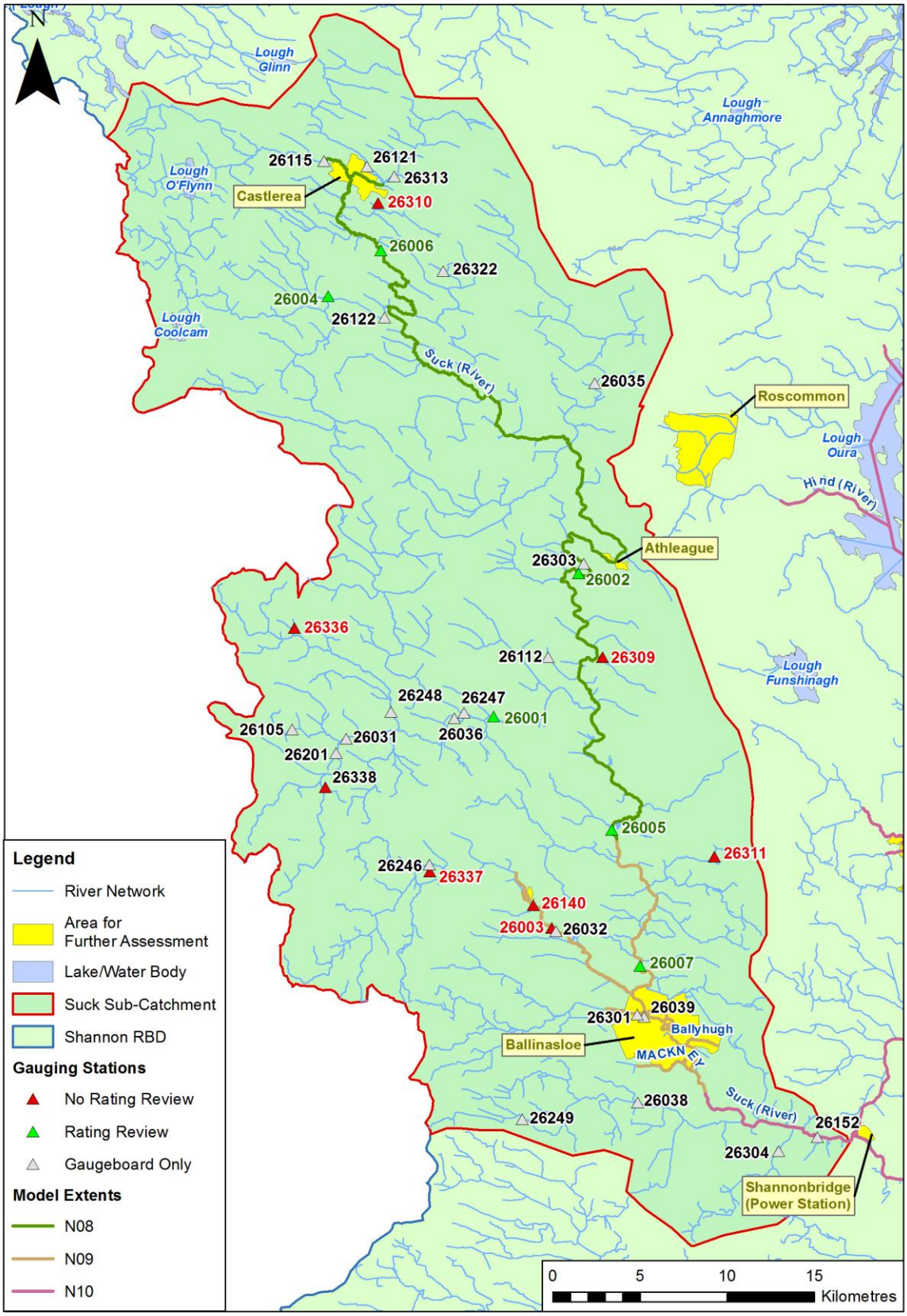


Figure A5.1 Suck Catchment Model Extent

Model	Gauging station	Name	Record data range	AMAX available	FSU quality class or HGF/QMED	CFRAMS rating review	Quality Comments
N08	26006	Willsbrook	1952 - 2010	Level and Flow	A1 (HGF/QMED ~ 2.2)	Yes	1
	26002	Rookwood	1952 - 2010	Level and Flow	A2 (HGF/QMED ~ 1.0)	Yes	2
	26005	Derrycahill	1954 - 2010	Level and Flow	A2 (HGF/QMED ~ 1.2)	Yes	3
	26004	Bookala	1972 - 2009	Level	Good (HGF/QMED ~ 0.9)	Yes	4
	26001	Ballinamore	1952 - 2010	1952-1969 Level and Flow; 1972 Level	Good (HGF/QMED ~ 0.8)	Yes	5
	26309	Mount Talbot	2001 - 2009	Level and Flow	N/A	No	6
N09	26007	Bellagill	1952 - 2010	Level and Flow	A1 (HGF/QMED) ~ 2.2)	Yes	7
	26003	Ballinruane	1954 - 1989	No	N/A	No	8
	26140	Ahascragh Pump Hse	1989 - 2009	Level	N/A	No	9

Table A5.1 Suck Catchment Gauging Stations

Table A5.1 Quality comments:

1. There is a significant amount of 15min data missing from January 1978 to May 2008, however the AMAX levels and flows for that period are available. Our rating review showed a good agreement with the OPW rating. The original AMAX values are retained for QMED estimation and single site analysis.
2. Drainage works at the gauging station were completed in 1976. A revised rating was applied to post-drainage values (after 1976) only. QMED estimation and single site analysis was based on the entire AMAX series as the drainage works do not appear to have affected the upstream catchment response, just the rating.
3. The OPW rating shows a good agreement with the model rating for high flows and is considered suitable for QMED estimation and single site analysis.
4. Drainage works were completed in Oct 1982. Data prior to this is to be excluded for flood estimation. A revised rating is to be applied to establish the post-drainage AMAX values, as detailed in Appendix C. This station is not on a modelled watercourse and it was not found to be useful for the CFRAM design hydrology.
5. Although Ballinamore (26001) is classified as 'Good', the OPW rating appears to be unreasonably steep for high flows above approximately 30m^3/s. The CFRAM revised modelled rating is recommended for updating the AMAX series, as detailed in Appendix C. This station is not on a modelled watercourse and it was not found to be useful for the CFRAM design hydrology.
6. This level and flow gauge is not on a modelled watercourse and was not found to be useful for the CFRAM design hydrology.
7. The existing rating for Bellagill produced by OPW was confirmed by several high flow check gaugings including one during the November 2009 flood (not at the peak), which suggests the OPW rating can be extended to at least 200 m^3/s, incorporating all AMAX

values except the peak of the 2009 event itself (224 m^3/s).All AMAX data from 1952 was used for flood estimation, and the rating extended assuming it was representative also for the November 2009 event.

8. With large amounts of data missing, this site could not be used for flood frequency analysis. However some data was obtained and used for the hydrograph shape analysis, see Section A5.7.
9. Ahascragh Pump Hse is a site with level only and has no rating.

A5.4 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A5.1 above. The river reaches are tabulated in Table A5.2 and shown on Figure A5.2 below. The variation in catchment descriptors for each reach is tabulated in Tables A5.3 to A5.9 below.

Reach	Description	Model Extent
1	River Francis and River Suck upstream of the confluence with River Island	N08
2	River Suck from upstream of the confluence with River Island (including 26_1176_4) to upstream of the confluence with River Shiven	N08
3	River Suck from upstream of the confluence with River Shiven (including 26_907_3) to upstream of the confluence with River Killegian	N08, N09
4	River Suck from upstream of the confluence with River Killegian to the confluence with River Shannon	N09, N10
5	River Bunowen (tributary of River Suck) and its tributary Ahascragh	N09
6	River Deerpark (tributary of River Suck)	N09
7	River Ballyhugh and River Mackney (tributaries of River Suck)	N09

Table A5.2 River Reaches in the Catchment

Reach 1			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	56 (26_3787_3)	219 (26_1176_1)
BFIsoil	-	0.48 (26_1142_2)	0.64 (26_3787_3)
SAAR	mm	1107 (26_1176_1)	1159 (26_3787_3)
FARL	-	0.90 (26_3787_3)	1.00 (26_3795_1)
DRAIND	-	0.68 (26_1142_2)	1.12 (26_3787_3)
S1085	m/km	0.4 (26_3787_7)	2.5 (26_3795_1)
ARTDRAIN2	%	0.0 (26_3795_1)	0.0 (26_1176_1)
URBEXT	%	0.1 (26_3787_3)	0.7 (26_1249_3)

Table A5.3 Reach 1 Catchment Descriptor Range

Reach 2			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	221 (26_1176_4)	703 (26_1391_1)
BFIsoil	-	0.48 (26_1176_4)	0.61 (26_4080_2)
SAAR	mm	1061 (26_1391_1)	1106 (26_1176_4)
FARL	-	0.975 (26_1176_4)	0.984 (26_3830_1)
DRAIND	-	0.78 (26_1391_1)	0.92 (26_1176_4)
S1085	m/km	0.5 (26_3631_11)	0.8 (26_3909_1)
ARTDRAIN2	%	0.0 (26_1176_4)	0.0 (26_1391_1)
URBEXT	%	0.2 (26_3631_3)	0.5 (26_1176_4)

Table A5.4 Reach 2 Catchment Descriptor Range

Reach 3			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	714 (26_907_3)	1123 (26_1385_2)
BFIsoil	-	0.59 (26_1385_2)	0.61 (26_907_3)
SAAR	mm	1053 (26_1385_2)	1063 (26_854_1)
FARL	-	0.979 (26_907_3)	0.983 (26_1433_2)
DRAIND	-	0.75 (26_1385_2)	0.79 (26_854_1)
S1085	m/km	0.4 (26_1385_2)	0.5 (26_907_3)
ARTDRAIN2	%	0.0 (26_907_3)	0.0 (26_1385_2)
URBEXT	%	0.2 (26_1385_2)	0.3 (26_1385_2)

Table A5.5 Reach 3 Catchment Descriptor Range

Reach 4			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	1187 (26_3831_2)	1599 (26_1447_3)
BFIsoil	-	0.59 (26_1447_3)	0.65 (26_1419_2)
SAAR	mm	1039 (26_1447_3)	1048 (26_3978_2)
FARL	-	0.98 (26_1453_1)	0.99 (26_1447_3)
DRAIND	-	0.75 (26_1453_1)	0.78 (26_1393_1)
S1085	m/km	0.38 (26_1415_2)	0.42 (26_1453_1)
ARTDRAIN2	%	0.0 (26_1453_1)	0.0 (26_3831_2)
URBEXT	%	0.2 (26_1442_1)	0.5 (26_3831_2)

Table A5.6 Reach 4 Catchment Descriptor Range

Reach 5			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	95 (26_3863_3)	137 (26_3041_5)
BFIsoil	-	0.59 (26_2753_1)	0.63 (26_3863_3)
SAAR	mm	1080 (26_3041_5)	1092 (26_3863_3)
FARL	-	0.998 (26_3863_3)	0.999 (26_3041_5)
DRAIND	-	0.73 (26_2753_1)	0.75 (26_1139_8)
S1085	m/km	1.9 (26_3041_1)	2.4 (26_3863_3)
ARTDRAIN2	%	0.0 (26_3863_3)	0.0 (26_3041_5)
URBEXT	%	0.3 (26_3863_3)	0.6 (26_3748_3)

Table A5.7 Reach 5 Catchment Descriptor Range

Reach 6			
Catchment descriptor	Units	Lower limit (with HEP node)	Upper limit (with HEP node)
AREA	km^2	57 (26_682_6)	62 (26_3977_5)
BFIsoil	-	0.641 (26_682_6)	0.642 (26_3977_5)
SAAR	mm	1064 (26_3977_5)	1072 (26_682_6)
FARL	-	0.993 (26_682_6)	0.994 (26_3977_5)
DRAIND	-	0.93 (26_3977_4)	0.97 (26_682_6)
S1085	m/km	2.8 (26_3977_5)	3.3 (26_682_6)
ARTDRAIN2	%	0.0 (26_682_6)	5.6 (26_3977_5)
URBEXT	%	0.7 (26_682_6)	1.6 (26_3977_5)

Table A5.8 Reach 6 Catchment Descriptor Range

Reach 7			
Catchment descriptor	**Units**	**Lower limit (with HEP node)**	**Upper limit (with HEP node)**
AREA	km^2	2.1 (26_3033_1)	8.4 (26_3824_10)
BFIsoil	-	0.69 (26_3033_1)	0.74 (26_3824_10)
SAAR	mm	920 (26_3033_1)	973 (26_3824_5)
FARL	-	1.00 (26_3033_1)	1.00 (26_3824_10)
DRAIND	-	0.16 (26_3033_1)	0.82 (26_3824_5)
S1085	m/km	3.4 (26_3824_10)	14.6 (26_3033_1)
ARTDRAIN2	%	0.0 (26_3033_1)	0.0 (26_3824_10)
URBEXT	%	0.2 (26_3824_5)	7.3 (26_3033_5)

Table A5.9 Reach 7 Catchment Descriptor Range

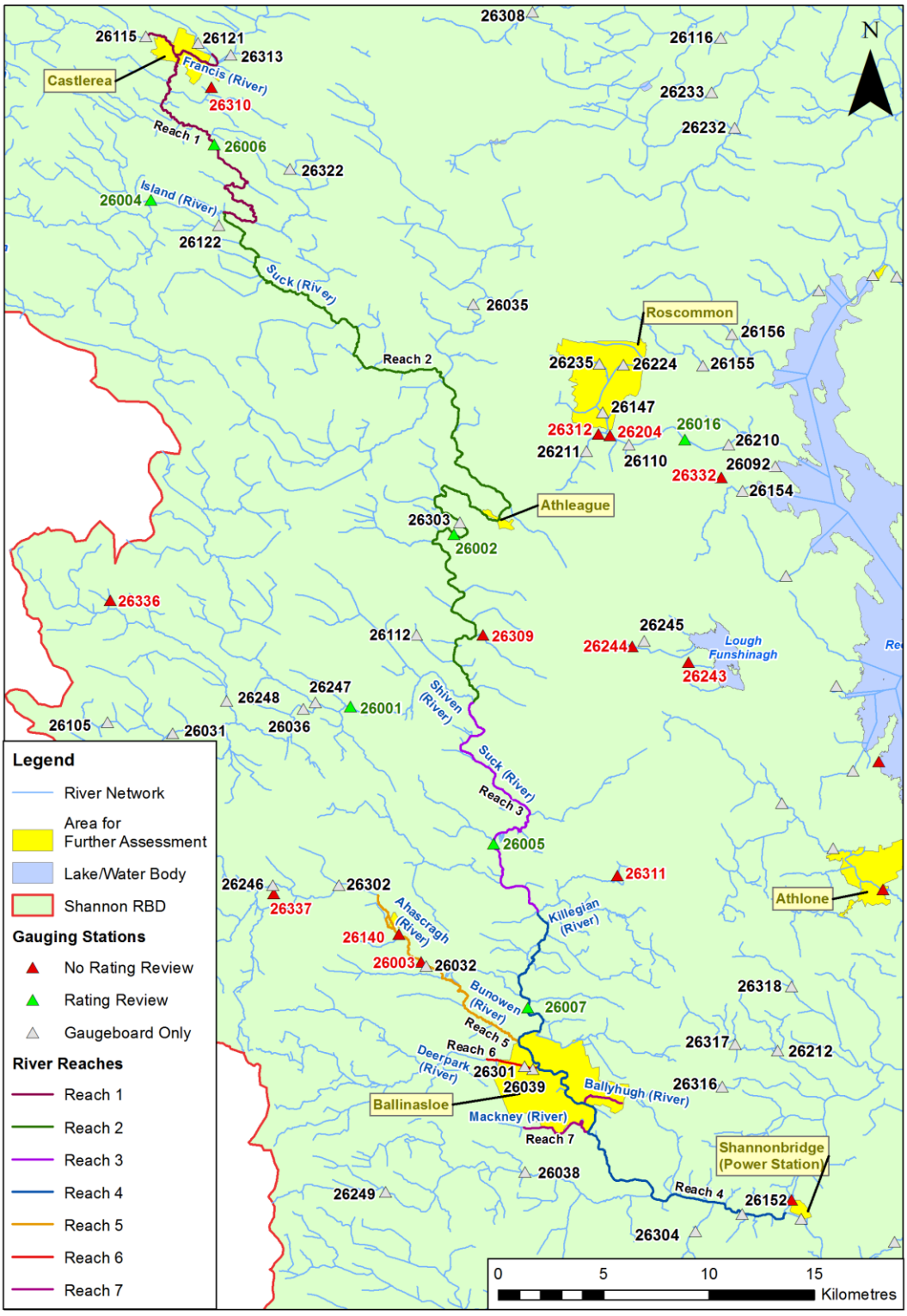


Figure A5.2 Suck Catchment River Reaches

The selection of the QMED adjustment factors, growth curves and hydrograph shapes for these reaches is detailed in Sections A5.5 to A5.7 below.

A5.5 QMED Adjustment Factors

Table A5.10 below gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED. Notes on the adjustment factor estimates are provided below the table.

Gauging station number	Reach	QMED observed (m^3/s)[1]	QMED (urban) synthetic (m^3/s)	Adjustment Factor (-)	Model Extent	Note
26006	1	26.8	25.5	1.05	N08	1
26002	2	61.0	60.1	1.01	N08	2
26005	3	87.9	99.2	0.89	N08	3
26007	4	88.2	92.5	0.95	N09	4

Table A5.10 QMED Adjustment Factors

1. Modelled rating and the existing OPW rating are very similar from 0.8xQMED to 3xQMED, and the OPW rating can be used up to the local water level of 3.29m (approximately 80 m^3/s). AMAX series (1952 to 2009) are not amended.
2. The entire AMAX series were used for QMED estimation, with the existing OPW rating retained for pre-drainage values (1952 to 1975) and revised rating curve applied to post-drainage values (1976 to 2009).
3. The existing OPW rating is retained as modelled rating showed a good agreement. AMAX series (1954 to 2009) are not changed.
4. The CFRAM rating review for this station showed that the AMAX flow series based on the OPW rating appears to be valid for the full period of record from 1952 to 2009. Only the 2009 flood peak is outside the range of check gaugings. Considering the good fit with the available check gaugings, the OPW rating is preferred over the model rating (see the rating review sheet in Appendix C).

The QMED adjustment factors for the ungauged reaches (or reaches with level gauges only) in the catchment (Reaches 5-7) were estimated using pivotal sites.

The adjustment factors for Reaches 5-7 in the N09 model extent were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A5.11-13). The use of a single pivotal site was considered but no suitable station was found that was hydrologically similar and sufficiently near to the subject site. The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: $\prod (\text{Adjustment Factor}^{\text{Weight}})$.

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
29001	RATHGORGIN	1	0.126	0.322	0.90
26010	RIVERSTOWN	2	0.142	0.285	1.03
16006	BALLINACLOGH	3	0.248	0.164	1.08
16005	AUGHNAGROSS	4	0.346	0.117	1.00
25044	KILMASTULLA	5	0.362	0.112	1.02
Weighted Geometric Mean					**1.01**

Table A5.11 QMED Adjustment Factor for HEP 26_3748_4 (Reach 5)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
16006	BALLINACLOGH	1	0.465	0.227	1.11
19020	OWENNACURRA	2	0.484	0.218	1.08
26010	RIVERSTOWN	3	0.567	0.186	1.02
25027	GOURDEEN	4	0.568	0.186	1.01
13002	COROCK	5	0.573	0.184	0.93
Weighted Geometric Mean					**1.14**

Table A5.12 QMED Adjustment Factor for HEP 26_3977_4 (Reach 6)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
25034	L. ENNELL TRIB	1	0.235	0.560	1.12
25040	BUNOW	2	1.160	0.114	0.93
10022	CABINTEELY	3	1.163	0.113	1.06

30020	DALGAN	4	1.230	0.107	0.96
16051	CLOBANNA	5	1.243	0.106	0.97
Weighted Geometric Mean					**1.03**

Table A5.13 QMED Adjustment Factor for HEP 26_3824_10 (Reach 7)

Table A5.14 shows the QMED adjustment factor applied to each reach in the catchment, with a justification for the selection of the gauging station.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	1.05	26006	Only flow gauging station in the reach. Reliable for QMED estimation
2	1.01	26002	Nearest reliable gauge to the AFA Athleague and the only in the reach. Station 26004 and 26309 located on the tributaries of the River Suck are considered inappropriate.
3	0.89	26005	Only flow gauging station in the reach. Reliable for QMED estimation.
4	0.95	26007	Only flow gauging station in the reach. Reliable for QMED estimation.
5	1.01	26140 / 26_3748_4	Station 26140 has a short level AMAX series only. Station 26003 has no AMAX series available. QMED estimation for this reach is based on geometric mean of adjustment factors at 5 pivotal sites.
6	1.14	26_3977_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
7	1.03	26_3824_10	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.

Table A5.14 QMED Adjustment Factors Applied to Each Reach

A5.6 Flood Frequency Curves

Five stations suitable for flood frequency analysis, together with two additional locations along the ungauged tributaries, were identified in the catchment: stations 26006 (Willsbrook), 26002 (Rookwood), 26005 (Derrycahill), 26007 (Bellagill), 26140 (Ahascragh Pump Hse), HEP node 26_3977_3 (Tributary Deerpark), and HEP node 26_3824_10 (Tributary Mackney). The flood frequency curves (or growth curves) are plotted in Figures A5.3 and A5.4 below. The flood frequency curve plots for all relevant stations are included in Appendix E.

The figures show the at-site AMAX series (made dimensionless by dividing the flows by QMED), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate (on a Gringorten plot). Section 2.5 in the main report describes the general selection process for the growth curve to be adopted for the study. Details for individual gauging stations are provided below.

Willsbrook Gauging Station (26006)

A rating review has been undertaken for gauge station 26006 Willsbrook. Modelled rating and OPW existing rating are very similar, and the AMAX series (from 1952 to 2009) remains unchanged. Further details are shown in the rating review summary sheet for gauging station 26006 in Appendix C.

The Willsbrook at-site and pooled growth curves are compared to check gaugings, which is shown on Figure A5.3 below.

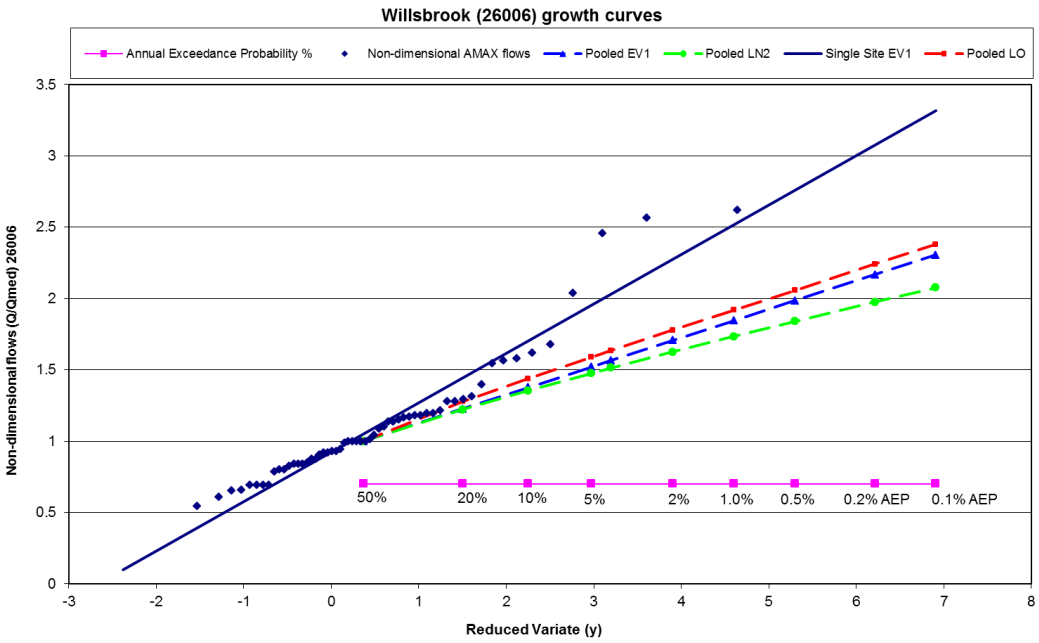


Figure A5.3 26006 Willsbrook – Flood Frequency Curves

With 58 years of reliable data the on-site data can be used directly to estimate growth factors for return periods up to approximately 29 years (1/2 N with N=58), i.e. the approximate 3% AEP flood.

Figure A3.5 shows that the pooled growth curves are much flatter than suggested by the on-site AMAX data. If any of the pooled curves would be trusted, then the 1% AEP (1 in 100 year return period) flood would have been exceeded four times during the 58 years of record.

Large parts of the catchment (mainly in the east and north) are reported as regionally important karstified aquifers, with permeability through conduits (see Figures 3.3 to 3.5 in the main report), and the Geological Survey of Ireland have surveyed a large amount of karst features within the Suck catchment, shown on Figure 3.5.

As karst features are found throughout the catchment, in accordance with the methodology described in the main report (see Section 3.5) more credence is given to at-site data than pooled data, as the latter relies on recorded flows in other catchments which are likely to have very different runoff responses.

In accordance with the recommendation in FSU report WP 2.2 two-parameter distributions were considered first. Figure A5.3 shows that the Extreme Value (EV1) distribution gives a good fit through the AMAX data.

Rookwood Gauging Station (26002)

A rating review has been undertaken for gauging station 26002 Rookwood, details of which are provided in Appendix C. The existing OPW AMAX flows from 1952 to 1975 (pre-drainage work) and the revised AMAX flows from 1976 are used for QMED estimation and flood frequency analysis.

There are 58 years of AMAX data available for flood frequency analysis. This data can be used to directly estimate growth factors with reasonable confidence for return periods up to approximately 29 years (1/2 N with N=58), i.e. the approximate 3% AEP flood. As described for Station 26006 above, the pooled distributions are considered less appropriate than a distribution for the at-site data as the catchment response can be expected to be affected by the karst geology.

In accordance with the recommendation in FSU report WP 2.2 two-parameter distributions were considered first. Figure A5.4 below shows that the EV1 distribution gives a good fit through the AMAX data.

Figure A5.4 also shows that the pooled curves are all flatter than the curve through the at-site data. The at-site EV1 growth curve suggests that the highest AMAX flow (that of November 2009) has a return period between 500 and 1000 years. The flatter pooled distributions would suggest that the return period of that event is much higher than 1000 years, which is considered excessive.

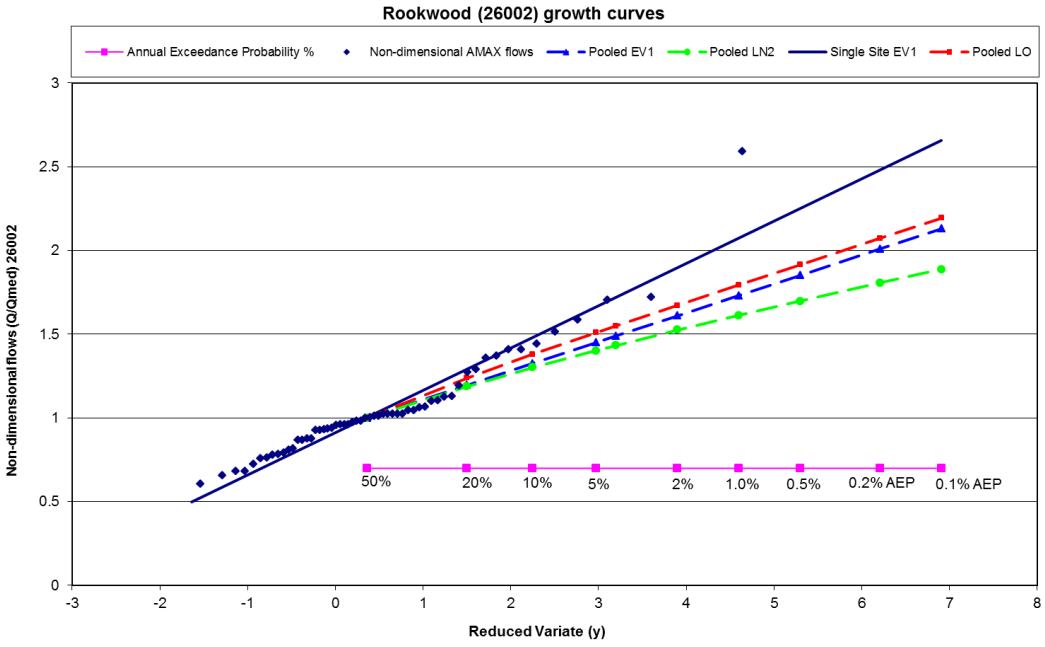


Figure A5.4 26002 Rookwood – Flood Frequency Curves

Derrycahill Gauging Station (26005)

A rating review has been undertaken for gauging station 26005 Derrycahill, details of which are provided in Appendix C. The existing OPW rating showed a good agreement with the model rating for high flows. It is therefore not considered necessary to revise the AMAX flow series.

There are 56 years of AMAX data utilised for flood frequency analysis. This data can be used to directly estimate growth factors with reasonable confidence for return periods up to approximately 28 years (1/2 N with N=56), i.e. the approximate 3% AEP flood. However, as described for Station 26006 above, for this station the pooled distributions are considered less appropriate than a distribution fitted to at-site data as the catchment response can be expected to be affected by the karst geology.

To obtain a reasonable return period for the November 2009 flood event the GLO (Generalised Logistic), LN3 (3-parameter Log-normal), GEV (Generalised Extreme Value), LO (2-parameter Logistic), LN2 (2-parameter Log-normal) and EVI (Extreme Value Type 1) distributions fitted using L-moments were further investigated, with the GLO providing the best fit with the AMAX series. The GLO distribution suggests that the 2009 flood had a return period of about 500 years, whilst the others suggest even higher return periods.

Figure A5.5 below shows that the GLO distribution provides a better fit to the AMAX data than the at-site EV1 and the pooled distributions. It is noted that the at-site GLO and EV1 distributions are similar for the range of design floods up to the 200-year return period (0.5% AEP) event.

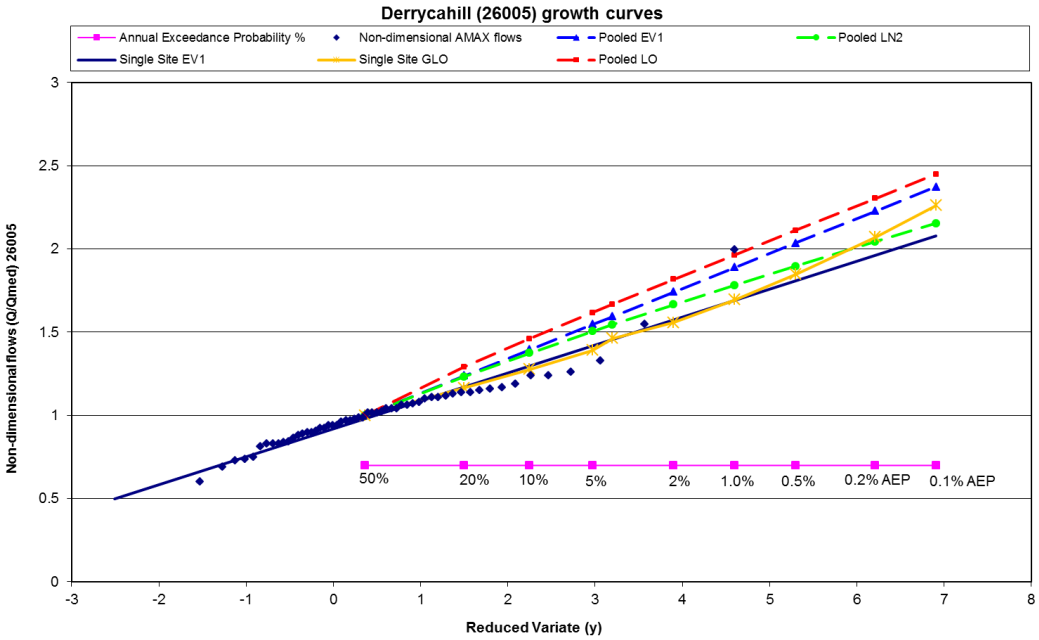


Figure A5.5 26005 Derrycahill – Flood Frequency Curves

Bellagill Gauging Station (26007)

A rating review has been undertaken for gauging station 26007 Bellagill, details of which are provided in Appendix C. The existing OPW rating showed a good agreement with check gaugings for high flows (up to 2.2xQMED). It is therefore not considered necessary to revise the AMAX flow series. A model rating was produced but its fit through the medium range check gaugings was not quite as good as the OPW rating. With the OPW rating the flood frequency curve is slightly steeper than with the model rating, but the difference can be expected to be marginal.

There are 58 years of AMAX data available for flood frequency analysis. This data can be used to directly estimate growth factors with reasonable confidence for return periods up to approximately 29 years (1/2 N with N=58), i.e. the approximate 3% AEP flood. However, as described for Station 26006 above, for this station the pooled distributions are considered less appropriate than a distribution fitted to at-site data as the catchment response can be expected to be affected by the karst geology.

The EV1 and GLO distributions fitted to the at-site data were compared and contrasted with the November 2009 flood peak, see Figure A5.6 below. The GLO curve fits better to the recorded AMAX than the at-site EV1 and pooled distributions, and gives a more reasonable return period to the November 2009 flood (300-400 years). It is noted that the at-site GLO and EV1 distributions give similar growth factors for peak flows up to the 100-year return period (1% AEP) event.

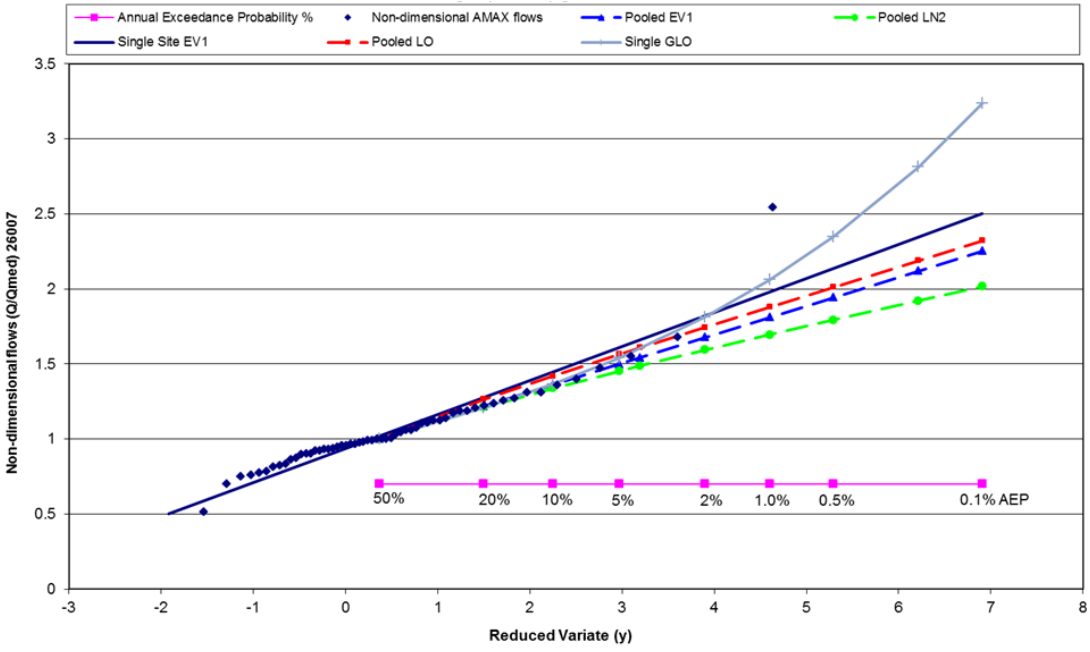


Figure A5.6 26007 Bellagill – Flood Frequency Curves

River Reach Flood Frequency

(i) Flood Frequency Curve Reach 1

Station 26006 (Willsbrook) is the only reliable station for flood frequency analysis within the reach. Growth curves derived from the at-site data and those from pooled analysis are shown in Figure A5.3. The EV1 distribution fitted to the at-site AMAX data has been adopted for Reach 1.

(ii) Flood Frequency Curve Reach 2

Station 26002 (Rookwood) is the only reliable station for flood frequency analysis within the reach. Figure A5.4 shows the single site EV1 curve to provide a better fit with the recorded AMAX data than pooled curves derived from this site. The at-site EV1 has been adopted.

(iii) Flood Frequency Curves Reach 3

Station 26005 (Derrycahill) is the only reliable station for flood frequency analysis within the reach. At-site and pooled growth curves were compared and shown in Figure A5.5. The at-site GLO curve fits best with the at-site AMAX data and suggests a believable return period for the November 2009 event, and has been adopted for Reach 3.

(iv) Flood Frequency Curves Reach 4

Station 26007 (Bellagill) is the only reliable station for flood frequency analysis within the reach. At-site and pooled growth curves were compared and shown in Figure A5.6. The at-site GLO curve fits best with the at-site AMAX data and suggests a believable return period for the November 2009 event, and has been adopted for Reach 3.

(v) Flood Frequency Curves Reach 5

Station 26140 Ahascragh Pump Hse and station 26003 on Reach 5 have no or insufficient reliable data for flood frequency analysis. Instead, pooled analysis at station 26140, the closer station to the AFA Ahascaragh, was undertaken and the resulting pooling group of 519 years of data is considered suitably homogenous. A representative growth curve EV1 was obtained and adopted for Reach 5.

(vi) Flood Frequency Curve Reach 6

No gauging station for flood frequency analysis is present within Reach 6. Instead, pooled analysis at HEP node 26_3977_3 was undertaken. The resulting pooling group of 517 years of data is considered suitably homogenous. A represented growth curve EV1 was obtained and adopted for Reach 6.

(vii) Flood Frequency Curve Reach 7

No gauging station for flood frequency analysis is present within Reach 7, two small tributaries. Instead, pooled analysis at HEP node 26_3824_10 was undertaken. The resulting pooling group of 517 years of data is considered suitably homogenous. A represented growth curve EV1 was obtained and adopted for Reach 6.

(viii) Conclusion

The growth curve distributions applied to the relevant reaches are shown in Table A5.15. Growth factors generated for a range of AEPs have been detailed in Table A5.16.

Reach	Station	Single Site or Pooled	Selected distribution
1	26006 – Willsbrook	Single Site	EV1
2	26002 – Rookwood	Single Site	EV1
3	26005 – Derrycahill	Single Site	GLO
4	26007 – Bellagill	Single Site	GLO
5	26140 – Ahascragh Pump Hse	Pooled	EV1
6	Ungauged 26_3977_3	Pooled	EV1
7	Ungauged 26_3824_10	Pooled	EV1

Table A5.15 Final Growth Curves Selected

Annual Exceedance Probability (%)	Growth Factors Reach 1	Growth Factors Reach 2	Growth Factors Reach 3	Growth Factors Reach 4	Growth Factors Reach 5	Growth Factors Reach 6	Growth Factors Reach 7
50%	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20%	1.45	1.29	1.16	1.21	1.21	1.26	1.35
10%	1.71	1.48	1.28	1.37	1.34	1.43	1.58
5%	1.95	1.66	1.39	1.54	1.47	1.59	1.81
2%	2.28	1.90	1.56	1.81	1.64	1.80	2.10
1%	2.52	2.08	1.69	2.06	1.77	1.96	2.31
0.5%	2.76	2.25	1.85	2.35	1.89	2.12	2.53
0.1%	3.32	2.66	2.26	3.23	2.18	2.49	3.03

Table A5.16 Final Growth Factors Applied to the Suck Catchment

Table A5.16 allows for the comparison of the growth factors (e.g. for the 1% AEP design flood) for the different reaches along the main River Suck (Reaches 1-4) and the tributaries (Reaches 5-7).

For the main stem it is noted that the 1% AEP peak flows for Reaches 2 and 4 are similar, and that the peak flow for Reach 1 is much higher, and for Reach 3 much lower than those for Reaches 2 and 4. This could indicate that the growth curves for Reaches 1 and 3 are less reliable than the others. However, as the growth curves are based on actual observed data it was decided to retain these growth curves. The varying results may be partly caused by an atypical

catchment response affected by locally highly permeable areas including karst features.

For the tributaries there appears to be a trend for flatter growth curves for larger catchments, which is a trend that can be observed in the overall FSU dataset for small catchments, as shown in Figure A5.7 below. L_{cv} in the figure is a measure for how spread out the AMAX series is, and therefore a measure for the steepness of the growth curve.

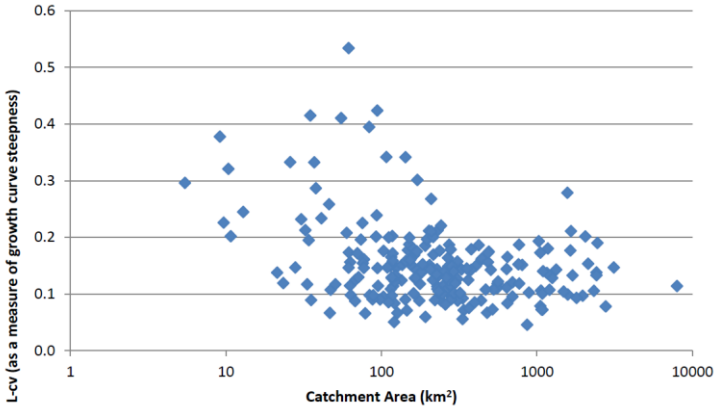


Figure A5.7 L_{cv} versus Catchment Area for FSU Gauged Stations

A5.7 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

Station 26006 Willsbrook is the logical choice for Reach 1 as it is the only reliable gauge within the reach and the closest to the AFA Castlerea.

Station 26002 Rookwood is the closest station to AFA Athleague and is the only reliable choice for Reach 2. Hydrograph derived from this site is also applied to Reach 3 within N08 model extent

Station 26007 Bellagill is considered suitable for hydrograph shape extraction for Reach 3 and 4 within the N09 and N10 model extents, as this site is the closest reliable gauging station around Ballinasloe.

Following event data supplied by OPW, station 26003 Ballinruane is a suitable station for the hydrograph shape derivation for Reach 5. The hydrograph shape is also applied to Reach 6 as Station 26003 is a reliable gauging station in a neighbouring catchment with similar catchment descriptors.

As there is no suitable flow gauging station on Reach 7 (Tributary Mackney and Tributary Ballyhugh), the OPW hydrograph generator was used to establish an appropriate hydrograph shape from a hydrologically similar pivotal site. Station 13002 is selected as an appropriate pivotal site for hydrograph shape of those two tributaries.

Table A5.17 summaries the reaches distinguished for the design event hydrograph shape selection and the flow gauging station used for each reach.

Reach	Gauging Station
1	26006 – Willsbrook
2 - 3 (N08 only)	26002 – Rookwood
3 (N09 only) – 4	26007 – Bellagill
5 - 6	26003 – Ballinruane
7	13002 – Foulk's Mill (pivotal)

Table A5.17 Hydrograph Shape Sub-Reaches – Gauging Stations

Tables A5.19–21 and Figures A5.8–11 show the highest flood events chosen for comparison at stations 26006, 26002, 26007 and 26003. The hydrographs in Figures A5.8-11 are presented in a non-dimensional manner by dividing flows by their respective flood peaks. The hydrograph that best represents a typical or median storm duration has then been selected as the representative design hydrograph shape.

The hydrograph widths are visually compared at 0.8xQpeak.

Date	Peak Flow (m^3/s)	Comments
20/11/2009	65.73	
29/11/1999	45.23	
09/01/2005	34.92	
01/02/2009	31.26	Selected for hydrograph shape

Table A5.18 Highest Flood Peaks for Gauging Station 26006

The February 2009 historic flood hydrograph was selected for station 26006. Figure A5.8 shows that this event is a good representation of the median of the four highest hydrographs.

Date	Peak Flow (m^3/s)	Comments
21/11/2009	161.16	
26/12/1990	84.76	
26/12/1999	88.34	Selected for hydrograph shape
08/02/1990	85.81	

Table A5.19 Highest Flood Peaks for Gauging Station 26002

The December 1999 historic flood hydrograph was selected for station 26002. Of the five highest events the second longest hydrograph was selected (at 0.8xQpeak), see Figure A5.9.

Date	Peak Flow (m^3/s)	Comments
21/11/2009	224.27	
26/12/1999	124.70	
08/02/1990	120.34	
08/02/2002	116.74	
11/11/1977	111.72	Selected for hydrograph shape

Table A5.20 Highest Flood Peaks for Gauging Station 26007

Figure A5.10 shows that the rising limb for the second longest event at station 26007 was unusually long, with the risk that this event is not representative. The fifth highest event, November 1977 event, was then included for comparison. The 1977 event is the third longest, and median in total length and rising limb length, and therefore was selected as an appropriate hydrograph shape for the design hydrographs.

Date	Peak Flow (m^3/s)	Comments
10/11/1977	28.99	Selected for hydrograph shape
22/01/1975	23.77	
09/09/1974	19.69	
28/04/1977	19.44	

Table A5.21 Highest Flood Peaks for Gauging Station 26003

As shown in Figure A5.11 the November 1977 event (the second longest) is considered to be a good proxy for the median flood duration.

Figure A5.12 shows the hydrograph shape derived from pivotal station 13002 using the OPW hydrograph generator, adopted for Reach 7.

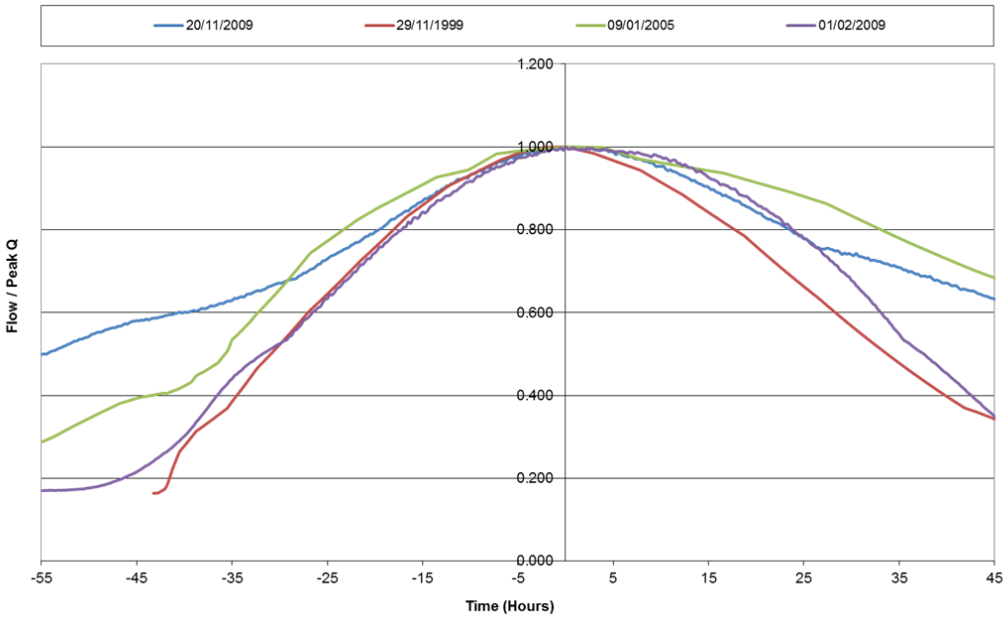


Figure A5.8 Non-dimensional Hydrographs for Gauging Station 26006

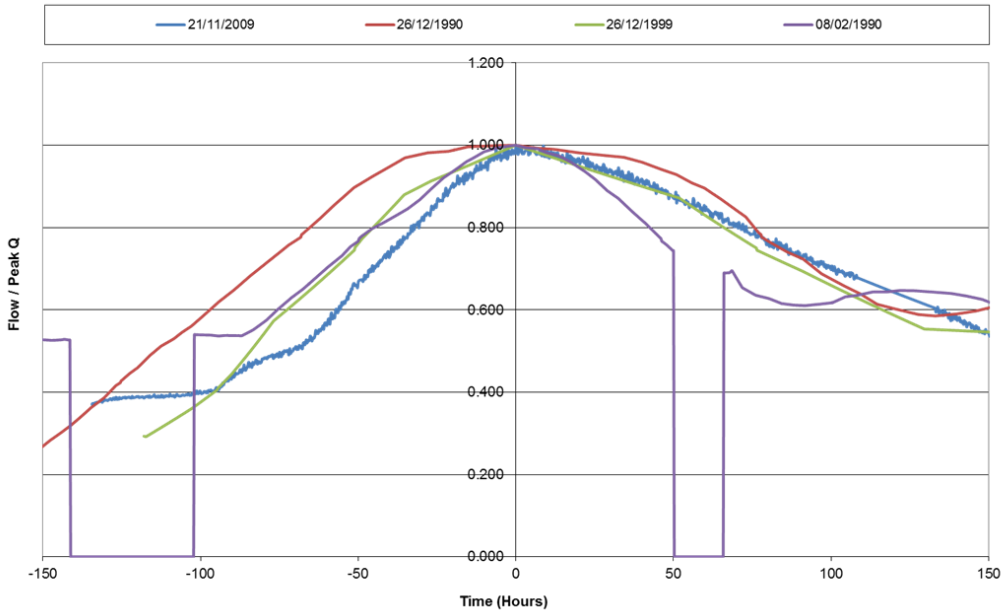


Figure A5.9 Non-dimensional Hydrographs for Gauging Station 26002

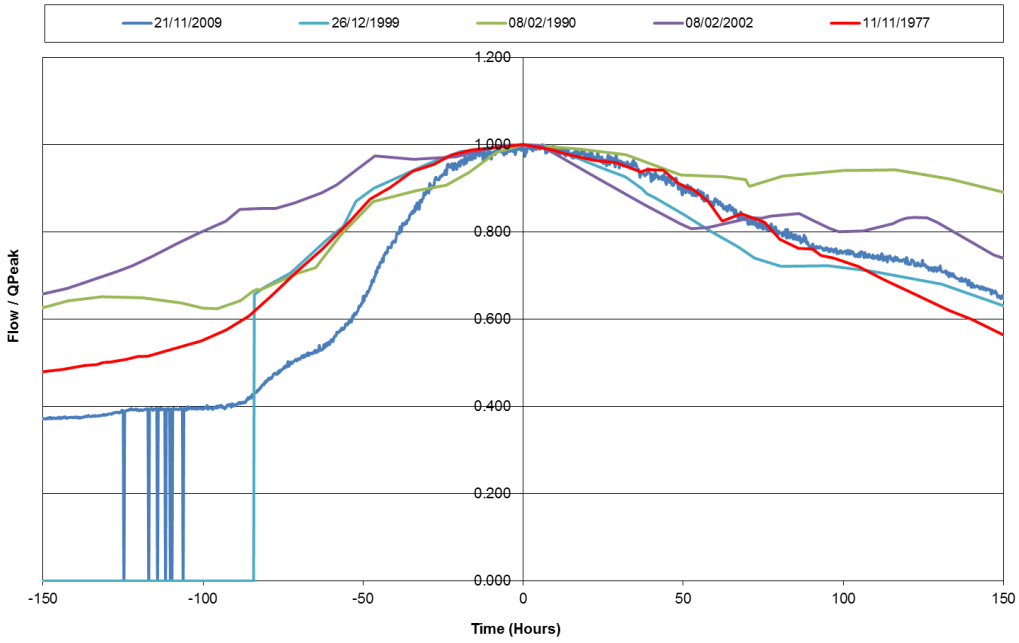


Figure A5.10 Non-dimensional Hydrographs for Gauging Station 26007

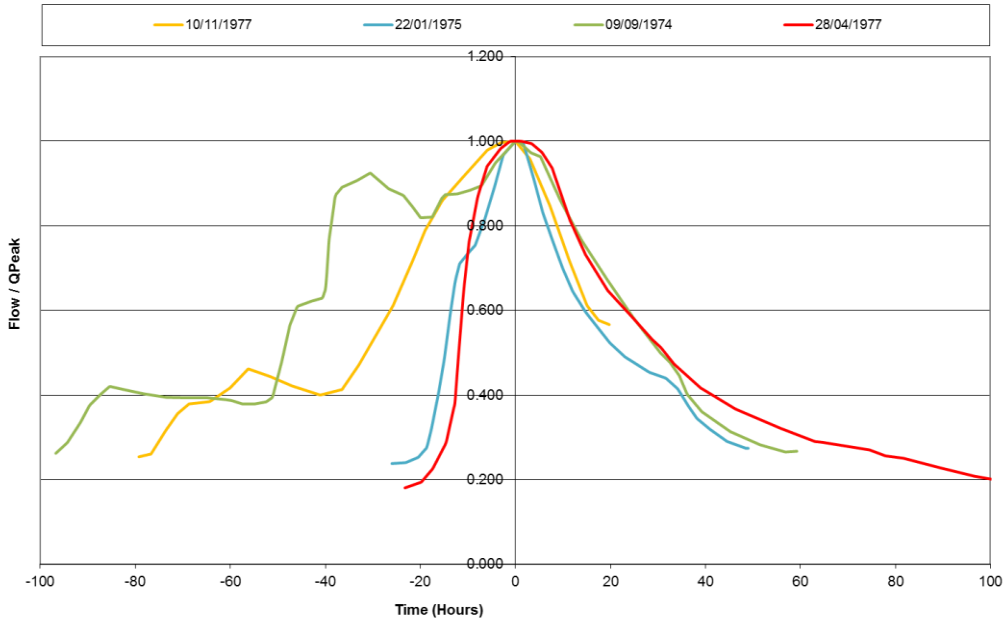


Figure A5.11 Non-dimensional Hydrographs for Gauging Station 26003

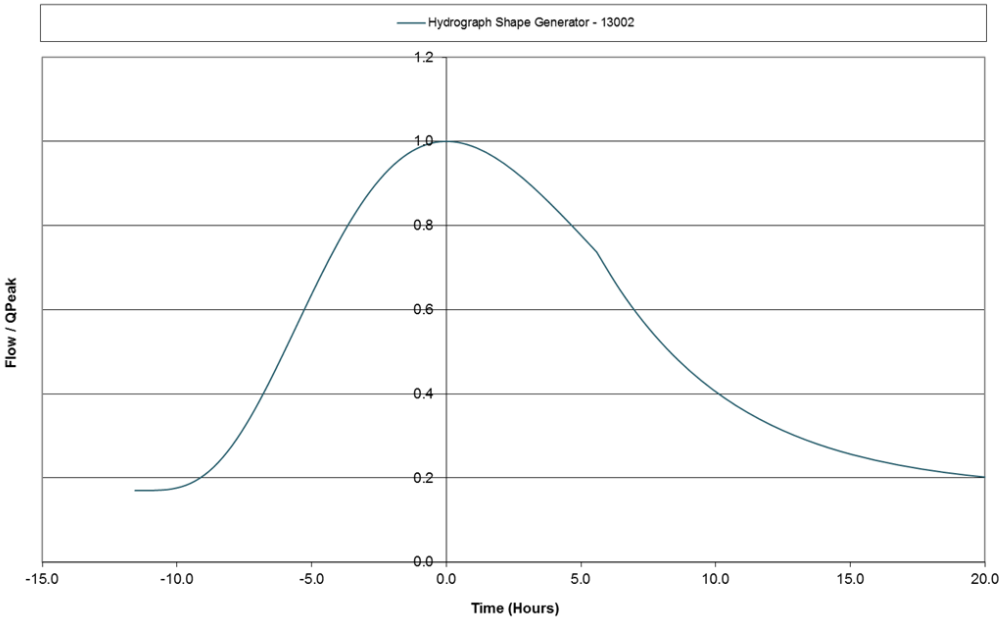


Figure A5.12 Non-dimensional Hydrographs for Pivotal Station 13002

A5.8 Flows and Hydrological Estimation Points

The design flood estimation is described in Sections 2.3 to 2.5 and Section 2.7.2 of the main report. The resulting inflows at individual HEPs for each model are provided in Appendix B.

A5.9 Calibration

The calibration and verification of hydraulic models is discussed in Section 2.7.3 of the main report. Model specific information is provided in Appendix B.

A6 Lower and Middle Shannon Catchment

A6.1 Catchment Description

This report summarises the hydrological work carried out for the hydraulic modelling on the Lower and Middle Shannon downstream of (and including) Lough Ree. It reports on the hydrological analysis undertaken for the main Shannon and modelled tributaries not included in the other sub catchments reported on in Chapters A1-A5 and A7-A10. The general description of the Lower and Middle Shannon catchment (see Figures A6.1a/b/c) is given in Table A6.1.

Parts of modelled river sections in other units of management in and around the urban area of the Limerick City AFA (UoM 24 and 27) have been included in the N16 model in this catchment to ensure continuity in the assessment of flood risk in the Limerick area.

Attribute	Description
Unit of Management (UoM)	25/26
Main watercourses / water bodies (entire Shannon Catchment)	River Shannon Lough Ree Lough Derg River Hind Rivers Owenacharra/Inny River Suck River Brosna River Little Brosna River Mulkear
Outflow point	Shannon Estuary
Total catchment area	11,600 km^2 (entire catchment to Shannon Estuary outflow)
Areas for Further Assessment (AFAs) (excluding AFAs in separately studied subcatchments)	Athlone, Portumna, Killaloe/Ballina, O'Briens Bridge, Shannon Harbour, Castleconnell, Springfield, Limerick City
Individual Risk Receptors (IRRs) (excluding IRRs in separately studied subcatchments)	Shannonbridge and Lanesboro Power Station
Model Extents*	N10 (downstream of and including Lough Ree), N12 (part) and N16 (part)
General topography	Min altitude = 0 m AOD Max altitude = 690 m AOD The upstream boundary of this catchment is delineated to the north by Lough Ree and to the east and west by rolling hills, with water draining in towards a large plain forming the central lowlands. The central lowlands are gently undulating. The Arra Mountains and Slieve Bernagh rise up steeply around the southern extent of Lough Derg, the largest lough in the Shannon basin. Eskers, relicts of the last glaciation, cross the river basin from east to west e.g. the low-lying hills at Clonmacnoise (between Athlone and Shannonbridge) and

	along with drumlins provide ideal environments for the formation of bog. Localised sediment accumulation has resulted in the formation of varying sized water bodies across the central plain. The downstream boundary of the catchment is where the River Shannon joins the Shannon Estuary at Limerick City draining out into the Atlantic Ocean.
Average annual rainfall**	885 mm to 1247 mm
Soils and geology (entire Shannon catchment)	Subsoils comprise primarily peat and low to moderate permeability glacial tills over predominantly limestone and sandstone bedrock with minor shale, siltstone and mudstone. Extensive peat deposits occur predominantly over areas of higher ground and in the region between Lough Ree and Lough Derg. Glacial sands and gravels also occur within the till between Lough Ree and Lough Derg and to the south of Lough Derg and form locally important gravel aquifers. Alluvial deposits occur throughout, associated with existing watercourses. Limestone bedrock predominates and is both a locally important bedrock aquifer over much of the Shannon catchment area and a regionally important karstified aquifer north and west of Lough Ree, between Borrisokane and Kilbeggan and south of Lough Derg between Ardnacrusha and Oola. Limestone bedrock forms isolated surface outcrops within the till east of Lough Derg and west of Lough Ree. Sandstone bedrock forms the higher ground around Lough Allen, between Lough Key and Lough Garra, to the south and west of Lough Derg where it occurs at or close to surface and forms a poor bedrock aquifer. Elsewhere the sandstone and other bedrocks are predominantly locally important aquifers. Refer to Figure 3.3 in the Main Report for the hydrogeological characteristics of the underlying rock formations. Poorly drained soils and peat predominate in areas of higher ground and where bedrock is at or close to surface with well drained soils covering much of the rest of the Shannon catchments. Refer to Figure 3.4 in the Main Report for the distribution of differing soil drainage classes.
Urban areas	The urban areas within the Lower and Middle Shannon catchment include the towns of Athlone, Shannon Harbour, Portumna, Killaloe/Ballina, O'Briens Bridge, Castleconnell, Springfield and Limerick City, all of which are located on the River Shannon. Locally these settlements raise URBEXT values on the small tributaries rivers draining through the towns. However, the influence of these urban tributaries on URBEXT values on the River Shannon is limited, as the urbanisation of the entire River Shannon catchment is low.

Loughs and canals	There are two large loughs along the Lower and Middle River Shannon, namely Lough Ree and Lough Derg. The water levels on Lough Ree and Lough Derg are managed by the ESB. The outflows from Lough Ree and Lough Derg are regulated by large weir structures, Athlone Weir and Parteen Weir respectively. The canal system along the River Shannon, known as the Shannon Navigation, is under the authority of Waterways Ireland. Waterways Ireland operate a number of lock and weir structures along the River Shannon (e.g. Clarendon Lock, Victoria Lock, etc.) to maintain suitable water levels along the Shannon for boat navigation. The Head Race Canal diverts flow from the River Shannon at Parteen Weir to the Ardnacrusha Power Station. The flow from the power station re-joins the tidal Shannon at Parteen Bridge through the Tail Race Canal.

* Specific hydrological details for the models are provided in Chapters B10, B12 and B16 in Appendix B
** range of SAAR values taken from the FSU catchment descriptors covering the extent of modelling

Table A6.1 Lower and Middle Shannon Catchment Description

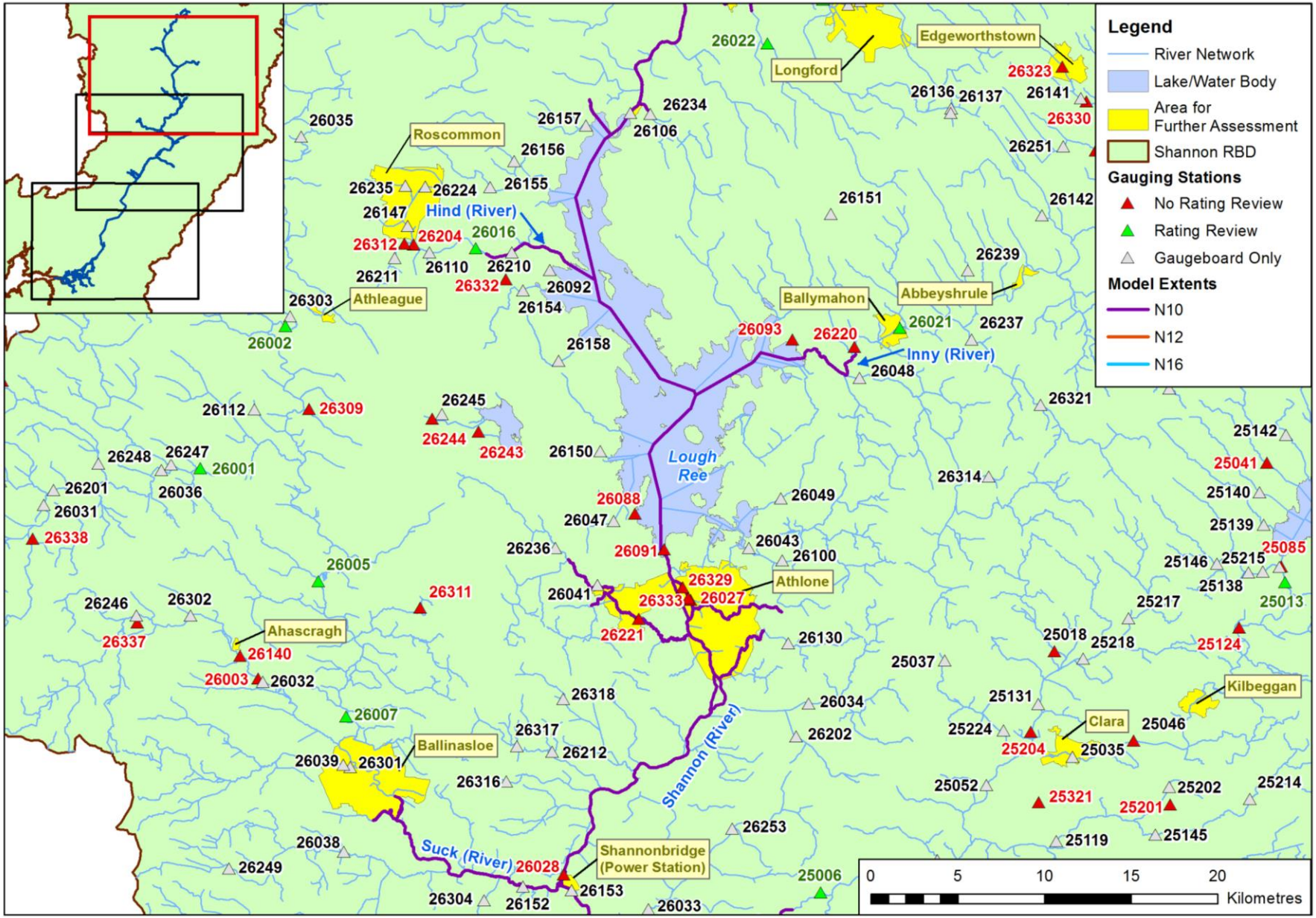


Figure A6.1a Lower and Middle Shannon Catchment with Model Extents (North)

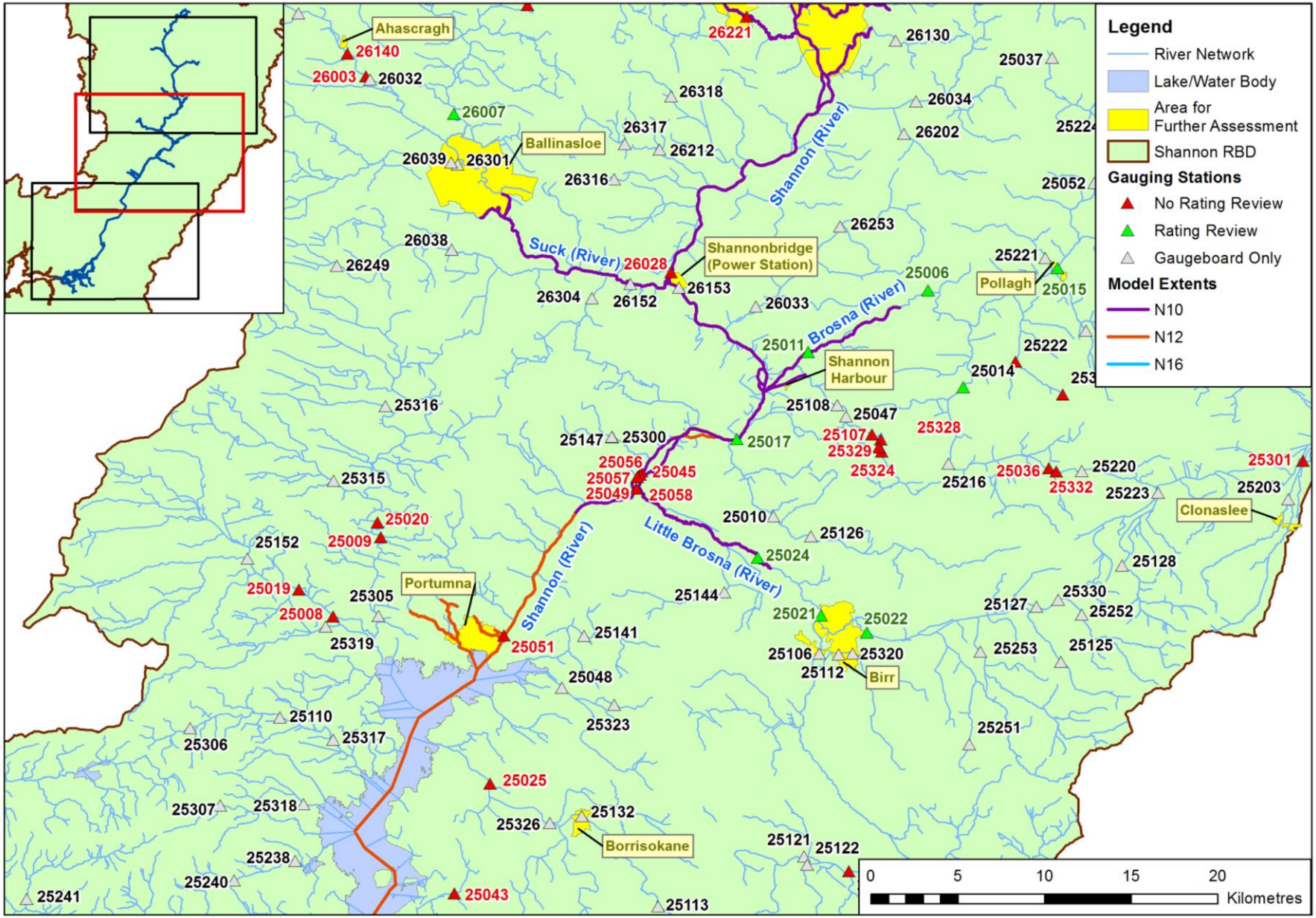


Figure A6.1b Lower and Middle Shannon Catchment with Model Extents (Central)

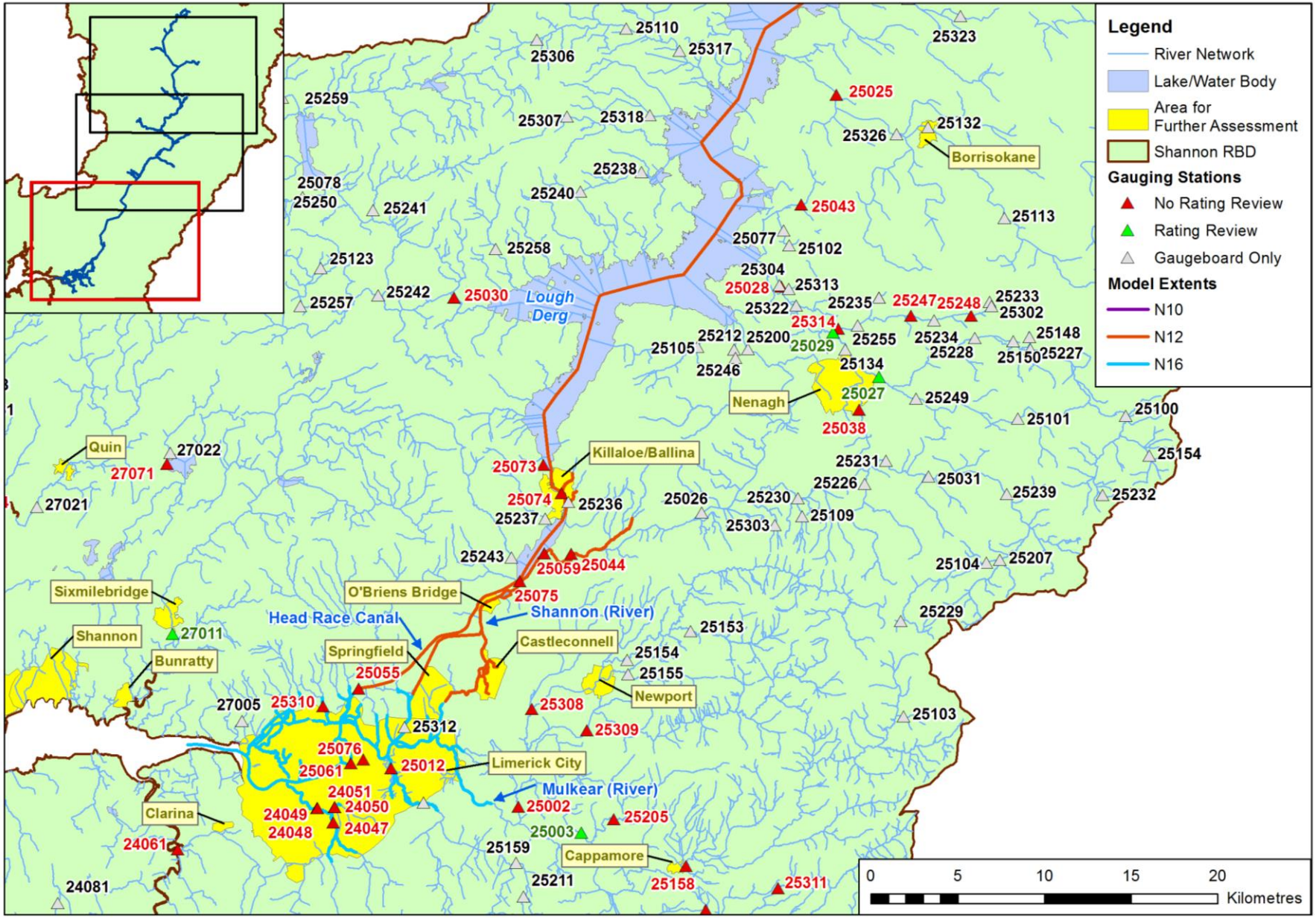


Figure A6.1c Lower and Middle Shannon Catchment with Model Extents (South)

A6.2 Hydrometric Stations in the Lower and Middle Shannon Subcatchment

Details of the gauging stations in the Lower and Middle Shannon subcatchment are tabulated in Table A6.2. They are also shown on Figures A6.1a/b/c.

The gauging stations in the modelled subcatchments contributing to the Lower and Middle Shannon (Upper Shannon, Inny, Hind, Brosna, Suck, Little Brosna, Ballyfinboy, Nenagh and Mulkear) are listed in the Appendix A chapters for each of these respective subcatchments and not repeated in Table A6.2. Some gauging stations that are not on any model extents were found to be irrelevant for flood estimation on the model extents and have also been omitted from Table A6.2.

Model	Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments
N10	25017	Banagher	1950 to date	Level and flow	A1 HGF/QMED= 1.51	Yes	1
	25049	Victoria Lock D/S	1932 to date	Level only	N/A	No	2
	25056	Meelick Weir U/S	1985 to date	Level only	N/A	No	
	25057	Meelick Weir D/S	N/A	Level only	N/A	No	3
	25058	Victoria Lock U/S	1932 to date	Level only	N/A	No	2
	26027	Athlone	1952 to date	Level and flow	HGF/QMED = 1.75	No	
	26028	Shannonbridge	1954 to date	Level only	N/A	No	
	26221	Summerhill	2001 to date	Level and flow	HGF/QMED = 0.8	No	4
	26329	Athlone Intake	2008 to ?	Level and flow	N/A	No	5
	26333	Athlone Weir U/S	2003 to date	Level only	N/A	No	6
N12	25044	Coole	1961 to date	Level and flow	HGF/QMED = 0.8	No	7
	25051	Portumna	1932 to date	Level only	N/A	No	2
	25059	Fort Henry Bank	-	Level only	N/A	No	2
	25073	Ballyvalley	1997 to date	Level only	N/A	No	2
	25074	Killaloe	1932 to date	Level only	N/A	No	2
	25075	Parteen Weir	1932 to date	Level and flow	N/A	No	
N16	25012	Groody Bridge	1972 to date	Level only	N/A	No	8
	25055	Ardnacrusha	-	Level and flow	N/A	No	9
	25310	Knockalisheen	2003-2004	Level only	N/A	No	10
	25061	Ball's Br.	1957 to date	Level only	N/A	No	
	25076	Parklock	1980-2005	Level only	N/A	No	11
	24047	Rossbrien Rly Br.	1998 to date	Level only	N/A	No	12
	24048	Ballinacurra D_S	1998 to date	Level only	N/A	No	
	24049	Ballinacurra U_S	1998 to date	Level only	N/A	No	

Model	Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments
	24050	Ballinacurra Gardens	1998-2000	Level only	N/A	No	10
	24051	Huntsfield	1998-2000	Level only	N/A	No	10
	25075	Parteen Weir	1932 to date	Level and flow	HGF/QMED = 1.5	No	13

Table A6.2 Lower and Middle Catchment Gauging Stations

Table A6.2 Hydrometric Data Quality Comments:

1. The rating review of gauging station 25017 showed that the existing OPW rating is reliable for high flows and is therefore appropriate for flood flow estimation on the River Shannon.
2. ESB level gauge without rating. No period of record specified for station 25059.
3. According to the EPA Hydrometric gauging station data register gauging station 25057 was active between 1985 and 1994. However, OPW has confirmed that there is no hydrometric data available for this site.
4. Quality checks at gauging station 26221 revealed that the site had a weir removed in 2005 resulting in a slight reduction in flow estimates. However, the site was deemed suitable for flow estimates up to QMED based on available check gaugings before and after the weir removal.
5. No record end date is provided, but this station is recorded as 'inactive' with a start date in 2008. It is understood that this gauging station is monitoring the inflows to a drinking water intake for Dublin County Council and therefore irrelevant for flood estimation on the River Shannon.
6. Gauging station 26333 is a level only station with a short record from 2003.
7. Gauging station 25044 was deemed suitable for estimation of flows up to 0.8 x QMED based on a review of the check gaugings and AMAX flow data for the site.
8. Station 25012 is a level gauge without rating.
9. ESB provided daily flow records from January 1970 for Parteen Weir, split up in the flow into the Head Race Canal and the flow into the River Shannon.
10. Inactive gauging stations with very short records. Therefore, these stations could not be used for flood estimation.
11. 25076 is a level gauge without rating.
12. Station 24047 is recorded as a flow and level gauge, but it is believed to be a level gauge only. No flow data has been made available for this station.
13. Station 25075 (Parteen Weir) is located at the downstream end of Parteen Basin, which was formed as part of the Ardnacrusha Power Station development. Parteen Basin is effectively a southern extension of the natural Lough Derg. Flows are affected by lake storage and the operation of sluices (discussed below).

At Parteen Weir, during non-flood conditions most of the flow from the River Shannon is diverted to the Ardnacrusha Power Station through the Head Race Canal. A flow of approximately 10 m^3/s is retained in the River Shannon downstream of Parteen Weir. The flow from the power station re-joins the tidal River Shannon at Parteen Bridge, through the Tail Race Canal.

During floods the flow in the Head/Tail Race Canal system can be increased to 400 m^3/s, but during the highest flood of November 2009 only 345 m^3/s was diverted to it. The rest of the flood flow is directed to the River Shannon. It is noted that the QMED (2-year return period) flow for the total runoff from Lough Derg at Parteen Weir is estimated as 544 m^3/s, which is well above the Head Race Canal's maximum allowable flow. Therefore, for the full range of flood return periods considered in the CFRAM study the peak flows through the Head Race Canal can

be considered equal to the maximum allowable flow. In this study a conservatively low value of 345 m^3/s was adopted for the maximum flow through the Head Race Canal for all return periods. This is conservative because adopting a slightly lower flow in the Head Race Canal causes a slightly higher flow in the lower River Shannon, which is where flooding could occur.

A6.3 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A6.2 above.

The river reaches are tabulated in Table A6.3. The node numbers and river names can be found on the model extent maps in Appendix B (Chapters B10, B12 and B16 for models N10, N12 and N16 respectively). The reaches are shown on Figures A6.2a/b/c below.

Canals have not been included in the list of reaches as none of them have a significant catchment draining to them. The canals in the study area include: (downstream of Lough Derg) the Head Race/Tail Race Canals (conveying runoff to/from Ardnacrusha Power Station) and the Drummeen Canal, and (upstream of Lough Derg) the Grand Canal, Portumna Canal, Boranagh Canal and Athlone Canal.

The variation in catchment descriptors for each reach is tabulated in Tables A6.4 to A6.36 below.

Reach	Description	Model Extent
1	Shannon - Lough Ree to Suck confluence (26_3922_1 to 26_1450_3)	N10
2	Shannon - Suck to Brosna confluences (26_1448_1 to 25_927_1)	N10
3	Shannon - Brosna to Lough Derg (25_700_1 to 25_655_4)	N10/N12
4	Derryloughbannow River (26_1469_1a to 26_1469_3)	N10
5	Culiaghy tributary (26_2818_1 to 26_2818_2)	N10
6	Garrycastle tributary (26_784_1a to 26_4030_4)	N10
7	Cross (26_676_1 to 26_1111_3)	N10
8	Cuilglass tributary (26_1459_1 to 26_1459_4)	N10
9	Fardrum tributary (26_3750_1 to 26_293_2)	N10
10	Fairyhill tributary (25_3708_0a to 25_3708_4)	N12
11	Deerpark and Lickmolassy (25_811_1a/25_3471_0a to 25_2616_4)	N12
12	Drumbane tributary (25_1019_1 to 25_1019_4)	N12
13	Grange tributary (25_2360_4 to 25_2360_6)	N12

Reach	Description	Model Extent
14	Unnamed tributary to River Killmastulla (25_864_1 to 25_783_3)	N12
15	Killmastulla (25_3881_1 to 25_3881_9)	N12
16	Shannon - Lough Derg outflow to Shannon Estuary (25_3837_1 to 25_1201_3)	N12/N16
17	Stradbally East and Cederwood tributary (25_3823_6a/8a to 25_3823_6b/8b)	N12
18	Cappavilla (25_1205_1 to 25_1205_4)	N16
19	Blackwater (25_3825_1 to 25_3329_2)	N16
20	Shannakyle (25_2824_1 to to 25_2824_5)	N16
21	Groody (25_3858_3a to 25_2822_2)	N16
22	Towlerten (25_3605_1a to 25_1222_2)	N16
23	Ballykeelaun (25_2823_1 to 25_2823_5)	N16
24	Coolnallira (25_1150_2 to 25_1150_4)	N16
25	Parteen (25_181_2)	N16
26	Ballycannan (25_185_3 to 25_2411_5)	N16
27	Ballygrennan (25_186_1a to 25_3896_2)	N16
28	Clonmacken (27_54_1a, 27_345_1a, 27_53_1a to 27_54_3)	N16
29	Ballynaclogh (24_1850_5a to 24_1580_6)	N16
30	Ballincurra (24_121_8 to Shannon Confluence)	N16
31	Ballysheedy (24_1720_3a to Ballincurra Creek Confluence, 24_1720_4)	N16
32	Upper Crompaun (upstream of node 27_275_2)	N16
33	Lower Crompaun (downstream of node 27_275_2)	N16

Table A6.3 River Reaches in the Catchment

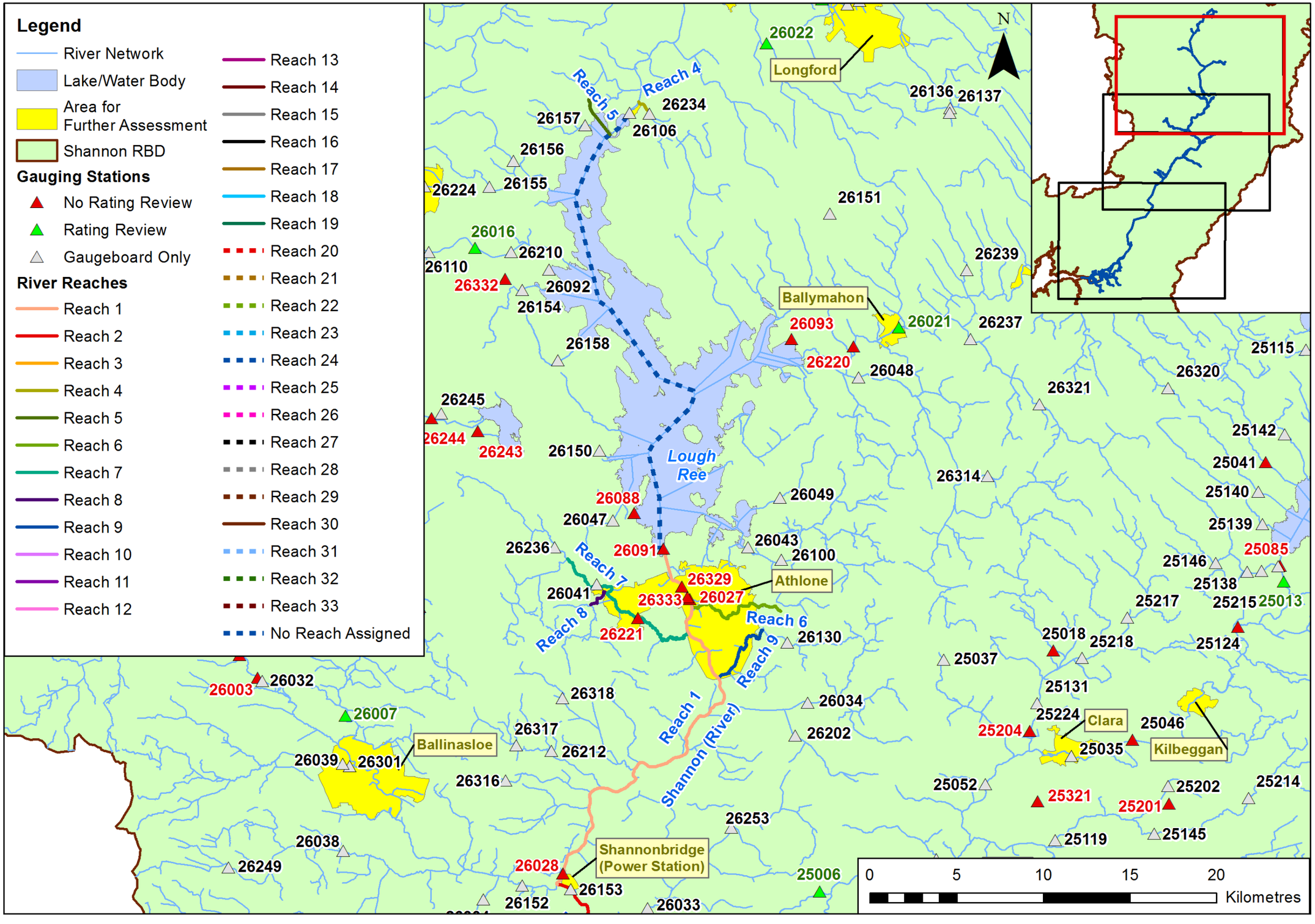


Figure A6.2a Lower and Middle Shannon Model Reaches (North)

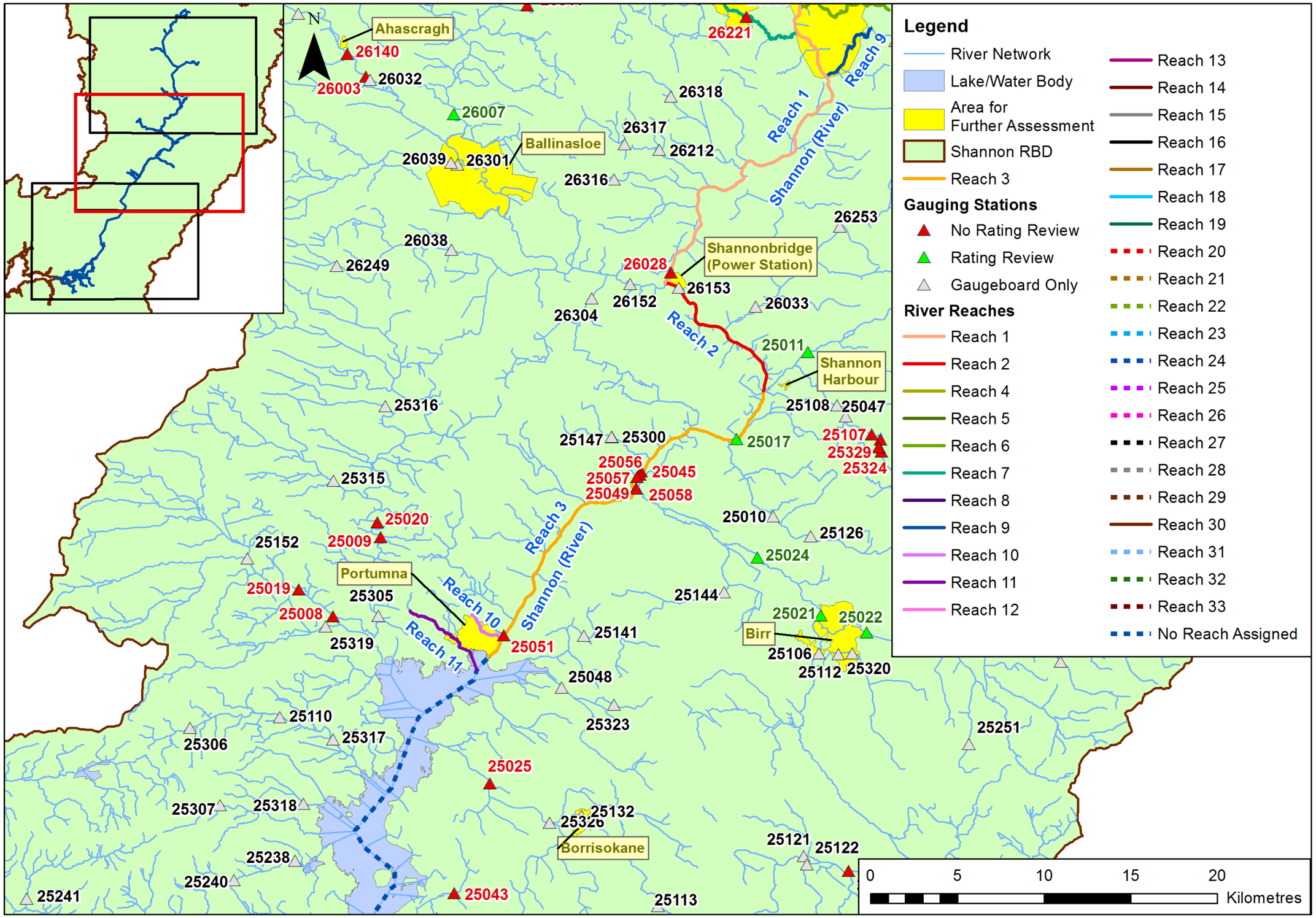


Figure A6.2b Lower and Middle Shannon Model Reaches (Central)

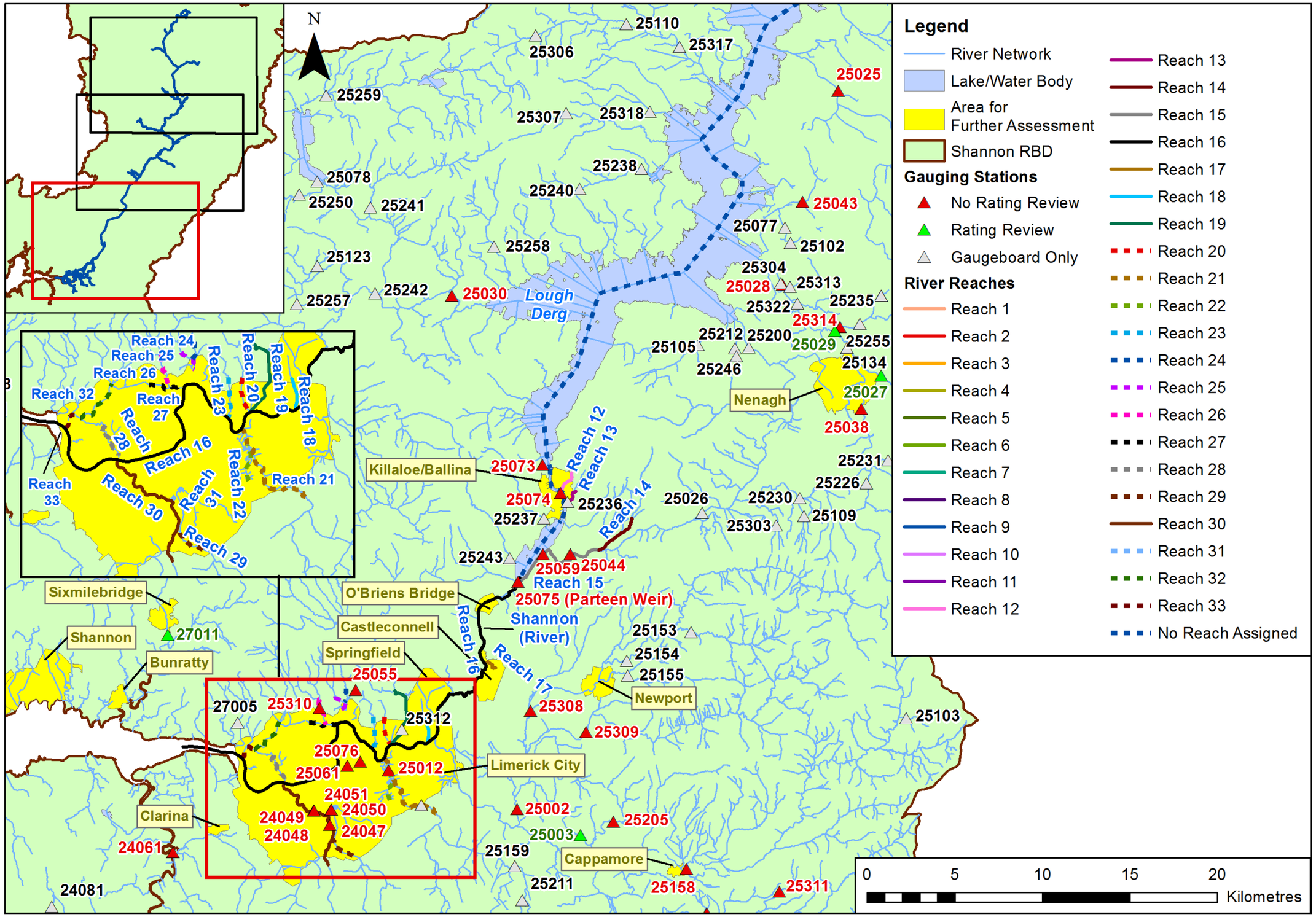


Figure A6.2c Lower and Middle Shannon Model Reaches (South)

Reach 1		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	4592 (26_3922_1)	4975 (26_1450_3)
BFIsoil	0.69 (all nodes)	0.69 (all nodes)
SAAR (mm)	1048 (26_1450_3)	1059 (26_3922_1)
FARL	0.67 (various)	0.80 (26_1116_3)
DRAIND	0.85 (26_1451_4)	0.86 (26_1112_1)
S1085 (m/km)	0.26 (26_1116_1)	0.32 (26_3922_1)
ARTDRAIN2 (%)	21.2 (26_1450_3)	22.9 (26_3922_1)
URBEXT (%)	0.50 (26_3922_1)	0.66 (various)

Table A6.4 Reach 1 Catchment Descriptor Range

Reach 2		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	6574 (26_1448_1)	6714 (25_927_1)
BFIsoil	0.67 (all nodes)	0.67 (all nodes)
SAAR (mm)	1042 (25_927_1)	1046 (26_1448_1)
FARL	0.75 (26_1448_1)	0.76 (25_927_1)
DRAIND	0.82 (25_927_1)	0.83 (26_1448_1)
S1085 (m/km)	0.26 (25_927_1)	0.28 (26_1448_1)
ARTDRAIN2 (%)	15.9 (25_927_1)	16.1 (26_1448_1)
URBEXT (%)	0.61 (various)	0.62 (25_3569_2)

Table A6.5 Reach 2 Catchment Descriptor Range

Reach 3		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	7963 (25_700_1)	8810 (25_655_4)
BFIsoil	0.65 (25_3195_1)	0.68 (25_655_4)
SAAR (mm)	1013 (25_655_4)	1024 (25_700_1)
FARL	0.79 (25_700_1)	0.80 (25_655_4)
DRAIND	0.80 (25_3346_3)	0.81 (25_978_1)
S1085 (m/km)	0.21 (25_656_2)	0.26 (25_700_1)
ARTDRAIN2 (%)	19.1 (25_655_4)	21 (25_700_1)
URBEXT (%)	0.80 (25_700_1)	0.83 (various)

Table A6.6 Reach 3 Catchment Descriptor Range

Reach 4		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	38.6 (26_1469_3)	N/A
BFIsoil	0.42 (26_1469_3)	N/A
SAAR (mm)	907 (26_1469_3)	N/A
FARL	1.0 (26_1469_3)	N/A
DRAIND	0.65 (26_1469_3)	N/A
S1085 (m/km)	1.1 (26_1469_3)	N/A

ARTDRAIN2 (%)	0.0 (26_1469_3)	N/A
URBEXT (%)	0.84 (26_1469_3)	N/A

Reach 4 only has one HEP node that has FSU data available. The other HEP node, 26_1469_1a, was added manually to define an inflow node at a location where no FSU data was available or required (the design flow was derived at the node downstream of the new node).

Table A6.7 Reach 4 Catchment Descriptor Range

Reach 5		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	4.4 (26_2818_1)	5.3 (26_2818_2)
BFIsoil	0.47 (26_2818_2)	0.49 (26_2818_1)
SAAR (mm)	952 (26_2818_2)	956 (26_2818_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.13 (26_2818_1)	0.18 (26_2818_2)
S1085 (m/km)	4.38 (26_2818_1)	7.60 (26_2818_2)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (26_2818_1)	6.01 (26_2818_2)

Table A6.8 Reach 5 Catchment Descriptor Range

Reach 6		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.0 (26_784_1)	3.1 (26_4030_4)
BFIsoil	0.41 (26_784_1)	0.55 (26_4030_4)
SAAR (mm)	901 (26_4030_4)	905 (26_784_1)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	1.6 (26_4030_4)	2.1 (26_784_1)
S1085 (m/km)	0.1 (26_784_1)	3.46 (26_4030_2)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (26_784_1)	30.4 (26_4030_4)

Table A6.9 Reach 6 Catchment Descriptor Range

Reach 7		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	77.1 (26_676_1)	109 (26_1111_3)
BFIsoil	0.80 (26_1111_3)	0.83 (26_676_1)
SAAR (mm)	932 (26_1111_3)	937 (26_676_1)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	0.42 (26_676_1)	0.57 (26_1111_3)
S1085 (m/km)	1.5 (26_1111_3)	2.5 (26_676_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (26_676_1)	1.1 (26_1111_3)

Table A6.10 Reach 7 Catchment Descriptor Range

Reach 8		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	15.0 (26_1459_1)	16.3 (26_1459_4)
BFIsoil	0.57 (26_1459_3)	0.59 (26_1459_4)
SAAR (mm)	923 (all nodes)	923 (all nodes)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	0.96 (26_1459_3)	0.97 (26_1459_2)
S1085 (m/km)	1.8 (26_1459_4)	2.2 (26_1459_2)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.11 Reach 8 Catchment Descriptor Range

Reach 9		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	10.3 (26_3750_1)	19.9 (26_293_2)
BFIsoil	0.70 (26_294_2)	0.74 (26_3750_2)
SAAR (mm)	915 (26_293_2)	924 (26_3750_1)
FARL	0.98 (26_3750_1)	0.99 (26_293_2)
DRAIND	1.1 (26_294_2)	1.3 (26_3750_3)
S1085 (m/km)	3.6 (26_3750_3)	4.4 (26_293_2)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.92 (26_3750_1)	2.7 (26_3750_5)

Table A6.12 Reach 9 Catchment Descriptor Range

Reach 10		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.0 (25_3708_1)	1.6 (25_3708_4)
BFIsoil	0.71 (25_3708_1)	0.72 (25_3708_4)
SAAR (mm)	885 (25_3708_4)	899 (25_3708_1)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	0.94 (25_3708_1)	1.4 (25_3708_4)
S1085 (m/km)	4.8 (25_3708_4)	10.5 (25_3708_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	34.9 (25_3708_4)	36.1 (25_3708_1)

Table A6.13 Reach 10 Catchment Descriptor Range

Reach 11		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	0.35 (25_811_1d)	8.8 (25_2616_4)
BFIsoil	0.64 (25_3471_0a)	0.69 (25_811_5)
SAAR (mm)	913 (25_2616_4)	936 (25_3471_0a)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	1.2 (25_3619_1)	2.3 (25_3471_0a)
S1085 (m/km)	4.2 (25_811_5)	6.8 (25_3471_0a)

ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (25_3471_0a)	1.9 (25_3619_2)

Table A6.14 Reach 11 Catchment Descriptor Range

Reach 12		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.0 (25_1019_1)	1.8 (25_1019_4)
BFIsoil	0.60 (all nodes)	0.60 (all nodes)
SAAR (mm)	1240 (25_1019_1)	1247 (25_1019_4)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	0.99 (25_1019_1)	1.3 (25_1019_4)
S1085 (m/km)	12.3 (25_1019_1)	33.6 (25_1019_4)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (25_1019_1)	30.5 (25_1019_4)

Table A6.15 Reach 12 Catchment Descriptor Range

Reach 13		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	7.2 (25_2360_4)	7.8 (25_2360_6)
BFIsoil	0.58 (all nodes)	0.58 (all nodes)
SAAR (mm)	1223 (25_2360_4)	1224 (25_2360_6)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	0.21 (25_2360_4)	0.33 (25_2360_6)
S1085 (m/km)	23.3 (25_2360_4)	26.0 (25_2360_6)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.16 Reach 13 Catchment Descriptor Range

Reach 14		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	5.4 (25_864_1)	11.1 (25_783_3)
BFIsoil	0.53 (25_864_4)	0.54 (25_783_3)
SAAR (mm)	1205 (25_864_4)	1210 (25_783_1)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	1.1 (25_864_1)	1.9 (25_783_3)
S1085 (m/km)	29.1 (25_783_3)	35.0 (25_864_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.17 Reach 14 Catchment Descriptor Range

Reach 15		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	89.0 (25_3881_1)	102 (25_3881_9)
BFIsoil	0.57 (25_3881_1)	0.58 (25_3881_9)
SAAR (mm)	1185 (25_3881_9)	1187 (25_3881_6)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	1.2 (25_3881_9)	1.4 (25_3881_1)
S1085 (m/km)	2.5 (25_3881_6)	3.2 (25_3881_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.18 Reach 15 Catchment Descriptor Range

Reach 16		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	10,803 (25_3837_1)	10,836 (25_1201_3)
BFIsoil	0.73 (all nodes)	0.73 (all nodes)
SAAR (mm)	1025 (all nodes)	1025 (all nodes)
FARL	0.69 (all nodes)	0.69 (all nodes)
DRAIND	0.83 (all nodes)	0.83 (all nodes)
S1085 (m/km)	0.17 (25_3823_9)	0.19 (25_3837_1)
ARTDRAIN2 (%)	20.2 (all nodes)	20.2 (all nodes)
URBEXT (%)	0.77 (25_3823_5)	0.78 (various)

Table A6.19 Reach 16 Catchment Descriptor Range

Reach 17		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.6 (25_3823_6b)	3.1 (25_3823_8b)
BFIsoil	0.50 (all nodes)	0.50 (all nodes)
SAAR (mm)	1025 (all nodes)	1025 (all nodes)
FARL	1.0 (all nodes)	1.0 (all nodes)
DRAIND	0.41 (25_3823_8b)	0.59 (25_3823_6b)
S1085 (m/km)	1.3 (25_3823_8b)	5.7 (25_3823_6b)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	2.5 (25_3823_6b)	3.5 (25_3823_8b)

Table A6.20 Reach 17 Catchment Descriptor Range

Reach 18		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.0 (25_1205_1)	1.8 (25_1205_4)
BFIsoil	0.52 (25_1205_1)	0.54 (25_1205_4)
SAAR (mm)	1017 (25_1205_4)	1030 (25_1205_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.09 (25_1205_1)	1.48 (25_1205_4)
S1085 (m/km)	0.1 (25_1205_4)	0.7 (25_1205_4)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.21 Reach 18 Catchment Descriptor Range

Reach 19		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	59 (25_3825_1)	61 (25_3329_2)
BFIsoil	0.38 (25_3825_3)	0.39 (25_3825_1)
SAAR (mm)	1182 (25_3329_2)	1187 (25_3825_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.15 (25_3825_1)	1.20 (25_3329_2)
S1085 (m/km)	8.8 (25_3329_2)	12.7 (25_3825_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.2 (all nodes)	0.2 (all nodes)

Table A6.22 Reach 19 Catchment Descriptor Range

Reach 20		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.0 (25_2824_1)	2.8 (25_2824_5)
BFIsoil	0.54 (25_2824_1)	0.55 (25_2824_5)
SAAR (mm)	1027 (25_2824_5)	1064 (25_2824_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.03 (25_2824_5)	1.20 (25_2824_1)
S1085 (m/km)	4.9 (25_2824_5)	6.0 (25_2824_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.23 Reach 20 Catchment Descriptor Range

Reach 21		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	44 (25_3858_3)	57 (25_2822_2)
BFIsoil	0.70 (all nodes)	0.70 (all nodes)
SAAR (mm)	920 (25_3858_3)	925 (25_2822_2)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.19 (25_2053_2)	1.25 (25_3858_3)
S1085 (m/km)	3.2 (25_2822_2)	4.8 (25_3858_3)
ARTDRAIN2 (%)	37.6 (25_3858_3)	41.6 (25_2053_2)
URBEXT (%)	0.7 (25_3858_6)	6.7 (25_2822_2)

Table A6.24 Reach 21 Catchment Descriptor Range

Reach 22		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.5 (25_3605_1)	4.9 (25_1222_2)
BFIsoil	0.70 (all nodes)	0.70 (all nodes)
SAAR (mm)	932 (25_2049_1)	934 (25_1222_2)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.19 (25_2053_2)	1.25 (25_3858_3)
S1085 (m/km)	3.2 (25_2822_2)	4.8 (25_3858_3)
ARTDRAIN2 (%)	12.0 (25_2049_1)	39.2 (25_1222_2)
URBEXT (%)	1.0 (25_3605_1)	50.1 (25_1222_2)

Table A6.25 Reach 22 Catchment Descriptor Range

Reach 23		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.0 (25_2823_1)	1.9 (25_2823_5)
BFIsoil	0.54 (all nodes)	0.54 (all nodes)
SAAR (mm)	1029 (25_2823_5)	1054 (25_2823_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	2.16 (25_2823_1)	2.21 (25_2823_5)
S1085 (m/km)	3.4 (25_2823_1)	6.0 (25_2823_5)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	19.0 (25_2823_5)	22.7 (25_2823_1)

Table A6.26 Reach 23 Catchment Descriptor Range

Reach 24		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	2.4 (25_1150_2)	3.6 (25_1150_4)
BFIsoil	0.41 (25_1150_4)	0.48 (25_1150_2)
SAAR (mm)	1072 (25_1150_4)	1073 (25_1150_2)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.16 (25_1150_4)	1.35 (25_1150_2)
S1085 (m/km)	27.4 (25_1150_4)	32.0 (25_1150_2)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	3.6 (25_1150_2)	14.0 (25_1150_4)

Table A6.27 Reach 24 Catchment Descriptor Range

Reach 25		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	2.6 (25_181_2)	3.8 (25_181_4)
BFIsoil	0.46 (25_181_2)	0.48 (25_181_4)
SAAR (mm)	1070 (all nodes)	1070 (all nodes)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	2.78 (25_181_2)	2.82 (25_181_4)
S1085 (m/km)	37.2 (25_181_4)	44.9 (25_181_2)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.28 Reach 25 Catchment Descriptor Range

Reach 26		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	2.5 (25_185_3)	4.7 (25_2411_5)
BFIsoil	0.45 (25_2411_1)	0.47 (25_2411_5)
SAAR (mm)	1063 (25_2411_5)	1070 (25_185_3)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.89 (25_2411_2)	1.94 (25_185_3)
S1085 (m/km)	29.3 (25_2411_5)	53.2 (25_185_3)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (all nodes)	0.0 (all nodes)

Table A6.29 Reach 26 Catchment Descriptor Range

Reach 27		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.2 (25_186_1)	6.7 (25_3896_2)
BFIsoil	0.53 (25_3896_2)	0.55 (25_186_1)
SAAR (mm)	988 (25_186_2)	1043 (25_3896_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.73 (25_186_1)	1.60 (25_3896_2)
S1085 (m/km)	1.3 (25_186_1)	29.3 (25_3896_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	7.5 (25_3896_2)	29.1 (25_186_2)

Table A6.30 Reach 27 Catchment Descriptor Range

Reach 28		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.5 (27_345_1)	4.1 (27_54_3)
BFIsoil	0.54 (all nodes)	0.54 (all nodes)
SAAR (mm)	983 (27_54_3)	984 (27_345_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.11 (27_345_1)	0.84 (27_54_3)
S1085 (m/km)	0.1 (27_345_1)	0.7 (27_54_1)
ARTDRAIN2 (%)	56.7 (27_345_1)	100.0 (27_54_1)
URBEXT (%)	54.0 (27_54_1)	82.8 (27_345_1)

Table A6.31 Reach 28 Catchment Descriptor Range

Reach 29		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	23 (24_1580_5)	24 (24_1580_6)
BFIsoil	0.70 (all nodes)	0.70 (all nodes)
SAAR (mm)	919 (all nodes)	919 (all nodes)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.78 (24_1580_5)	0.80 (24_1580_6)
S1085 (m/km)	4.2 (24_1580_5)	4.6 (24_1580_6)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	1.6 (24_1580_5)	1.8 (24_1580_6)

Table A6.32 Reach 29 Catchment Descriptor Range

Reach 30		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	6.6 (24_121_8)	32 (24_1718_4)
BFIsoil	0.70 (24_1718_4)	0.71 (24_121_9)
SAAR (mm)	921 (24_1718_1)	926 (24_121_12)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.81 (24_121_8)	0.98 (24_121_12)
S1085 (m/km)	4.4 (24_121_9)	5.4 (24_1718_4)
ARTDRAIN2 (%)	0.0 (24_121_8)	1.1 (24_1718_4)
URBEXT (%)	0.0 (24_121_8)	2.4 (24_1718_4)

Table A6.33 Reach 30 Catchment Descriptor Range

Reach 31		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	10 (24_1720_4)	N/A
BFIsoil	0.70 (24_1720_4)	N/A
SAAR (mm)	932 (24_1720_4)	N/A
FARL	1.00 (24_1720_4)	N/A
DRAIND	0.50 (24_1720_4)	N/A
S1085 (m/km)	4.8 (24_1720_4)	N/A
ARTDRAIN2 (%)	4.2 (24_1720_4)	N/A
URBEXT (%)	24.3 (24_1720_4)	N/A

Reach 31 only has one HEP node that has FSU data available. The other HEP node, 24_1720_3a, was added manually to define an inflow node at a location where no FSU data was available or required. The design flow was derived at the node downstream of the new node..

Table A6.34 Reach 31 Catchment Descriptor Range

Reach 32		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	0.3 (27_1129_8)	9.3 (27_157_2)
BFIsoil	0.36 (27_415_4)	0.71 (27_338_1)
SAAR (mm)	1000 (27_1139_4)	1056 (27_1129_5)
FARL	0.96 (27_1139_4)	1.00 (27_1252_1)
DRAIND	0.15 (27_1129_8)	2.42 (27_1129_6)
S1085 (m/km)	4.4 (24_121_9)	5.4 (24_1718_4)
ARTDRAIN2 (%)	0.1 (27_338_3)	86.2 (27_1139_1)
URBEXT (%)	0.0 (27_1252_1)	15.2 (27_338_3)

Flow paths and FSU catchment descriptors within the Crompaun and its tributaries were revised in accordance with the topographic survey

Table A6.35 Reach 32 Catchment Descriptor Range

Reach 33		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	3.9 (27_1120_2)	18 (27_158_2)
BFIsoil	0.32 (27_1120_2)	0.48 (27_1259_3)
SAAR (mm)	984 (27_1120_2)	1036 (27_1259_3)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.17 (27_1260_2)	1.76 (27_158_2)
S1085 (m/km)	19.4 (27_1120_3)	27.3 (27_1259_3)
ARTDRAIN2 (%)	21.5 (27_1259_3)	51.0 (27_1120_3)
URBEXT (%)	0.0 (27_1120_2)	15.2 (27_1259_3)

Flow paths and FSU catchment descriptors within the Crompaun and its tributaries were revised in accordance with the topographic survey

Table A6.36 Reach 33 Catchment Descriptor Range

A6.4 QMED Adjustment Factors

Table A6.37 below gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED.

Reach	Gauging Station Number	QMED Observed (m^3/s)	QMED (urban) Synthetic (m^3/s)	Adjustment Factor (-)	Model Extent	Note
1	26027	240	145	1.66	N10	1
7	26221	7.6	8.2	0.93	N10	2
3	25017	426	325	1.31	N10	3
15	25044	20.1	20.6	0.98	N12	4
16	25075	544	282	1.93	N12	5

Table A6.37 Available Gauged QMED Adjustment Factors

Table A6.37 Comments:

1. QMED at gauging station 26027 is based on the full AMAX data series from 1952 to 2009.
2. Quality checks at gauging station 26221 revealed that the site had a weir removed in 2005 resulting in a slight reduction in flow estimates. However, the site was deemed suitable for flow estimates up to QMED based on available check gaugings before and after the weir removal.
3. QMED at gauging station 25017 is based on the full AMAX data series from 1950 to 2009.
4. Gauging station 25044 was deemed suitable for estimation of flows up to 0.8 x QMED based on a review of the check gaugings and AMAX flow data for the site.

5. At this station a sluice system allows for a split of the total flow from Lough Derg into the lower River Shannon and to the Ardnacrusha Power Station through the Head Race Canal. The AMAX flows used to estimate QMED are the total flows upstream of the flow split based on the entire 79 years (1932-2010) of OPW data.

The QMED adjustment factors for the ungauged reaches (or reaches with inadequate high flow monitoring) in the catchment were estimated using multiple pivotal sites in the absence of an adequate single pivotal site. The adjustment factors were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A6.38 – A6.64). The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: Π (Adjustment Factor^{Weight}).

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6033	CONEYBURROW BR.	1	0.807	0.264	1.52
24022	MAHORE	2	1.053	0.202	1.30
8012	BALLYBOGHIL	3	1.130	0.189	0.93
14033	OWENASS	4	1.223	0.174	1.17
6031	FLURRY	5	1.250	0.171	2.05
Weighted Geometric Mean					**1.35**

Table A6.38 QMED Adjustment Factor for Reach 4 based on Multiple Pivotal Sites (Target Location HEP 26_1469_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	1.011	0.307	2.32
8012	BALLYBOGHIL	2	1.569	0.198	0.93
24022	MAHORE	3	1.764	0.176	1.30
6031	FLURRY	4	1.924	0.161	2.05
6033	CONEYBURROW BR.	5	1.978	0.157	1.52
Weighted Geometric Mean					**1.60**

Table A10.39 QMED Adjustment Factor for Reach 5 based on Multiple Pivotal Sites (Target Location HEP 26_2818_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
10022	CABINTEELY	1	1.281	0.271	1.62
8005	SLUICE	2	1.344	0.259	2.28
10021	SHANGANAGH	3	2.115	0.164	1.49
9035	CAMMOCK	4	2.265	0.153	1.90
9002	LUCAN	5	2.285	0.152	1.17
Weighted Geometric Mean					**1.70**

Table A10.40 QMED Adjustment Factor for Reach 6 based on Multiple Pivotal Sites (Target Location HEP 26_4030_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
24022	MAHORE	1	0.854	0.203	1.30
8012	BALLYBOGHIL	2	0.860	0.202	0.93
6031	FLURRY	3	0.869	0.200	2.05
16051	CLOBANNA	4	0.872	0.199	0.73
8002	NAUL	5	0.881	0.197	1.39
Weighted Geometric Mean					**1.20**

Table A10.41 QMED Adjustment Factor for Reach 8 based on Multiple Pivotal Sites (Target Location HEP 26_1459_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
16051	CLOBANNA	1	0.470	0.327	0.73
25034	L. ENNELL TRIB	2	0.665	0.231	1.23
8002	NAUL	3	1.001	0.154	1.39
26058	INNY UPPER	4	1.037	0.148	0.63
14009	CUSHINA	5	1.103	0.139	1.03
Weighted Geometric Mean					**0.94**

Table A10.42 QMED Adjustment Factor for Reach 9 based on Multiple Pivotal Sites (Target Location HEP 26_293_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
10022	CABINTEELY	1	1.888	0.242	1.62
8005	SLUICE	2	2.175	0.211	2.28
25040	BUNOW	3	2.420	0.189	0.55
10021	SHANGANAGH	4	2.514	0.182	1.49
9002	LUCAN	5	2.606	0.176	1.17
Weighted Geometric Mean					**1.32**

Table A10.43 QMED Adjustment Factor for Reach 10 based on Multiple Pivotal Sites (Target Location HEP 25_3708_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
25034	L. ENNELL TRIB	1	0.686	0.326	1.23
16051	CLOBANNA	2	1.119	0.200	0.73
8002	NAUL	3	1.314	0.170	1.39
8012	BALLYBOGHIL	4	1.426	0.157	0.93
6031	FLURRY	5	1.520	0.147	2.05
Weighted Geometric Mean					**1.17**

Table A10.44 QMED Adjustment Factor for Reach 11 based on Multiple Pivotal Sites (Target Location HEP 25_2616_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
10022	CABINTEELY	1	2.399	0.218	1.62
22009	WHITE BRIDGE	2	2.456	0.213	1.23
25040	BUNOW	3	2.475	0.211	0.55
8005	SLUICE	4	2.792	0.187	2.28
10021	SHANGANAGH	5	3.058	0.171	1.49
Weighted Geometric Mean					**1.28**

Table A10.45 QMED Adjustment Factor for Reach 12 based on Multiple Pivotal Sites (Target Location HEP 25_1019_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	1.161	0.284	2.32
24022	MAHORE	2	1.789	0.184	1.30
36071	L. Scur	3	1.839	0.179	0.50
6031	FLURRY	4	1.866	0.177	2.05
19046	STATION ROAD	5	1.883	0.175	2.18
Weighted Geometric Mean					**1.53**

Table A10.46 QMED Adjustment Factor for Reach 13 based on Multiple Pivotal Sites (Target Location HEP 25_2360_6)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.845	0.318	2.32
24022	MAHORE	2	1.509	0.178	1.30
23012	BALLYMULLEN	3	1.558	0.173	0.58
6031	FLURRY	4	1.617	0.166	2.05
16006	BALLINACLOGH	5	1.642	0.164	1.58
Weighted Geometric Mean					**1.51**

Table A10.47 QMED Adjustment Factor for Reach 14 based on Multiple Pivotal Sites (Target Location HEP 25_783_3)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	1.222	0.312	2.32
8012	BALLYBOGHIL	2	2.054	0.186	0.93
24022	MAHORE	3	2.174	0.176	1.30
6031	CHARLEVILLE	4	2.306	0.165	2.05
8002	NAUL	5	2.366	0.161	1.39
Weighted Geometric Mean					**1.60**

Table A10.48 QMED Adjustment Factor for Reach 17 based on Multiple Pivotal Sites (Target Location HEP 25_3823_8b)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
9011	FRANKFORT	1	1.494	0.245	1.94
6030	BIG	2	1.764	0.207	2.32
10022	CABINTEELY	3	1.910	0.191	1.62
8005	SLUICE	4	2.039	0.179	2.28
25034	L. ENNELL TRIB	5	2.062	0.177	1.23
Weighted Geometric Mean					**1.85**

Table A10.49 QMED Adjustment Factor for Reach 18 based on Multiple Pivotal Sites (Target Location HEP 25_1205_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
34009	CURRAGHBONAUN	1	0.626	0.238	0.73
1041	SANDY MILLS	2	0.733	0.204	1.58
14033	OWENASS	3	0.751	0.199	1.17
35002	BILLA BR.	4	0.819	0.182	1.42
23012	BALLYMULLEN	5	0.841	0.177	0.58
Weighted Geometric Mean					**1.02**

Table A10.50 QMED Adjustment Factor for Reach 19 based on Multiple Pivotal Sites (Target Location HEP 25_3825_1)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
9011	FRANKFORT	1	1.330	0.239	1.94
6030	BIG	2	1.458	0.217	2.32
10022	CABINTEELY	3	1.617	0.196	1.62
25034	L. ENNELL TRIB	4	1.802	0.176	1.23
8005	SLUICE	5	1.846	0.172	2.28
Weighted Geometric Mean					**1.85**

Table A10.51 QMED Adjustment Factor for Reach 20 based on Multiple Pivotal Sites (Target Location HEP 25_2824_5)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
26058	INNY UPPER	1	0.456	0.229	0.63

16051	CLOBANNA	2	0.469	0.223	0.73
14009	CUSHINA	3	0.531	0.197	1.03
13002	COROCK	4	0.549	0.191	0.67
25023	MILLTOWN	5	0.650	0.161	1.07
Weighted Geometric Mean					**0.79**

Table A10.52 QMED Adjustment Factor for Reach 21 based on Multiple Pivotal Sites (Target Location HEP 25_2822_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
25034	L. ENNELL TRIB	1	0.759	0.305	1.23
10022	CABINTEELY	2	1.146	0.202	1.62
9011	FRANKFORT	3	1.209	0.191	1.94
25040	BUNOW	4	1.484	0.156	0.55
30020	DALGAN	5	1.586	0.146	0.67
Weighted Geometric Mean					**1.15**

Table A10.53 QMED Adjustment Factor for Reach 22 based on Multiple Pivotal Sites (Target Location HEP 25_1222_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
9011	FRANKFORT	1	1.503	0.241	1.94
6030	BIG	2	1.694	0.213	2.32
10022	CABINTEELY	3	1.891	0.191	1.62
25034	L. ENNELL TRIB	4	2.038	0.177	1.23
8005	SLUICE	5	2.041	0.177	2.28
Weighted Geometric Mean					**1.85**

Table A10.54 QMED Adjustment Factor for Reach 23 based on Multiple Pivotal Sites (Target Location HEP 25_2823_5)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	1.023	0.345	2.32
9011	FRANKFORT	2	2.005	0.176	1.94

8007	ASHBOURNE	3	2.182	0.162	1.02
8005	SLUICE	4	2.197	0.161	2.28
10022	CABINTEELY	5	2.278	0.155	1.62
Weighted Geometric Mean					**1.86**

Table A10.55 QMED Adjustment Factor for Reach 24 based on Multiple Pivotal Sites (Target Location HEP 25_1150_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	1.148	0.296	2.32
9011	FRANKFORT	2	1.636	0.208	1.94
10022	CABINTEELY	3	1.930	0.176	1.62
8005	SLUICE	4	2.020	0.168	2.28
8012	BALLYBOGHIL	5	2.227	0.152	0.93
Weighted Geometric Mean					**1.82**

Table A10.56 QMED Adjustment Factor for Reach 25 based on Multiple Pivotal Sites (Target Location HEP 25_181_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.772	0.364	2.32
9011	FRANKFORT	2	1.576	0.178	1.94
10022	CABINTEELY	3	1.741	0.161	1.62
8005	SLUICE	4	1.860	0.151	2.28
8012	BALLYBOGHIL	5	1.919	0.146	0.93
Weighted Geometric Mean					**1.85**

Table A10.57 QMED Adjustment Factor for Reach 26 based on Multiple Pivotal Sites (Target Location HEP 25_2411_5)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
9011	FRANKFORT	1	1.419	0.254	1.94
6030	BIG	2	1.819	0.198	2.32
10022	CABINTEELY	3	1.880	0.192	1.62

8005	SLUICE	4	1.965	0.183	2.28
25034	L. ENNELL TRIB	5	2.083	0.173	1.23
Weighted Geometric Mean					**1.85**

Table A10.58 QMED Adjustment Factor for Reach 27 based on Multiple Pivotal Sites (Target Location HEP 25_186_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
9011	FRANKFORT	1	1.096	0.254	1.94
6030	BIG	2	1.371	0.203	2.32
10022	CABINTEELY	3	1.372	0.203	1.62
8005	SLUICE	4	1.586	0.176	2.28
25034	L. ENNELL TRIB	5	1.708	0.163	1.23
Weighted Geometric Mean					**1.85**

Table A10.59 QMED Adjustment Factor for Reach 28 based on Multiple Pivotal Sites (Target Location HEP 25_54_1)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
16051	CLOBANNA	1	0.527	0.266	0.73
25034	L. ENNELL TRIB	2	0.696	0.202	1.23
25040	BUNOW	3	0.738	0.190	0.55
26058	INNY UPPER	4	0.799	0.176	0.63
9035	CAMMOCK	5	0.842	0.167	1.90
Weighted Geometric Mean					**0.88**

Table A10.60 QMED Adjustment Factor for Reach 29 based on Multiple Pivotal Sites (Target Location HEP 25_1580_6)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
16051	CLOBANNA	1	0.221	0.416	0.73
25040	BUNOW	2	0.518	0.178	0.55
9035	CAMMOCK	3	0.670	0.138	1.90

10021	SHANGANAGH	4	0.683	0.135	1.49
26058	INNY UPPER	5	0.692	0.133	0.63
Weighted Geometric Mean					**0.86**

Table A10.61 QMED Adjustment Factor for Reach 30 based on Multiple Pivotal Sites (Target Location HEP 25_1718_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
25034	L. ENNELL TRIB	1	0.365	0.404	1.23
10022	CABINTEELY	2	0.882	0.167	1.62
25040	BUNOW	3	0.938	0.157	0.55
16051	CLOBANNA	4	1.003	0.147	0.73
10021	SHANGANAGH	5	1.182	0.125	1.49
Weighted Geometric Mean					**1.08**

Table A10.62 QMED Adjustment Factor for Reach 31 based on Multiple Pivotal Sites (Target Location HEP 25_1720_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.626	0.414	2.32
9011	FRANKFORT	2	1.690	0.153	1.94
8007	ASHBOURNE	3	1.753	0.148	1.02
8012	BALLYBOGHIL	4	1.808	0.143	0.93
10022	CABINTEELY	5	1.813	0.143	1.62
Weighted Geometric Mean					**1.67**

Table A10.63 QMED Adjustment Factor for Reach 32 based on Multiple Pivotal Sites (Target Location HEP 25_157_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.698	0.295	2.32
8007	ASHBOURNE	2	1.094	0.188	1.02
24022	MAHORE	3	1.114	0.185	1.30
36031	CAVAN	4	1.192	0.172	0.62

14033	OWENASS	5	1.281	0.160	1.17
Weighted Geometric Mean					**1.27**

Table A10.64 QMED Adjustment Factor for Reach 33 based on Multiple Pivotal Sites (Target Location HEP 25_158_2)

Table A6.65 below shows the final QMED adjustment factor applied to each reach in the catchment, each with a justification for selection.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	1.66	26027	Suitable station downstream of Lough Ree
2	1.49	26027 and 25017	Average between the QMED adjustment factors at gauging stations 26027 and 25017.
3	1.31	25017	Suitable gauging station on Reach 3
4	1.35	26_1469_3	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
5	1.60	26_2818_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
6	1.70	26_4030_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
7	0.93	26221	Only suitable gauging station on the River Cross.
8	1.20	26_1459_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
9	0.94	26_293_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
10	1.32	25_3708_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
11	1.17	25_2616_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
12	1.28	25_1019_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
13	1.53	25_2360_6	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
14	1.51	25_783_3	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
15	0.98	25044	Suitable gauging station on Reach 15
16	1.93 [1]	25075	Suitable gauging station on Reach 16

Reach	QMED adjustment factor	Station or HEP Node	Justification
17	1.60	25_3823_8b	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
18	1.85	25_1205_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
19	1.02	25_3825_1	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
20	1.85	25_2824_5	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
21	0.79	25_2822_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
22	1.15	25_1222_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
23	1.85	25_2823_5	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
24	1.86	25_1150_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
25	1.82	25_181_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
26	1.85	25_2411_5	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
27	1.85	25_186_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
28	1.85	27_54_1	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
29	0.88	24_1580_6	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
30	0.86	24_1718_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
31	1.08	24_1720_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
32	1.67	27_157_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
33	1.27	27_158_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.

Table A6.65 Final QMED Adjustment Factors Applied to Each Reach

[1] As explained in Section A6.2 the flow in the River Shannon (Reach 16) is split at Parteen Weir to allow for a flow to the Ardnacrusha Power Station. QMED at this station upstream of the flow split is estimated as 544 m^3/s. With a conservatively low maximum flow of 345 m^3/s diverted to the power station the rest of the 2-year (50% AEP) peak flow into the lower River Shannon is 199 m^3/s.

A6.5 Flood Frequency Curves

Gauging Station Flood Frequency Curves

Three gauging stations suitable for flood frequency analysis were identified: 26027 (Athlone), 25017 (Banagher) and 25075 (Parteen Weir). The flood frequency curves (or growth curves) are plotted in Figures A6.3 to A6.5 below. The flood frequency curve plots for all relevant stations are included in Appendix E. The figures below show the at-site AMAX series (made dimensionless by dividing the flows by QMED, and plotting positions based on the Gringorten formula) and a distribution fitted to the AMAX data plotted against the reduced variate and an AEP scale.

Athlone Gauging Station (26027)

58 years of acceptable AMAX data suggests single site analysis offers reasonably robust estimates up to return periods of 29 years i.e. AEP = 3.3% (based on ½N with N=58).

Pooled analysis is considered inappropriate for this site, due to the size of the catchment and the relatively large effect of lakes in the Shannon catchment. The at-site EV1 growth curve was therefore adopted for all return periods.

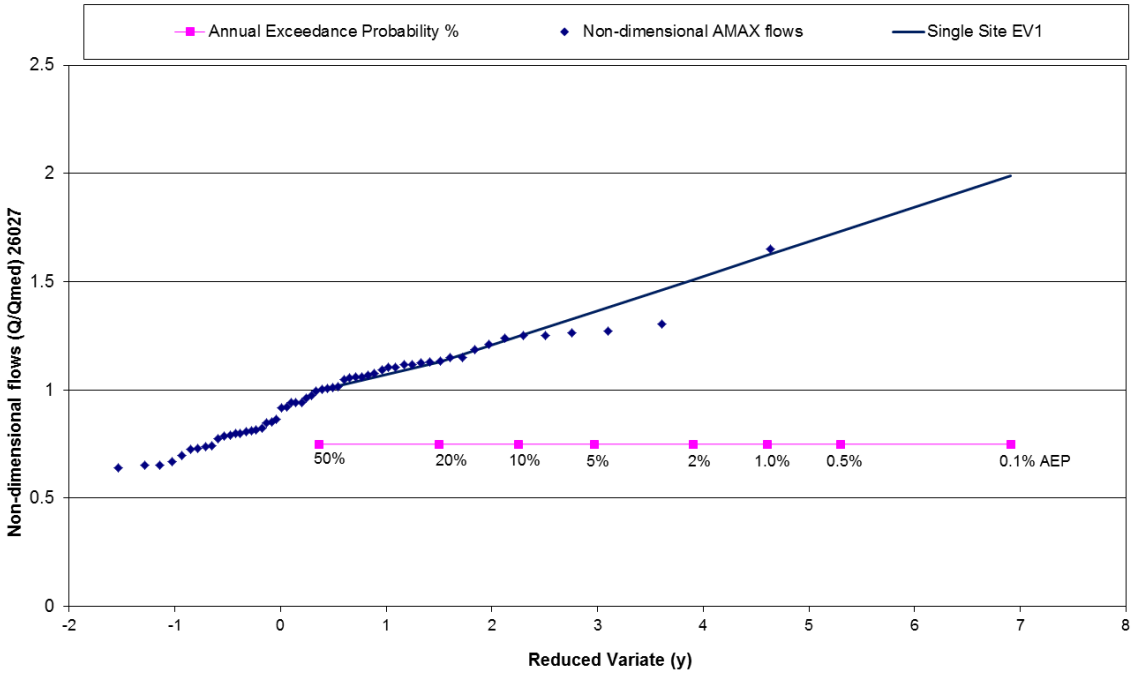


Figure A6.3 26027 Athlone – Flood Frequency Curve

Banagher Gauging Station (25017)

60 years of acceptable AMAX data suggests single site analysis offers reasonably robust estimates up to return periods of 30 years i.e. AEP = 3.33% (based on ½N with N=60).

Although there is a slight rising trend in the AMAX series, it is not considered strong enough to dismiss any of the AMAX data for flood frequency analysis.

Pooled analysis is considered inappropriate for this site, due to the size of the catchment and the relatively large effect of lakes in the Shannon catchment. The at-site EV1 growth curve was therefore adopted for all return periods.

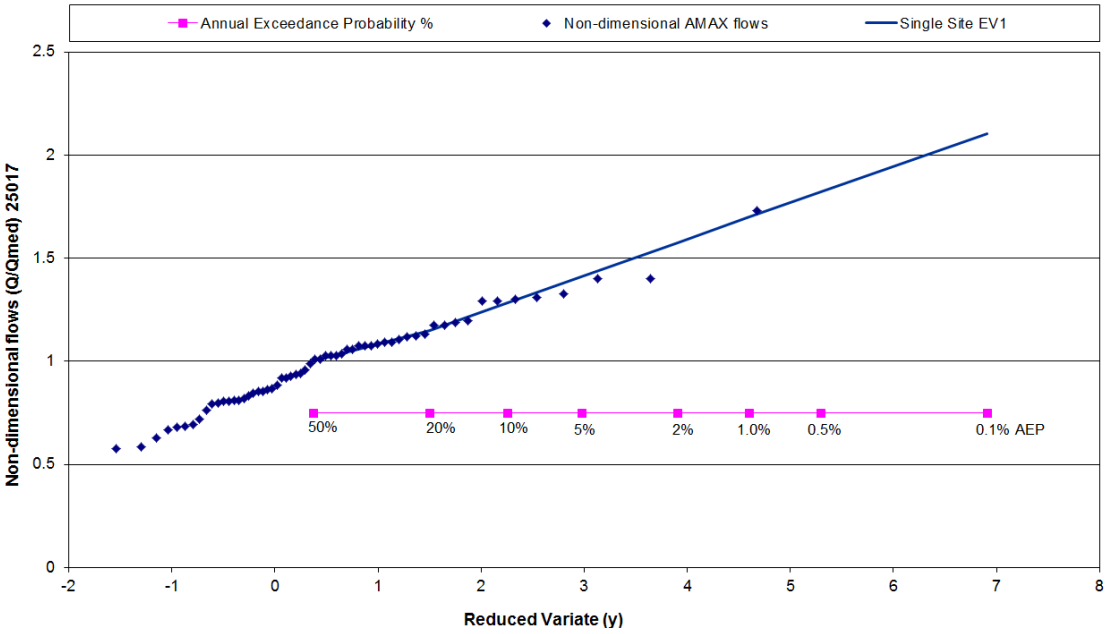


Figure A6.4 25017 Banagher – Flood Frequency Curve

Parteen Weir Gauging Station (25075)

At this location a sluice system allows for a split of the total flow from Lough Derg into the lower River Shannon and to the Ardnacrusha Power Station through the Head Race Canal. The AMAX flows used for the flood frequency analysis are the total flows upstream of the flow split.

79 years of acceptable AMAX data suggests single site analysis offers reasonably robust estimates up to return periods of at least 40 years i.e. AEP = 2.5% (based on ½N with N=79).

Pooled analysis is considered inappropriate for this site, due to the size of the catchment and the relatively large effect of lakes in the Shannon catchment. The at-site EV1 growth curve was therefore adopted for all return periods.

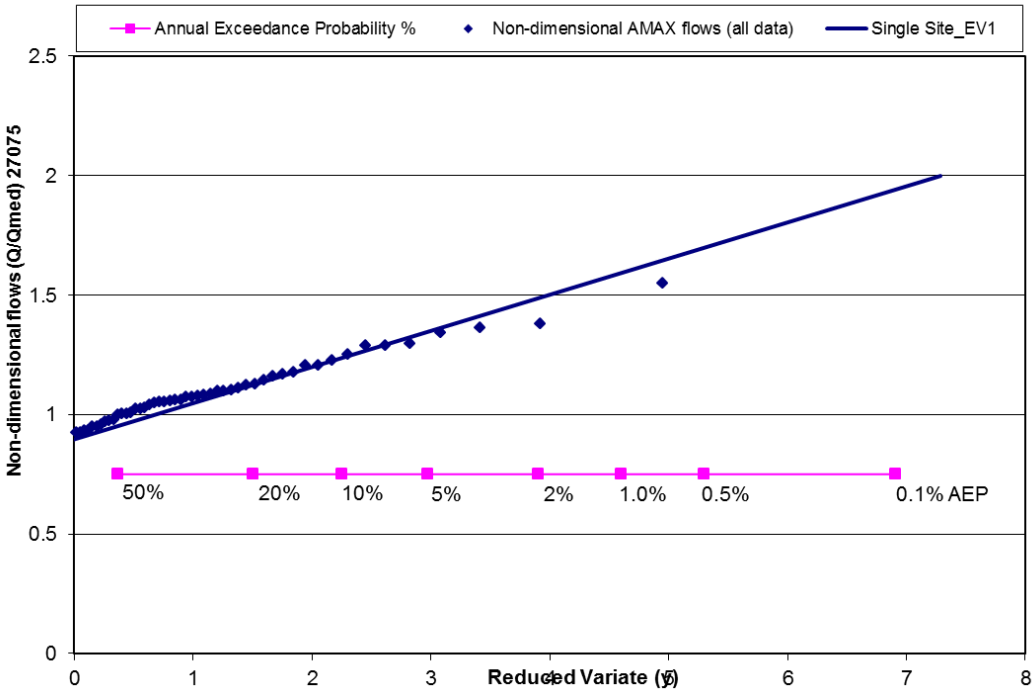


Figure A6.5 25075 Parteen Weir – Flood Frequency Curve

As explained in Section A6.2 the flow in the River Shannon (Reach 16) is split at Parteen Weir to allow for a flow to the Ardnacrusha Power Station. The maximum flow diverted to the power station is assumed to be 345 m^3/s. The rest of the total flow runs off through the lower River Shannon where it has the potential to cause flooding.

River Reach Flood Frequency

The growth curve distributions applied to the relevant reaches are shown in Table A6.66. Growth factors generated for a range of AEPs have been detailed in Tables A6.67a/b.

Reach	Station/HEP Node	Single Site or Pooled	Selected distribution
1, 2, 3	25017 - Banagher	Single Site	EV1
4	26_1469_2	Pooled	EV1
5	26_2818_2	Pooled	EV1
6	26_4030_4	Pooled	EV1
7	26221 – Summerhill (26_4018_4)	Pooled	EV1
8	26_1459_4	Pooled	EV1
9	26_293_2	Pooled	EV1
10	25_3708_4	Pooled	EV1
11	25_2616_4	Pooled	EV1
12	25_1019_4	Pooled	EV1
13, 14, 17	25_3823_8b	Pooled	EV1
15	25044 – Coole (25_3881_9)	Pooled	LN2
16	25075 – Parteen Weir	Single Site	EV1
19	25_3329_2	Pooled	LN2
18, 23, 24, 25, 26, 27	25_1205_4	Pooled	EV1
20, 21, 22, 29, 30, 31, 32, 33	27_158_2	Pooled	EV1
28	27_54_3	Pooled	EV1

Table A6.66 Final Growth Curves Selected

The Banagher (Station 25017) single site growth curve was applied to the entire section of the Shannon between Lough Ree and Lough Derg for reasons of consistency. A comparison of the Banagher growth curve with Athlone (Station 26027) showed a good match, with 1% AEP growth factors of 1.70 at Banagher and 1.62 at Athlone, which is a difference of less than 5%.

Observing the growth factors in Tables A6.67a/b it is apparent that there is a wide range of growth curves (e.g. the 1% AEP growth factors vary from 1.59 to 3.23). This is to be expected as there is a large variety of watercourses within the catchment ranging from the very large and nearly flat River Shannon to the steep small tributaries that discharge into the River Shannon (e.g. Garrycastle at Athlone).

The FSU gauged dataset shows an inverse correlation between the L_{cv} parameter (which is a measure of the steepness of the growth curve) and the catchment size, particularly for catchments up to approximately 100 km^2. A similar correlation can be observed when the 1% (1 in 100) AEP growth factors in Tables A6.67a/b are plotted against catchment area, see Figure A6.5b below.

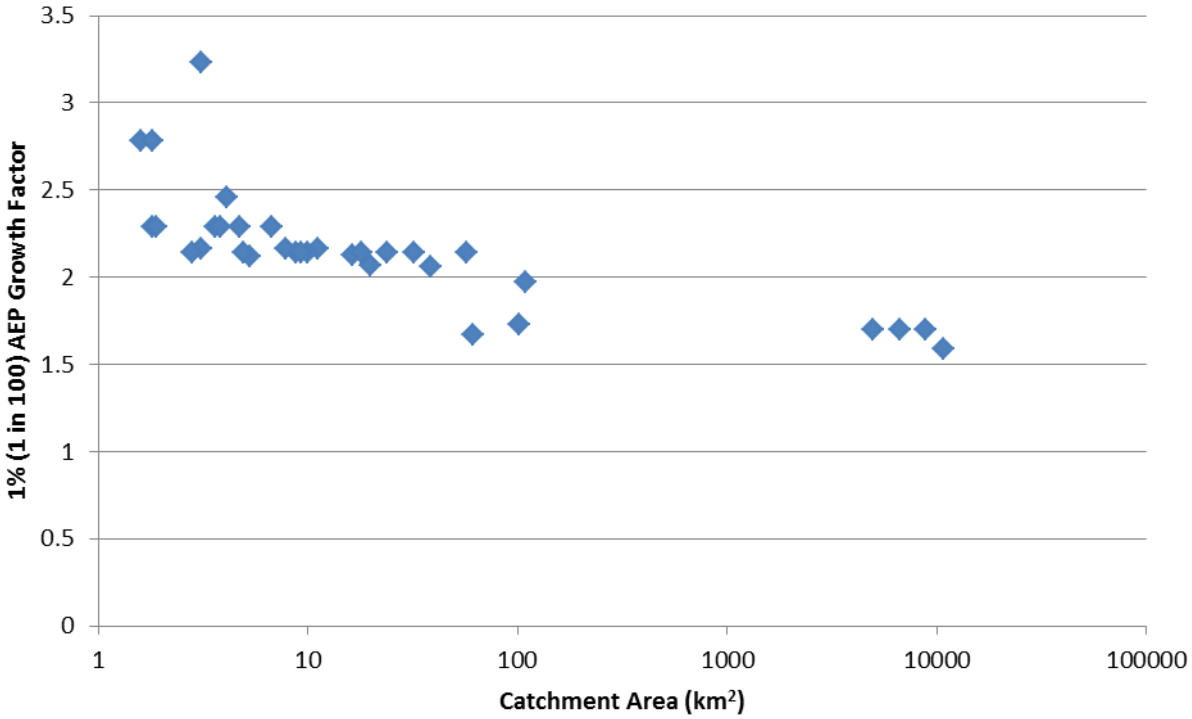


Figure A6.5b Graphic comparison of 1% (1 in 100) AEP growth factors vs catchment areas

It is speculated that the growth curve at Banagher may be particularly flat because of significant flood storage in the Callows, the low-lying area along the banks of the River Shannon between Lough Ree and Banagher, which adds a considerable storage volume to the catchment. A detailed study of this was outside of the scope of this project.

Annual Exceedance Probability (%)	Growth Factors Reaches 1, 2, 3	Growth Factors Reach 4	Growth Factors Reach 5	Growth Factors Reach 6	Growth Factors Reach 7	Growth Factors Reach 8	Growth Factors Reach 9	Growth Factors Reach 10	Growth Factors Reach 11
50%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20%	1.15	1.28	1.30	1.60	1.26	1.30	1.29	1.48	1.31
10%	1.28	1.47	1.50	1.99	1.43	1.50	1.48	1.79	1.51
5%	1.41	1.65	1.69	2.37	1.60	1.69	1.66	2.10	1.70
2%	1.57	1.89	1.93	2.86	1.81	1.94	1.90	2.49	1.96
1%	1.70	2.06	2.12	3.23	1.97	2.13	2.07	2.78	2.14
0.5%	1.82	2.24	2.30	3.60	2.13	2.31	2.25	3.08	2.33
0.1%	2.10	2.64	2.73	4.45	2.50	2.74	2.66	3.75	2.77

Table A6.67a Final Growth Factors Applied to the Lower and Middle Shannon Catchment

Annual Exceedance Probability (%)	Growth Factors Reach 12	Growth Factors Reaches 13, 14, 17	Growth Factors Reach 15	Growth Factors Reach 16	Growth Factors Reach 19	Growth Factors Reaches 18, 23, 24, 25, 26, 27	Growth Factors Reaches 20, 21, 22, 29, 30, 31, 32, 33	Growth Factors Reach 28
50%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20%	1.48	1.31	1.22	1.12	1.20	1.34	1.31	1.39
10%	1.79	1.52	1.35	1.24	1.33	1.57	1.51	1.65
5%	2.10	1.71	1.47	1.35	1.44	1.79	1.70	1.90
2%	2.49	1.97	1.62	1.49	1.57	2.07	1.95	2.22
1%	2.78	2.16	1.73	1.59	1.67	2.29	2.14	2.46
0.5%	3.08	2.35	1.84	1.70	1.76	2.50	2.33	2.70
0.1%	3.75	2.79	2.08	1.94	1.97	2.99	2.76	3.26

Table A6.67b Final Growth Factors Applied to the Lower and Middle Shannon Catchment

A6.6 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

Table A6.68 summarises the gauging stations used to produce the typical flood hydrograph shapes for the catchment reaches.

Reach	Gauging Station/HEP node
1, 2, 3	25017 - Banagher
4, 8	OPW Hydrograph Shape Generator (Pivotal Site 11001 - Owenavorragh)
5	Flood Studies Report (FSR) Hydrograph Shape (HEP 26_2818_2)
6, 24, 29	Flood Studies Report (FSR) Hydrograph Shape (HEP 26_4030_4)
7	26221 – Summer Hill
9, 30, 31, 32	OPW Hydrograph Shape Generator (Pivotal site 13002 – Foulk's Mill)
10, 12, 17	Flood Studies Report (FSR) Hydrograph Shape (HEP 25_1019_4)
11	OPW Hydrograph Shape Generator (Pivotal Site 16006 - Ballinaclogh)
13, 14	OPW Hydrograph Shape Generator (Pivotal Site 16013 - Fourmilewater)
15	25044 - Coole
16	25075 – Parteen Weir (River Shannon gauged flows downstream of Parteen Weir sluices)
18, 20	Flood Studies Report (FSR) Hydrograph Shape (HEP 25_2824_5)
19	OPW Hydrograph Shape Generator (Pivotal Site 1041 – Sandy Mills)
21, 22	OPW Hydrograph Shape Generator (Pivotal Site 25027 – Gourdeen Bridge)
24	Flood Studies Report (FSR) Hydrograph Shape (HEP 25_1150_4)
25	Flood Studies Report (FSR) Hydrograph Shape (HEP 25_181_4)
26, 27	OPW Hydrograph Shape Generator (Pivotal Site 22009 – White Bridge)
32, 33	OPW Hydrograph Shape Generator (Pivotal site 23012 - Ballymullen)

Table A6.68 Gauging Stations used to derive the Typical Hydrograph Shape in each Reach

Figures A6.6–24 identify the selected hydrograph shapes. For reaches where reliable gauged data was available the highest four events were plotted in a non-dimensional manner. The hydrograph that best represents a typical/median flood response has then been selected as the representative design hydrograph shape.

As Reach 16 covers the River Shannon downstream of Station 25075 (Parteen Weir) the event hydrographs representing the flows discharging to the River Shannon (gauged downstream of the sluices as opposed to the total flow hydrographs) were compared in Figure A6.17 below. Comparing Figures A6.6 and A6.17 it is observed that the hydrograph shape at Station 25017 (Banagher) is slightly longer than that at Station 25075 (Parteen Weir) even though Station 25017 is located further upstream. This is due to the diversion of flood flows to the Head

Race Canal at Parteen Weir during flood events, making the residual hydrograph to the River Shannon narrower.

Tables A6.69–72 show which event shape was selected for each of the relevant stations.

Date	Peak Flow (m^3/s)	Comments
27/11/2009	736	Selected hydrograph shape
27/12/1999	556	
16/12/2006	556	
09/02/1990	550	

Table A6.69 Highest Flood Peaks for Gauging Station 25017

Date	Peak Flow (m^3/s)	Comments
08/01/2005	12.5	
30/10/2002	10.5	Selected hydrograph shape
11/02/2002	9.7	
06/04/2010	9.1	

Table A6.70 Highest Flood Peaks for Gauging Station 26221

Date	Peak Flow (m^3/s)	Comments
07/01/2005	32.7	Selected hydrograph shape
23/11/2009	26.1	
06/02/2011	24.7	
30/03/2008	24.5	

Table A6.71 Highest Flood Peaks for Gauging Station 25044

Date	Peak Flow (m^3/s)	Comments
28/11/2009	498.20	Selected for hydrograph shape
31/12/1994	322.50	
27/12/1999	376.94	
17/12/2006	371.59	

Table A6.72 Highest Flood Peaks for Gauging Station 25075

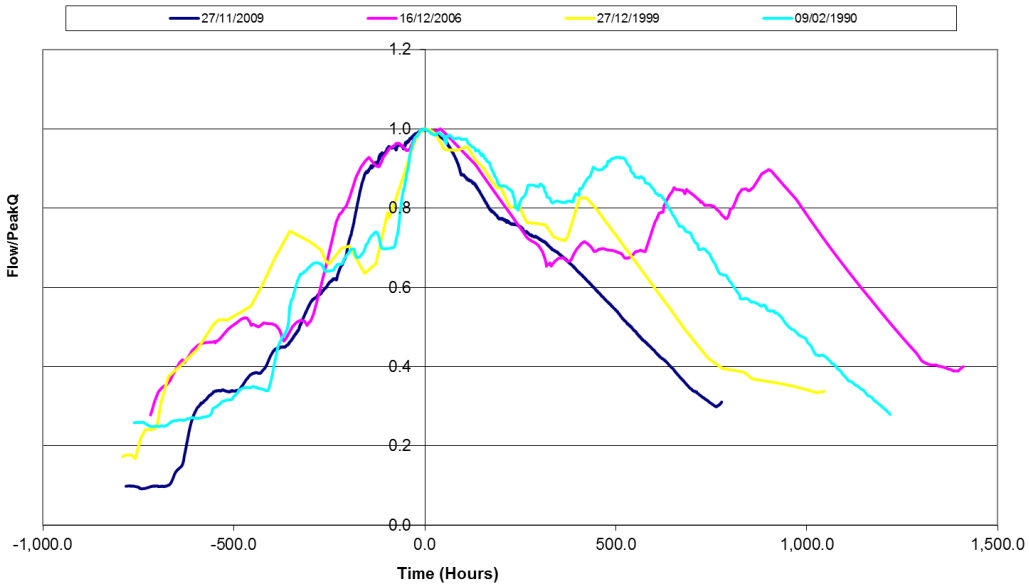


Figure A6.6 Non-dimensional Hydrographs for Gauging Station 25017 (Reaches 1, 2 and 3)

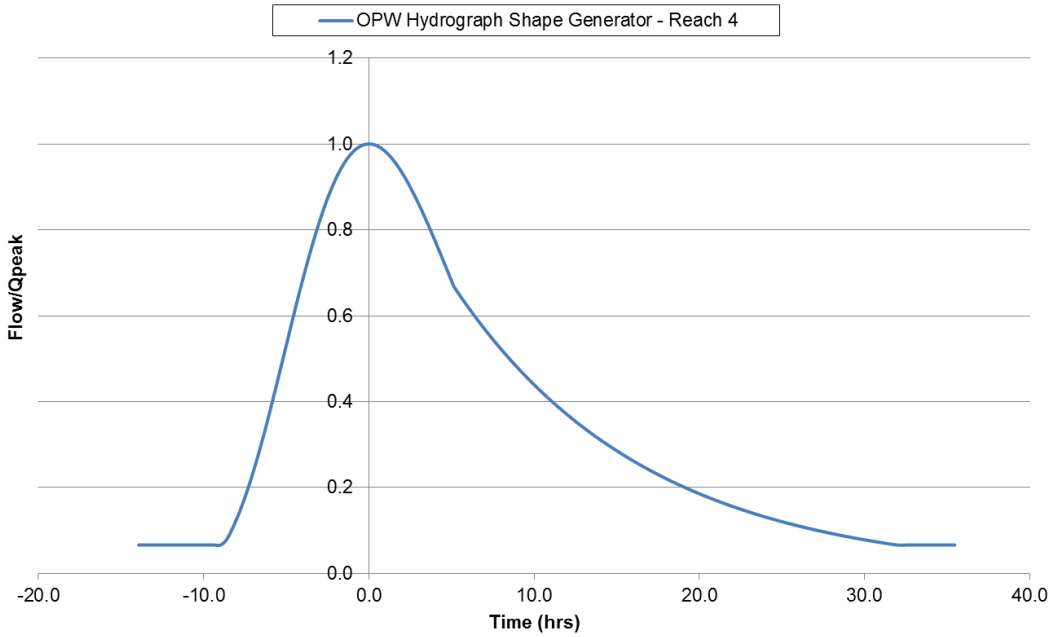


Figure A6.7 Non-dimensional Hydrograph for Pivotal Site 11001 (Reach 4)

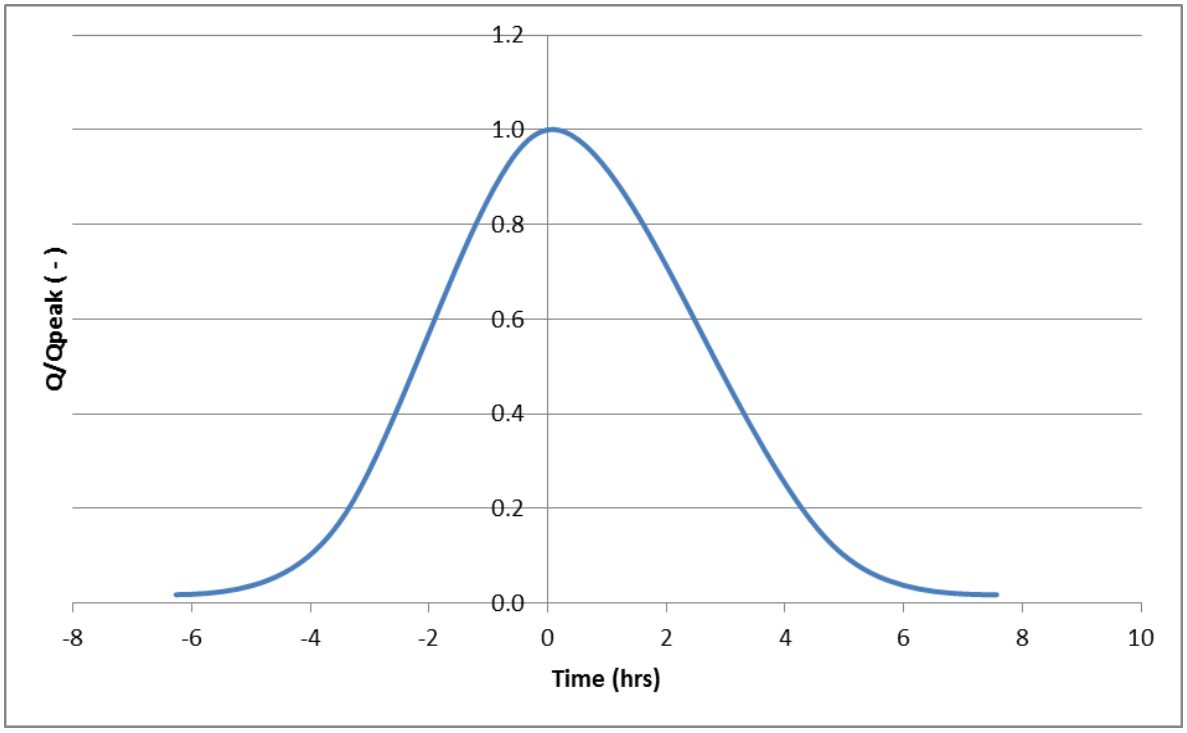


Figure A6.8 Non-dimensional FSR Hydrograph for Reach 5

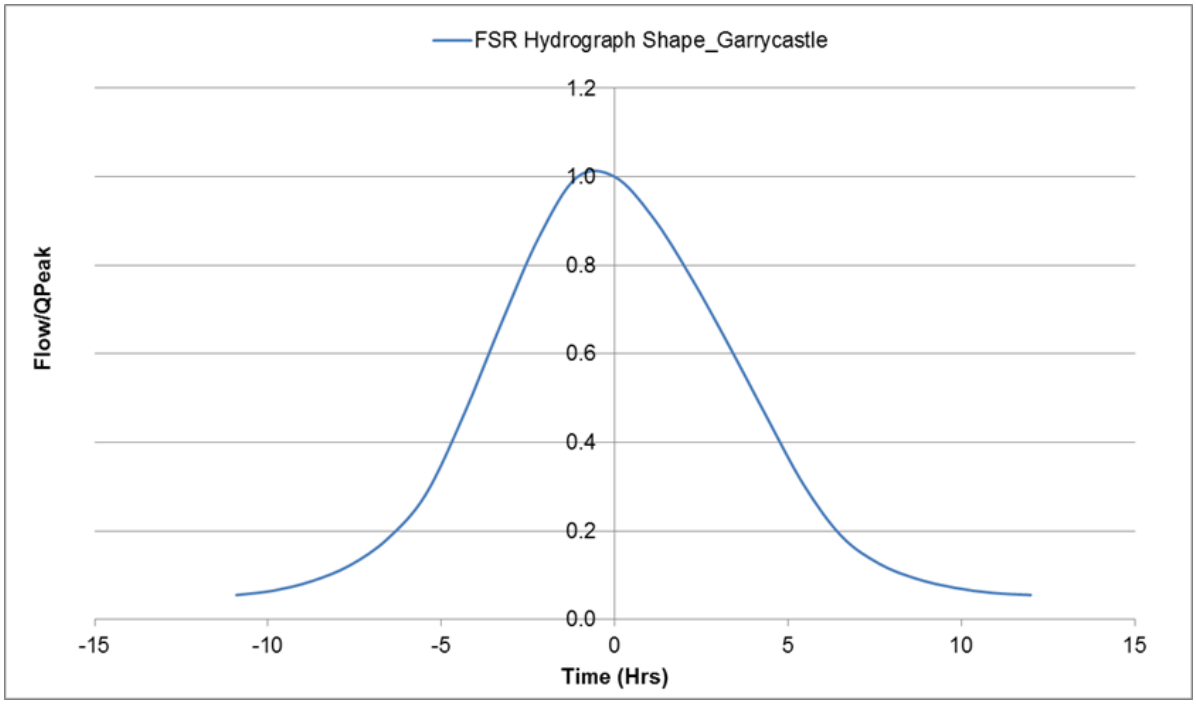


Figure A6.9 Non-dimensional FSR Hydrograph for Reaches 6, 24 and 29

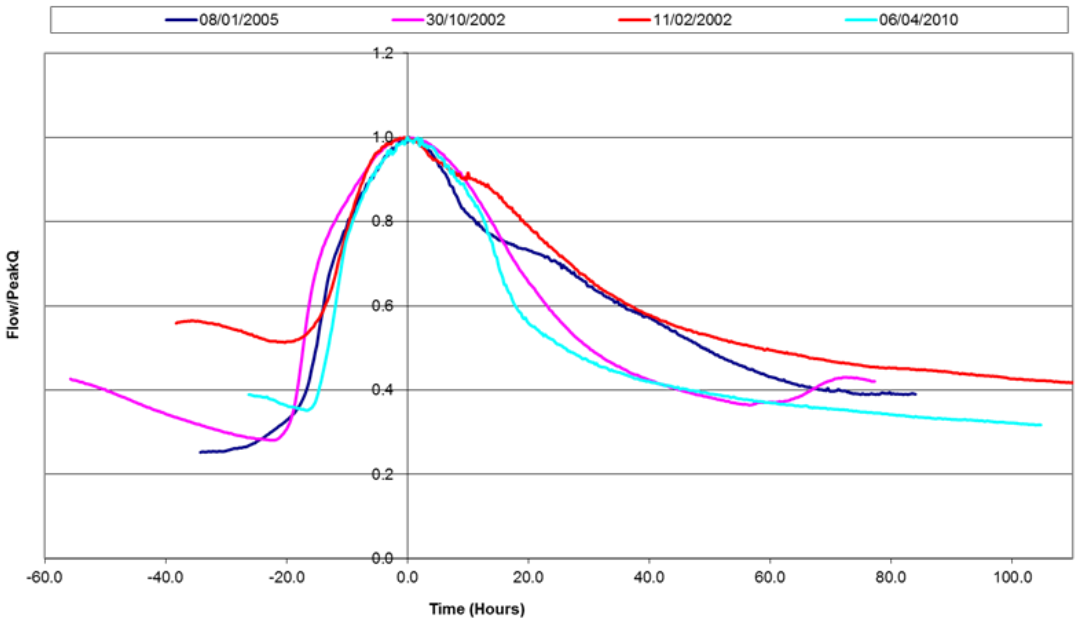


Figure A6.10 Non-dimensional Hydrographs for Gauging Station 26221 (Reach 7)

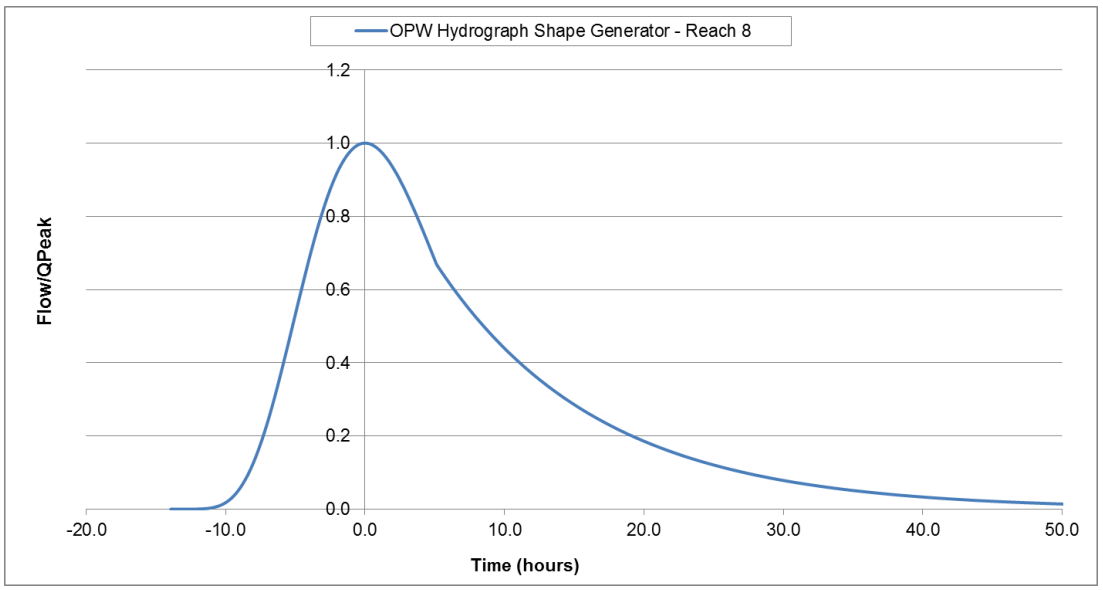


Figure A6.11 Non-dimensional FSR Hydrograph for Reach 8

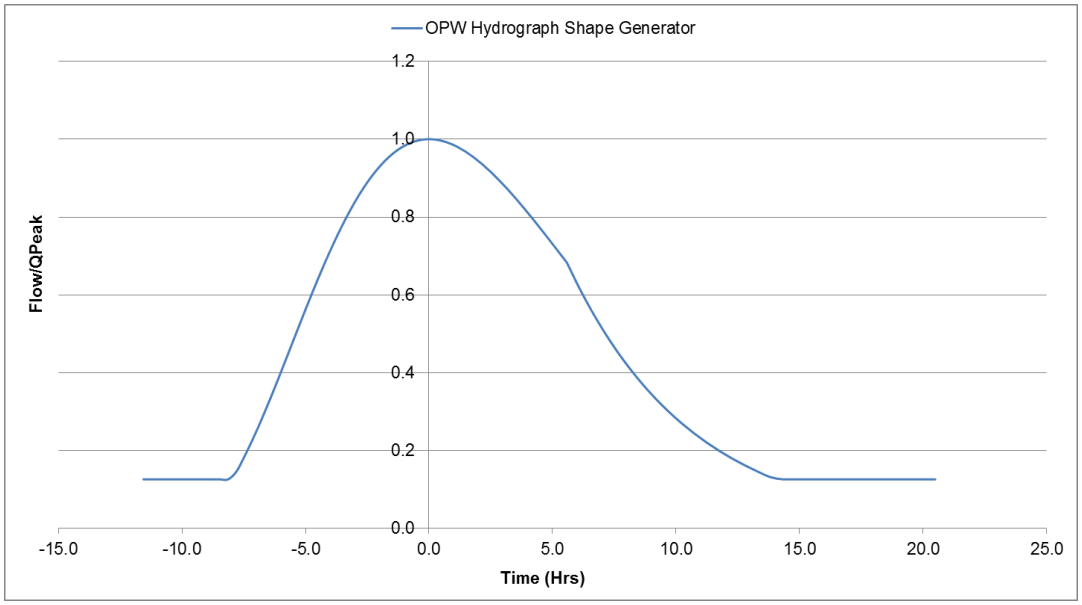


Figure A6.12 Non-dimensional Hydrograph for Pivotal Site 13002 (Reaches 9, 30, 31 and 32)

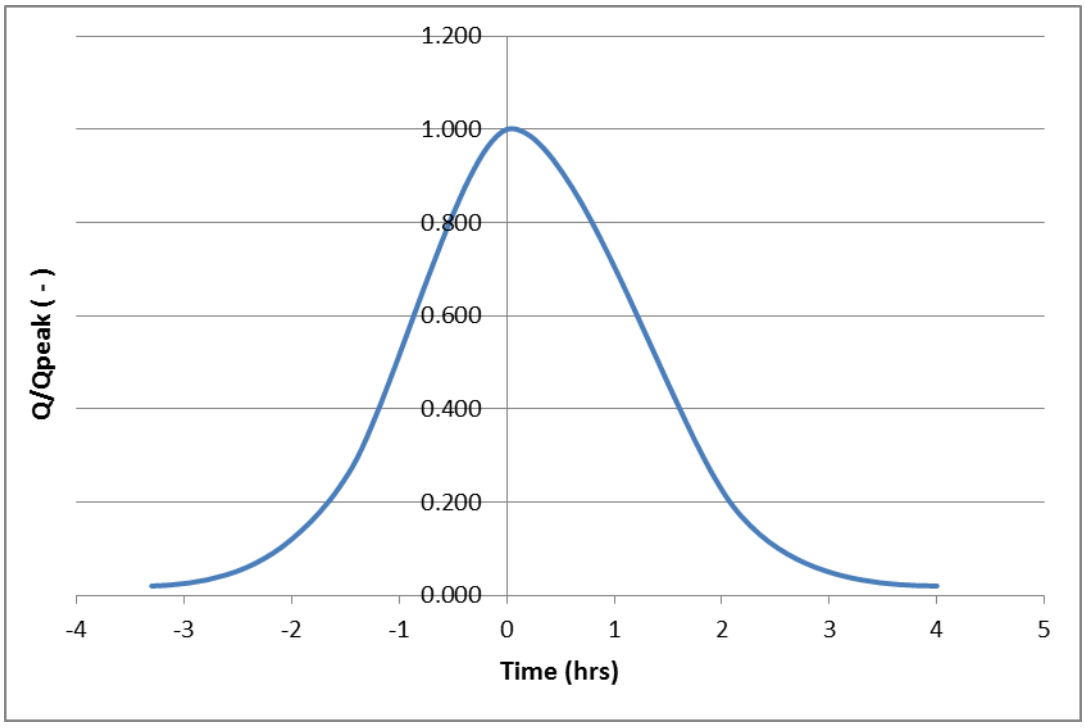


Figure A6.13 Non-dimensional FSR Hydrograph for Reaches 10, 12 and 17

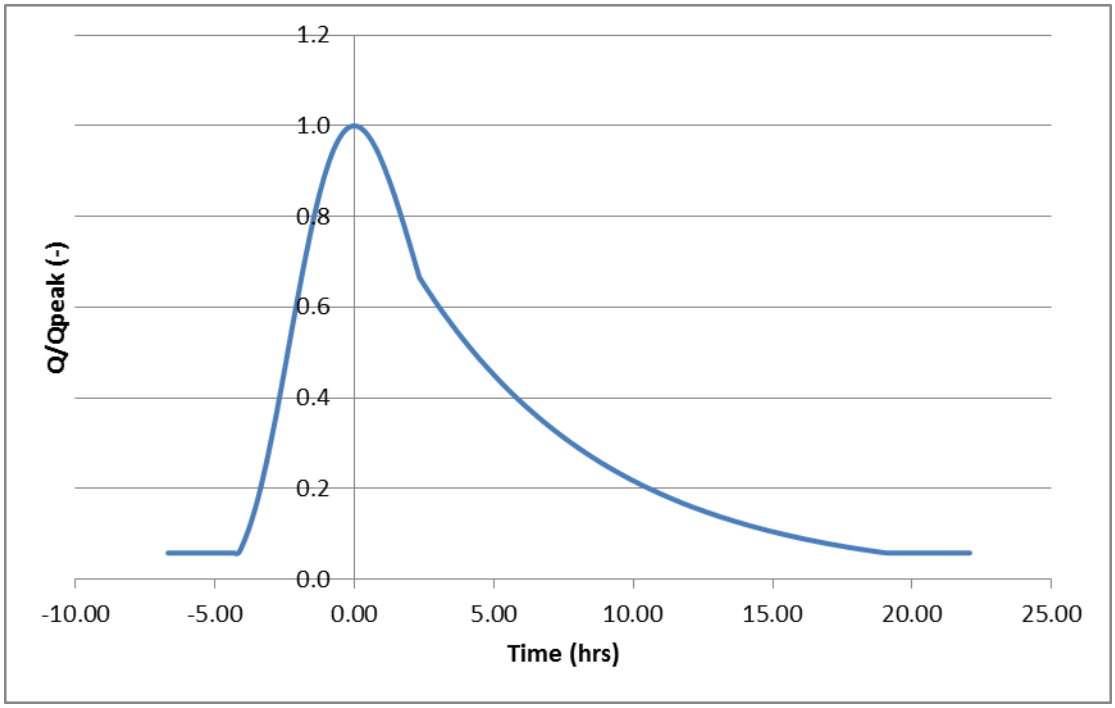


Figure A6.14 Non-dimensional Hydrograph for Pivotal Site 16006 (Reach 11)

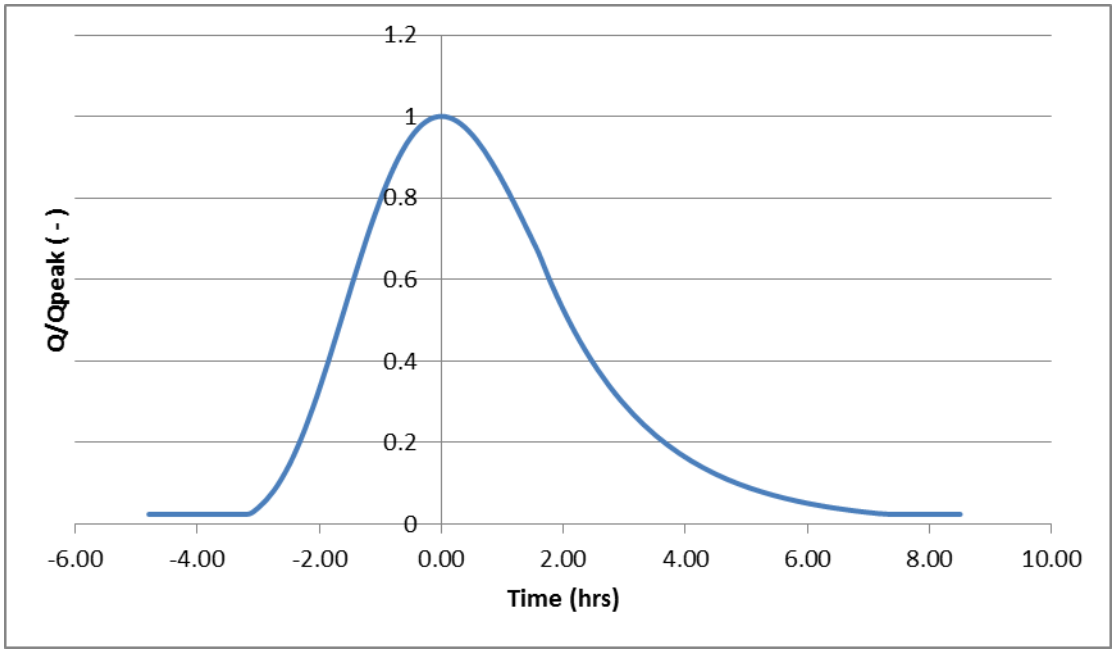


Figure A6.15 Non-dimensional Hydrograph for Pivotal Site 16013 (Reaches 13 and 14)

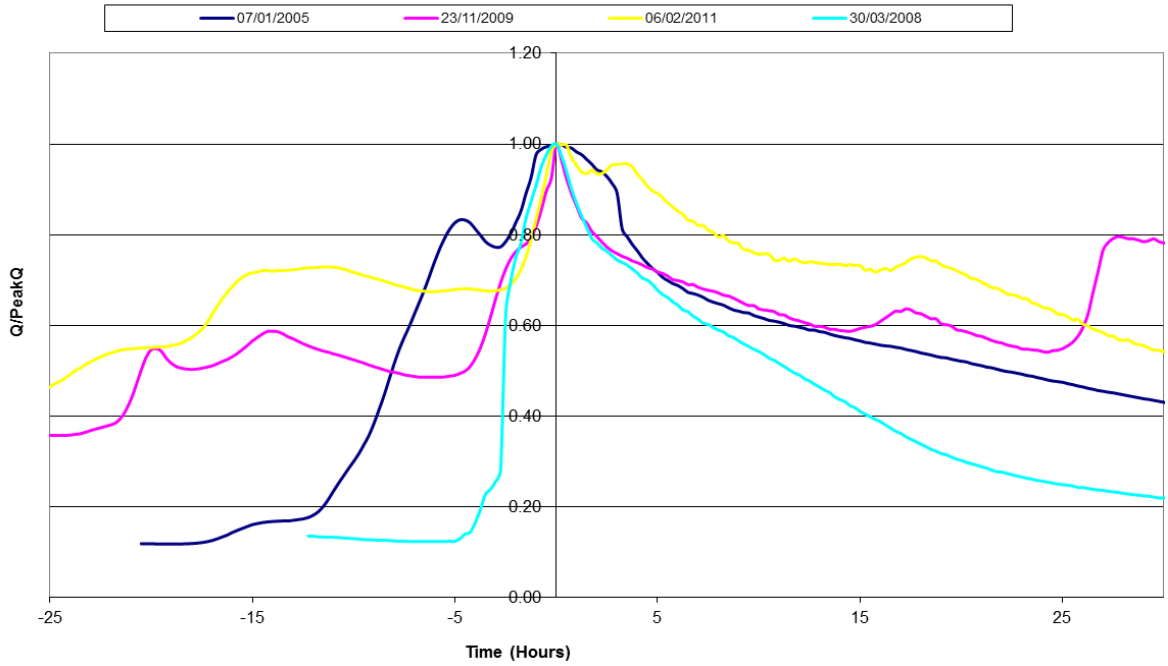


Figure A6.16 Non-dimensional Hydrographs for Gauging Station 25044 (Reach 15)

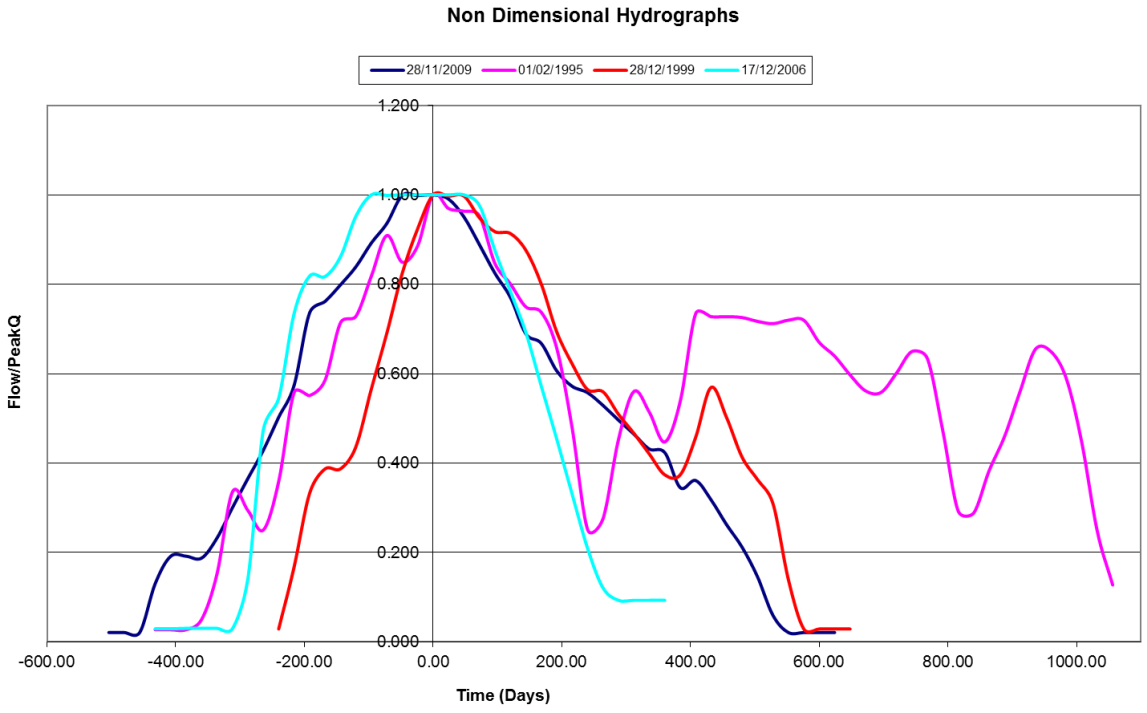


Figure A6.17 Non-dimensional Hydrographs for Gauging Station 25075 (Reach 16)

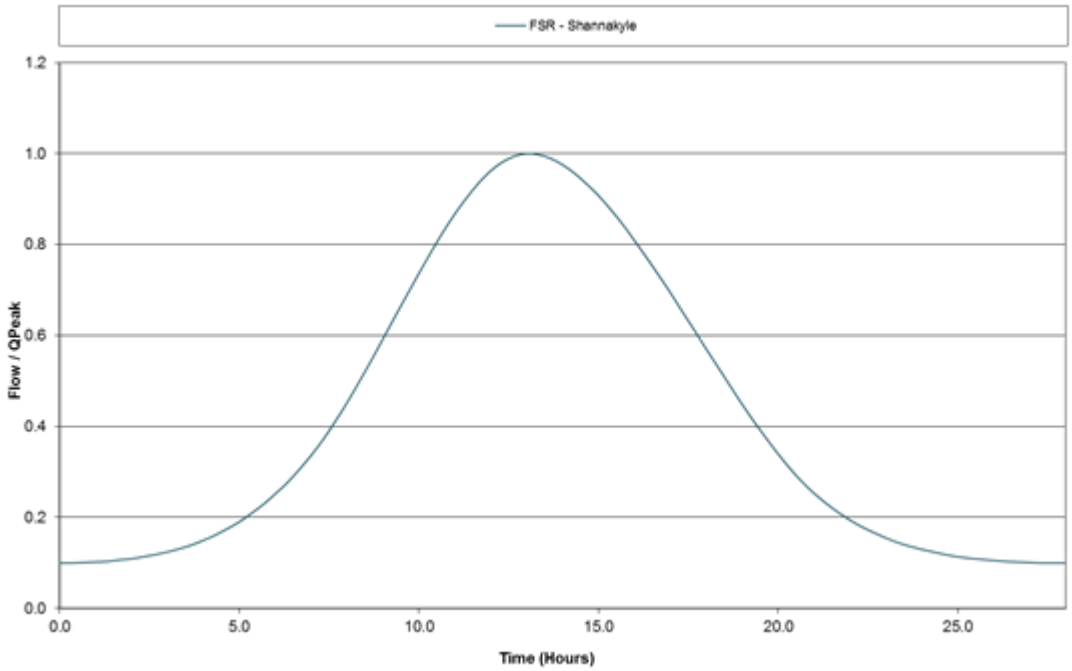


Figure A6.18 Non-dimensional FSR Hydrograph for Reaches 18 and 20

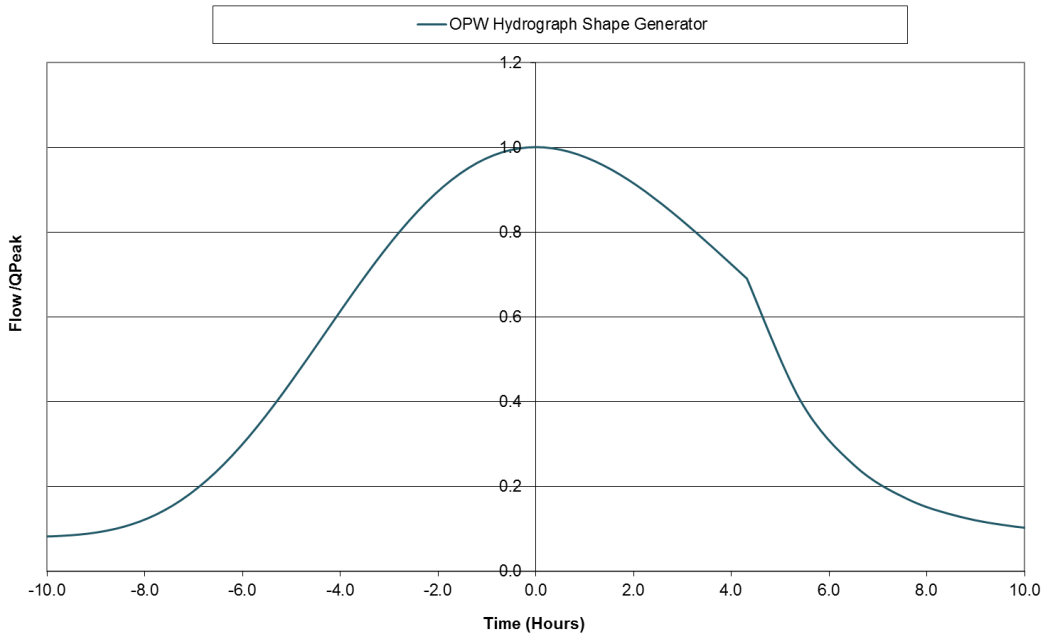


Figure A6.19 Non-dimensional Hydrograph for Pivotal Site 1041 (Reach 19)

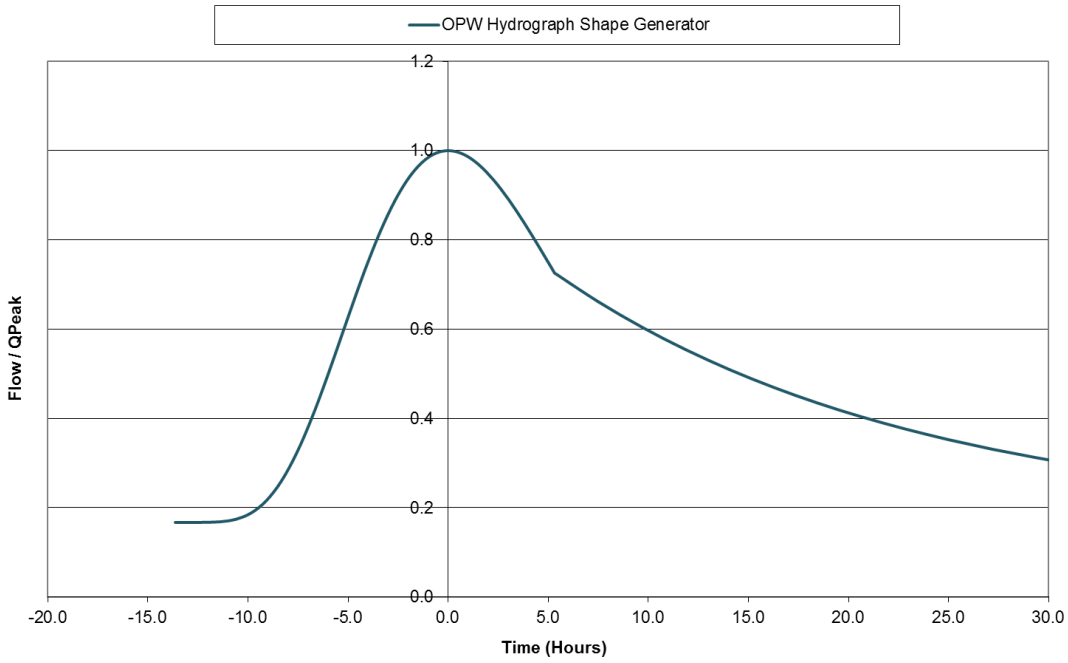


Figure A6.20 Non-dimensional Hydrograph for Pivotal Site 25027 (Reaches 21 and 22)

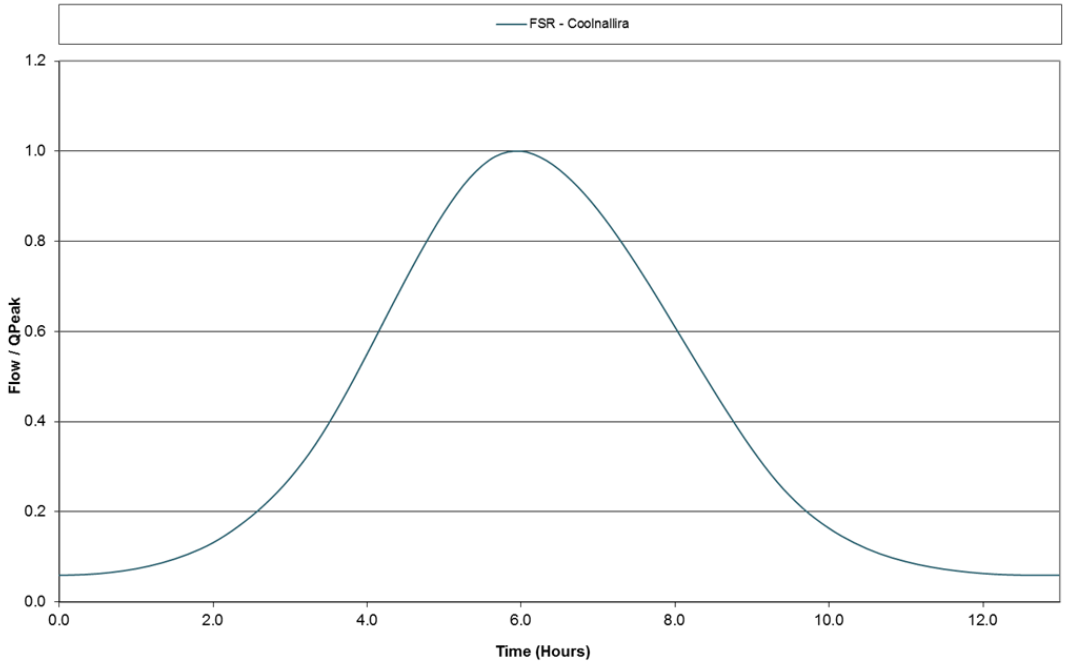


Figure A6.21 Non-dimensional FSR Hydrograph for Reach 24

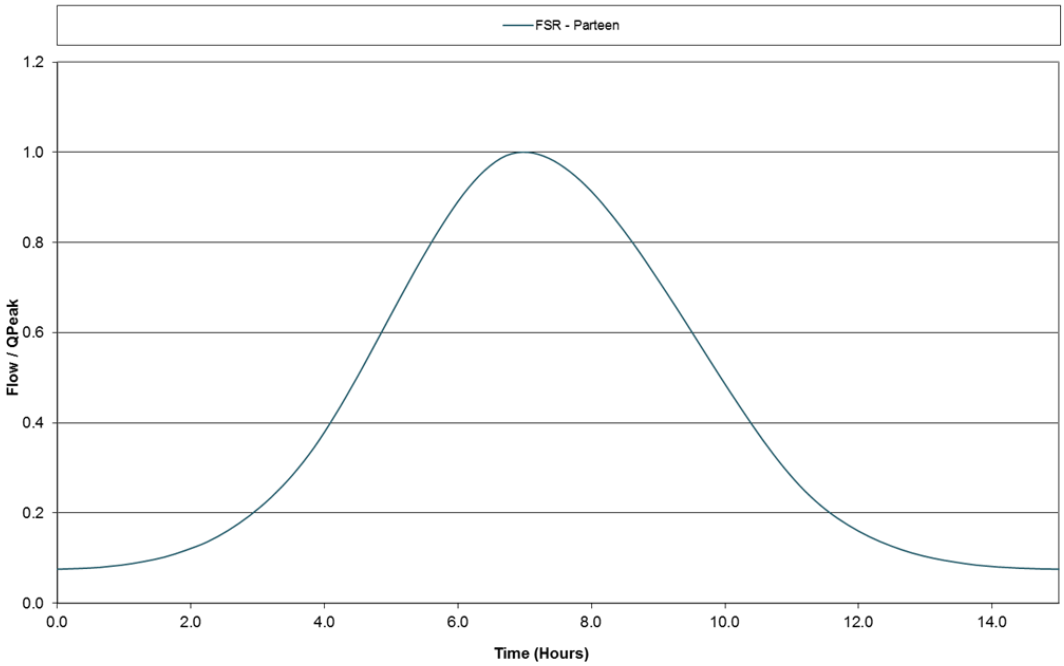


Figure A6.22 Non-dimensional FSR Hydrograph for Reach 25

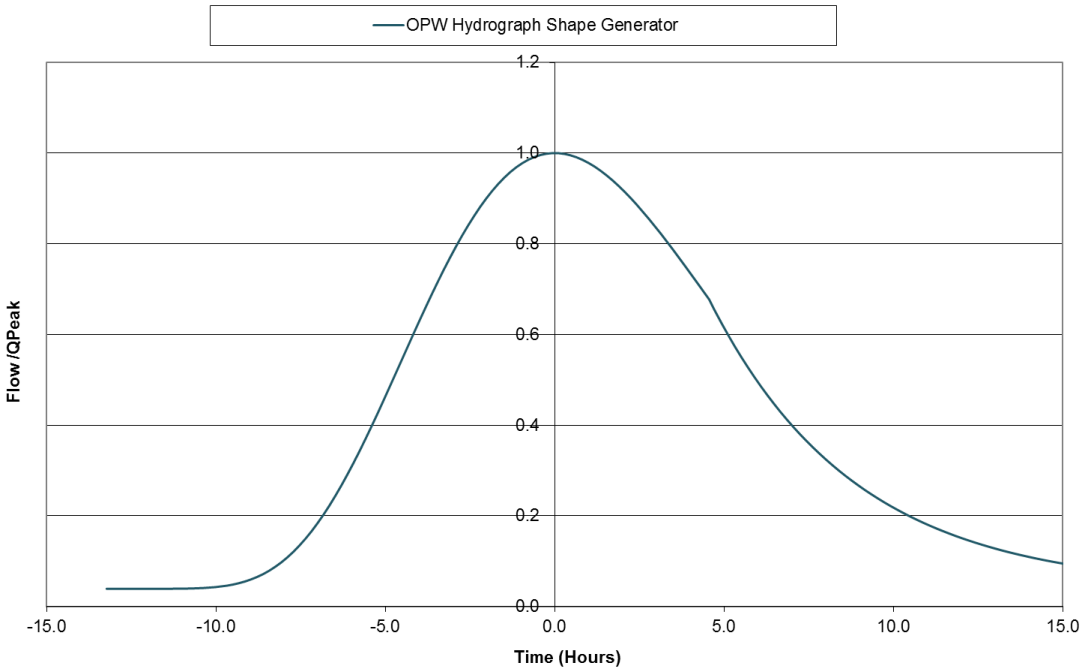


Figure A6.23 Non-dimensional Hydrograph for Pivotal Site 22009 (Reaches 26 and 78)

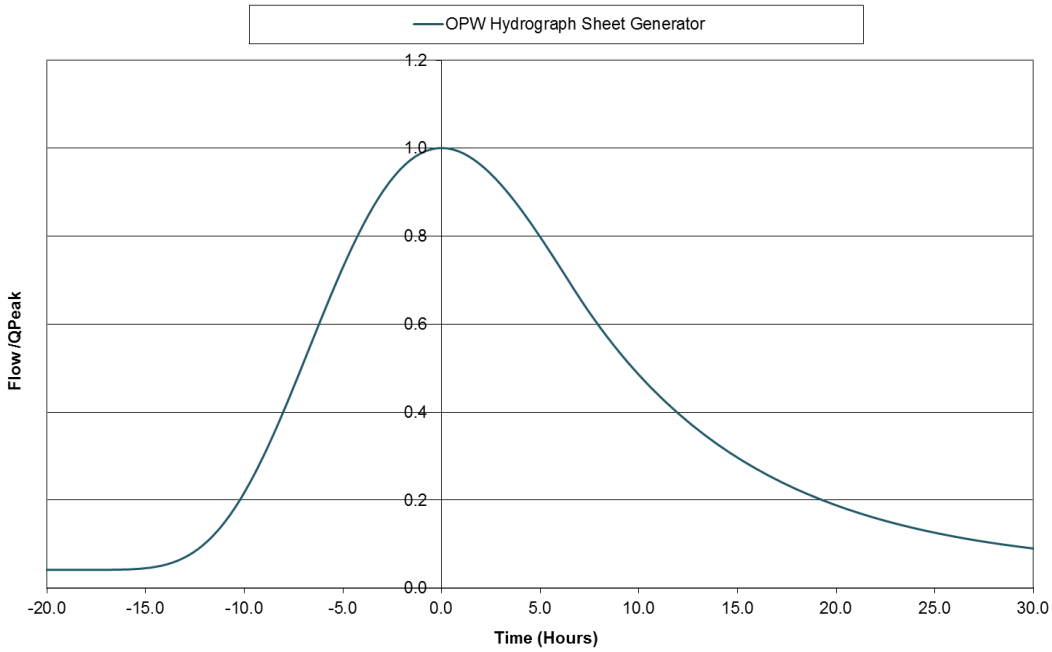


Figure A6.24 Non-dimensional Hydrograph for Pivotal Site 23012 (Reaches 32 and 33)

A6.7 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for each model is discussed in Chapters B10, B12 and B16 in Appendix B.

A6.8 Calibration

The calibration and verification of hydraulic models is discussed in Chapters B10, B12 and B16 in Appendix B.

A7 Little Brosna Catchment

A7.1 Catchment Description

The general description of the Little Brosna catchment (Figure A7.1) is given in Table A7.1.

Attribute	Description
Unit of Management (UoM)	25/26
Main water courses	River Little Brosna River Camcor and its tributary River Clonghil River Srahanbregagh River Bunnow and its tributary River Cornville and River Scart
Outflow point	River Little Brosna into the River Shannon near Friars island
Total catchment area	579 km^2
Areas for Further Assessment (AFAs)	Roscrea, Birr
Individual Risk Receptors (IRRs)	None
Model Extents*	N11, part of N10
General topology	Min altitude = 30 m AOD Max altitude = 527 mAOD Rolling hills in the southeast to flat lowland in the northwest
Average annual rainfall**	818mm to 1028mm.
Soils and geology	Well drained soils predominate with poorly drained soils limited to the higher ground around the Slieve Bloom Mountains. Peat deposits occur extensively throughout the catchment. (Refer to Figure 3.4 of the main report). Predominantly limestone bedrock. Classified as a regionally important karstified bedrock aquifer around Birr, elsewhere as a locally important aquifer. Sandstone (regionally important aquifer), shale and mudstone (poor aquifers) are limited to higher ground around the Slieve Bloom Mountains to the east where bedrock is at or close to surface. Glacial sands\ gravels occur around Roscoe and Birr and form highly permeable sand and gravel aquifers. (Refer to Figure 3.3 of the main report).
Urban areas	The towns of Roscrea and Birr are relatively small, therefore URBEXT values on the main rivers are similar to those outside the towns. The highest URBEXT is 10% on the Bunnow's tributary, Cornville. Along the River Little Brosna the URBEXT values vary between 1% and 2%. The URBEXT values are slightly increased to 3% on Tributary Srahanbregagh, upstream of the confluence with the main river. (In Figure A7.1 the AFA extents cover greater areas than the actual footprints of the towns).

* Specific hydrological details for the models are provided in Appendix B11 and Appendix B10
** range of SAAR values taken from the FSU catchment descriptors covering the extent of modelling

Table A7.1 Little Brosna Catchment description

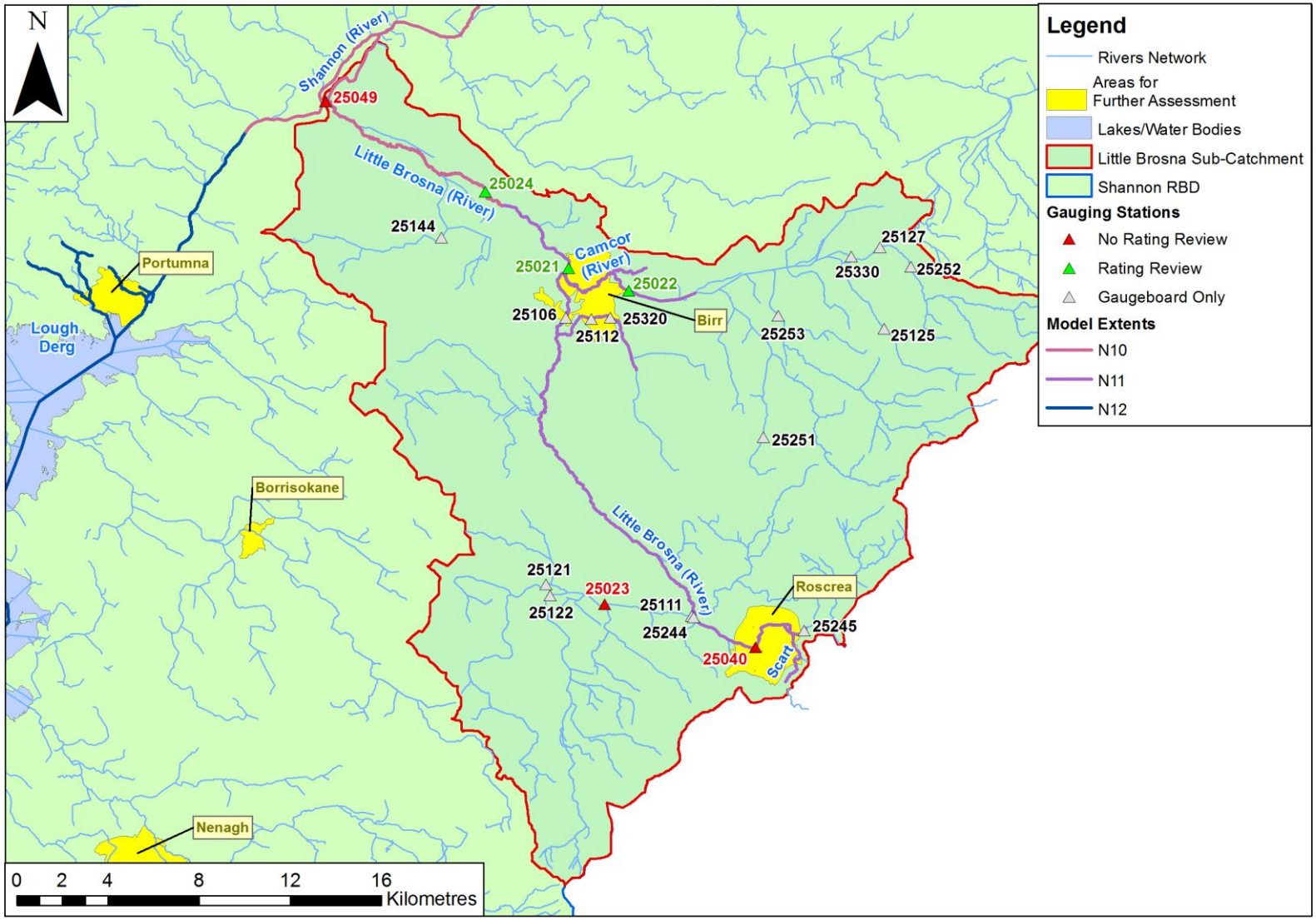


Figure A7.1 Little Brosna Catchment with both model extents and hydrometric stations indicated

A7.2 Hydrometric Stations in the Little Brosna Catchment

Details of the gauging stations in the Little Brosna catchment are tabulated in Table A7.2. They are also shown on Figure A7.1.

Model	Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments*
N11	25021	Croghan	1961 to present	Level and flow	A2	Yes	1
	25022	Syngefield	1953 to present	Level and flow	B	Yes	2
	25023	Milltown	1953 to present	Level and flow	A1	No	3
	25040	Roscrea	1980 to 1998	Flow	A2 (HGF/QMED~1.3)	No	4
N10	25024	New Bridge	1973 to 2010	Level	N/A	Yes	5

Table A7.2 Little Brosna Catchment Gauging Stations

***** Table A7.2 Hydrometric Data Quality Comments:

1. OPW rating is retained as Jacobs revised rating is not considered to be an improvement, although OPW rating is subject to uncertainty due to the scatter in the check gaugings. Site appears to be unsuitable for QMED and flood frequency estimation.
2. Station 25022 was moved downstream of Syngefield Bridge in 1975. The existing OPW AMAX is only revised since 1975 due to the change in gauging station location. However, as there is no evidence of significant catchment change, the whole AMAX series (existing OPW AMAX 1953-1974 and revised AMAX 1975-2009) can be used for QMED estimation and flood frequency analysis.
3. Station 25023 has a stable mud bed and natural channel control. It is located upstream of the model extent, on the main River Little Brosna upstream of a sharp bend in the river. It has 57 years of records classified as A1. This site is considered appropriate for QMED and flood frequency estimation.
4. Station 25040 was abandoned in 1998. This is an EPA station, not rating reviewed as part of CFRAM, and has a relatively short record (1980–1998) compared to 25022 (1953–present) and 25023 (1957–present).
5. Station 25024. This is a level only gauge (without historic ratings) that has been subject to a CFRAM rating review. The review highlighted that all mid and high flow check gaugings on the site are from two hydrometric years in the 1950s (1953 and 1954), and the geomorphology at the site can be expected to have changed since then. The N10 hydraulic model was used in an attempt to match the check gaugings, but a good fit could not be established with realistic calibration parameters. This could be evidence of geomorphological or other changes since the 1950s. For high water levels on the Shannon the station may also be affected by backwater effects. For these reasons this station was not used for QMED estimation and flood frequency analysis.

A7.3 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A7.2 above. The river reaches are tabulated in Table A7.3 and shown on Figure A7.2. The variation in catchment descriptors for each reach is tabulated in Tables A7.4 to A7.8.

Reach	Description	Model Extent
1	The entire N11 model extent along the River Little Brosna from HEP 25_344_2 to 25_3879_5, and a portion of the N10 model extent from HEP 25_3879_5 to 25_2101_7 the confluence with the River Shannon bypass channel, the Cribbies (refer to Appendices B11 and B10 for the HEP node numbering).	N11/N10
2	The River Bunnow from HEP 25_847_2 to 25_344_2	N11
3	The River Scart and Cornville, from HEP 25_1197_1a to 25_2454_4	N11
4	The River Srahanbregagh from HEP 25_3343_12 to 25_3344_8	N11
5	The River Camcor from HEP 25_631_1 to 25_1830_2	N11
6	The River Clonghil from HEP 25_2495_1a to 25_2495_4	N11

Table A7.3 River Reaches in the Catchment

Reach 1		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	190 (25_3846_1)	492(25_3879_5)
BFIsoil	0.58 (25_2101_7)	0.70 (25_633_8)
SAAR (mm)	898 (25_633_8)	931 (25_3846_1)
FARL	0.99 (25_3879_5)	1.00 (25_3846_1)
DRAIND	0.01(25_2101_7)	0.85 (25_3846_1)
S1085 (m/km)	0.1 (25_2101_7)	2.2 (25_3846_1)
ARTDRAIN2 (%)	0.0 (all)	0.0 (all)
URBEXT (%)	1.2 (25_635_8)	1.7 (25_3846_1)

Table A7.4 Reach 1 Catchment Descriptor Range

Reach 2		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	19 (25_847_2)	38 (25_344_2)
BFIsoil	0.50 (25_847_2)	0.61 (25_344_2)
SAAR (mm)	963 (25_344_2)	1028 (25_847_2)
FARL	1.00 (all)	1.00 (all)
DRAIND	1.06 (25_344_2)	1.34 (25_847_4)
S1085 (m/km)	8.8 (25_344_2)	23.2 (25_847_2)
ARTDRAIN2 (%)	0.0 (all)	0.0 (all)
URBEXT (%)	0.0 (25_847_2)	9.4 (25_841_1)

Table A7.5 Reach 2 Catchment Descriptor Range

Reach 3		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	2 (25_1197_1)	4 (25_2454_3)
BFIsoil	0.63 (25_1197_4)	0.65 (25_2454_1)
SAAR (mm)	904 (25_2454_3)	906 (25_1197_1)
FARL	1.00 (all)	1.00 (all)
DRAIND	0.10 (25_1197_1)	0.81 (25_2454_3)
S1085 (m/km)	0.1 (25_1197_4)	4.7 (25_2454_3)
ARTDRAIN2 (%)	0.0 (all)	0.0 (all)
URBEXT (%)	3.3 (25_2454_1)	10.6 (25_2454_3)

Table A7.6 Reach 3 Catchment Descriptor Range

Reach 4		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	16 (25_3343_12)	28 (25_3344_12)
BFIsoil	0.71 (all)	0.71 (all)
SAAR (mm)	858 (25_3344_12)	874 (25_3343_12)
FARL	1.00 (all)	1.00 (all)
DRAIND	0.34 (25_3343_12)	0.57 (25_3344_12)
S1085 (m/km)	2.7 (25_3344_5)	4.2 (25_3343_12)
ARTDRAIN2 (%)	0.0 (all)	0.0 (all)
URBEXT (%)	0.0 (25_3343_12)	3.1 (25_3344_12)

Table A7.7 Reach 4 Catchment Descriptor Range

Reach 5		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	137 (25_631_1)	154 (25_1830_2)
BFIsoil	0.61 (25_630_8)	0.62 (25_1830_2)
SAAR (mm)	990 (25_1830_2)	1012 (25_631_1)
FARL	0.98 (25_1830_2)	1.00 (25_631_1)
DRAIND	0.86 (25_816_1)	0.91 (25_631_1)
S1085 (m/km)	7.8 (25_1830_2)	12.1 (25_631_1)
ARTDRAIN2 (%)	0.0 (25_631_1)	0.0 (25_1830_2)
URBEXT (%)	0.2 (25_631_1)	0.9 (25_1830_2)

Table A7.8 Reach 5 Catchment Descriptor Range

Reach 6		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	2.9 (25_2495_1a)	3.7 (25_2495_4)
BFIsoil	0.36 (25_2495_1a)	0.55 (25_2495_4)
SAAR (mm)	818 (25_2495_4)	823 (25_2495_1a)
FARL	1.00 (all)	1.00 (all)
DRAIND	0.27 (25_2495_1a)	0.51 (25_2495_4)
S1085 (m/km)	2.9 (25_2495_4)	4.8 (25_2495_1a)
ARTDRAIN2 (%)	0.0 (all)	0.0 (all)
URBEXT (%)	0.0 (all)	0.0 (all)

Table A7.9 Reach 6 Catchment Descriptor Range

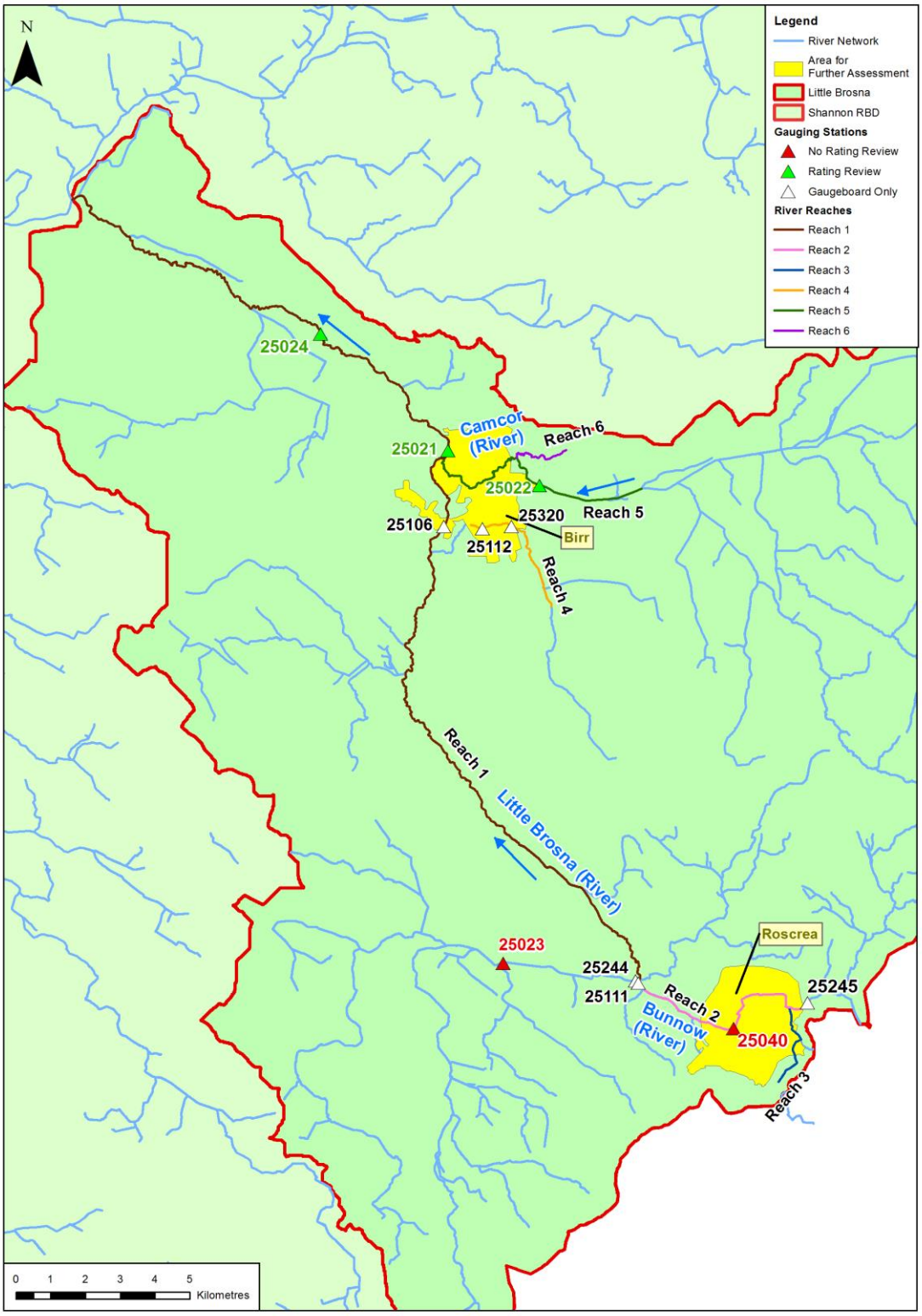


Figure A7.2 Little Brosna Catchment River Reaches

A7.4 QMED Adjustment Factors

Table A7.9 below gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED.

Reach	Gauging Station Number	QMED Observed (m^3/s)	QMED (urban) Synthetic (m^3/s)	Adjustment Factor (-)	Model Extent	Note
1	25021	29.1	49.2	0.59-1.19	N11	1
5	25022	27.2	25.5	1.06	N11	
N/A	25023	12.0	12.2	0.98	N11/ N10	2
2	25040	3.6	6.6	0.55	N11	3

Table A7.10 Available QMED Adjustment Factors in each reach

Notes:
1. Rating from station 25021 is subject to uncertainty as there is considerable scatter evident in check gaugings. Varying ratings suggest adjustment factors in the range given in the table. AMAX is not suitable for high flow analysis, but has been used for comparison, see note for Reach 1 in Table A7.11 below.

2. Station 25023 is located on the River Little Brosna, upstream of the model extent. The station is classified as A1, a comparatively reliable site on the main river.

3. Station 25040 Roscrea is the only gauging station within the Bunnow Catchment (Reaches 2 and 3). It has a reliable rating up to about 1.3xQMED. It has therefore been used for Reach 2 and as the single pivotal station for Reach 3. With a very low QMED adjustment factor it is recommended that more high flow check gaugings are obtained and that the rating and AMAX series are reviewed by OPW.

The QMED adjustment factors for the ungauged reaches in the catchment were estimated using pivotal sites.

The adjustment factors for these reaches were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A7.11).

The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: $\prod (\text{Adjustment Factor}^{\text{Weight}})$.

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
16051	ROSSESTOWN	1	0.350		0.73
9035	KILLEEN ROAD	2	0.511		1.90
10021	COMMON'S ROAD	3	0.511		1.49
9002	GRIFFEEN	4	0.654		1.17
25040	ROSCREA	5	0.731		0.55
Weighted Geometric Mean					**1.06**

Table A7.11 QMED Adjustment Factor for HEP 25_3344_8 (Reach 4)

The use of a single pivotal site was also considered, and for Reach 4 the adjustment factor found with the five most similar sites provided the same adjustment factor as that from Station 25022 on Reach 5, giving some confidence that this provides a reasonable adjustment.

Table A7.12 shows the final QMED adjustment factor applied to each reach in the catchment, each with a justification for selection.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	0.98	25023	QMED estimated from station 25021 Croghan is subject to uncertainty in the rating. Varying ratings suggest adjustment factors between 0.59 and 1.19. The value of 0.98 from Station 25023 is adopted for Reach 1 as Station 25023 is on the Little Brosna upstream of Reach 1, has a reliable rating and the adjustment factor is within the range 0.59-1.19 and slightly above the mean of that range.
2	0.55	25040	The only flow gauging station in the reach. The EPA rating curve was not subject to a CFRAM rating review.
3	0.75	Average of 25040 (0.55) and 25_2454_1 (0.95)	To give extra weight to Station 25040 which is situated downstream of Reach 3, the average of the ungauged adjustment factor for HEP 25_2454_1 and Station 25040 was considered a reasonable adjustment factor. The ungauged factor was estimated as the geometric mean of adjustment factors at 5 pivotal sites.
4	1.06	25_3344_8	Considered reasonable as it is identical to the adjustment factor from Station 25022 as a single pivotal station, which is reassuring due to the station's vicinity to the subject reach.
5	1.06	25022	The only reliable flow gauging station within Reach 5.
6	1.06	25022	Station 25022 was considered a reasonable pivotal site for this reach as it is situated in the same catchment, downstream of the subject site. In addition, the adjustment factor from five pivotal sites produces an adjustment factor of 1.33, which is higher than 1.06 from Station 25022. The QMED estimates at the nodes downstream of the confluence of Reach 6 into Reach 5 are smaller than QMED upstream of Reach 5 (in 25_630_5). Use of a higher adjustment factor and hence higher flow from Reach 6 would further increase the flow contribution to the downstream reach. Therefore, to achieve a more balanced flow u/s and d/s of the confluence, the smaller QMED adjustment factor from Station 25022 was considered more reasonable

Table A7.12 Final QMED Adjustment Factors Applied to Each Reach

A7.5 Flood Frequency Curves

Gauging Station Flood Frequency Curves

Two stations suitable for flood frequency analysis were identified in the catchment: 25023 (Milltown) and 25022 (Syngefield). The flood frequency curves (or growth curves) are plotted in Figures A7.3 and A7.4. (The flood frequency curve plots for all relevant stations are included in Appendix E). The figures show the at-site AMAX series (made dimensionless by dividing the flows by QMED, and plotting positions based on the Gringorten formula), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate and AEP scale.

a) **Milltown Gauging station (25023)**

57 years of acceptable AMAX data suggests single site analysis offers reasonably robust estimates up to return periods of 28 years i.e. AEP = 3.6% (based on 1/2N with N=57).

The Milltown at-site and pooled growth curves are shown on Figure A7.3. For lower AEPs (higher return periods) the pooled growth curve may be more appropriate.

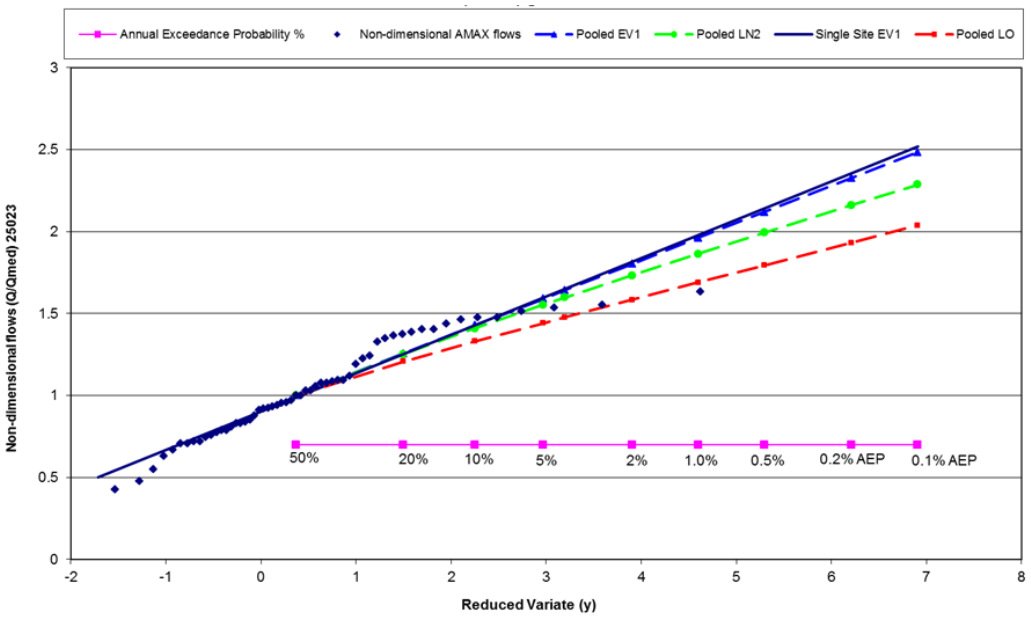


Figure A7.3 25023 Milltown – Flood Frequency Curves

b) Syngefield Gauging station (25022)

61 years of acceptable AMAX data suggests single site analysis offers reasonably robust estimates up to return periods of 30 years i.e. AEP = 3.3% (based on 1/2N with N=61).

The Syngefield at-site and pooled growth curves are shown on Figure A7.4.

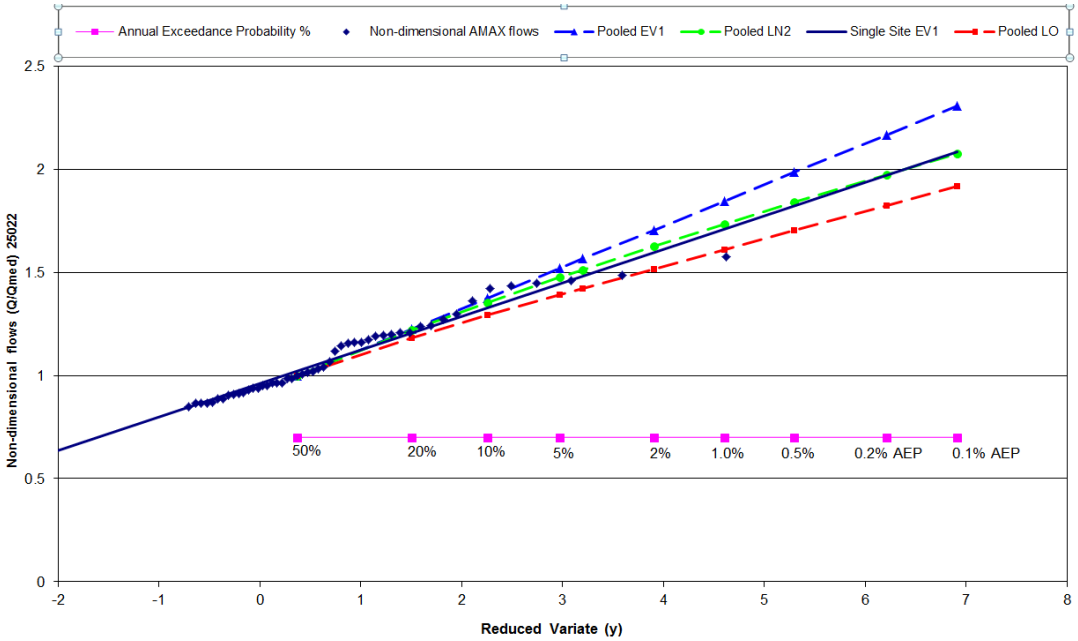


Figure A7.4 Syngefield 25022 – Flood Frequency Curves

c) Roscrea Gauging Station (25040)

The Roscrea gauging station has 19 years of AMAX flows. For comparison the single site analysis is shown against pooling group flood frequency curves Figure A7.5.

Due to the short record a pooled growth curve is preferred at this station. The LN2 distribution curve fits best with the at-site data (certainly up to the 10% AEP event) and has therefore been adopted.

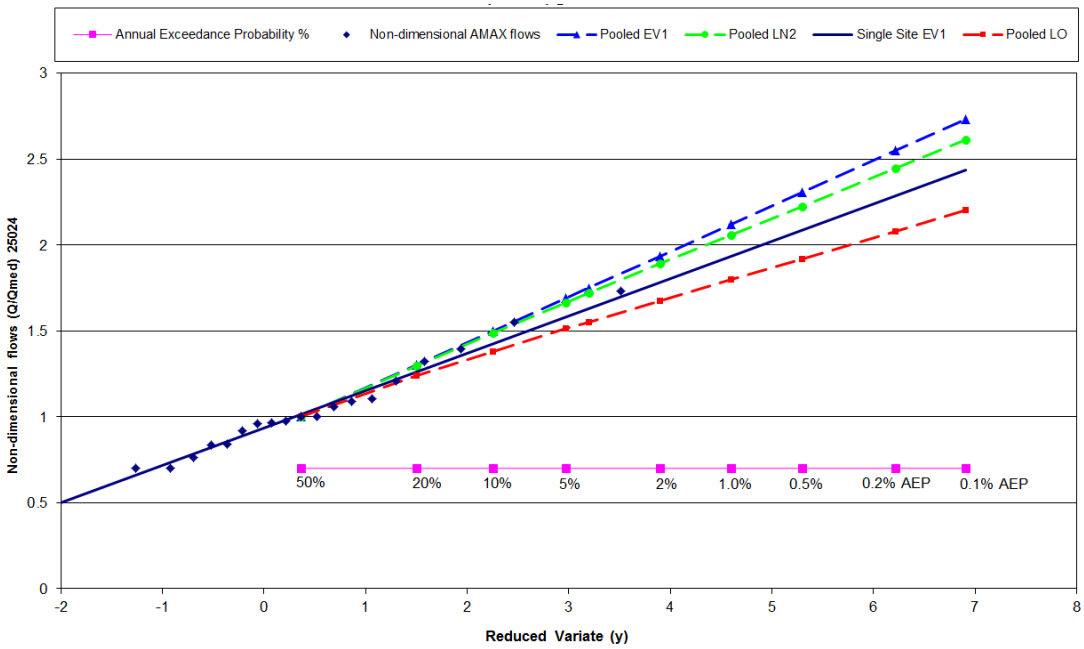


Figure A7.5 Roscrea 25040 – Flood Frequency Curves

River Reach Flood Frequency

The pooled growth factors for stations 25023 and 25022 are relatively similar. The growth curve distributions applied to the relevant reaches are shown in Table A7.11. Growth factors generated for a range of AEPs have been detailed in Table A7.12.

Reach	Station	Single Site or Pooled	Selected distribution
1, 4 and 5	25023 – Milltown	Pooled	EV1
2 and 3	25040 – Roscrea	Pooled	LN2

Table A7.12 Final Growth Curves Selected

The model rating review suggests that station 25021, the only flow gauging station along the main river (Reach 1), is not suitable for flood frequency analysis. Instead, pooled analysis at station 25023 was undertaken although it is located in the upstream of the main river outside of the model extent. The resulted pooling group of 518 years of data is considered suitably homogenous, and the represented growth curve EV1 was obtained and adopted.

The pooled LN2 curve from Station 25040 was adopted to represent Reaches 2 and 3 as Station 25040 is the only flow gauging station in the Bunnow sub catchment.

Annual Exceedance Probability (%)	Growth Factors Reaches 1, 4, 5	Growth Factors Reaches 2, 3
50%	1.00	1.00
20%	1.26	1.30
10%	1.43	1.49
5%	1.59	1.67
2%	1.80	1.89
1%	1.96	2.06
0.5%	2.12	2.23
0.1%	2.49	2.61

Table A7.13 Final Growth Factors Applied to the Little Brosna Catchment

A7.6 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

Table A7.13 summarises the gauging stations used to produce the typical flood hydrograph shapes for the catchment reaches.

Reach	Gauging Station
1	25023 – Milltown
2-3	25040 - Roscrea
4	30030 – Dalgan (Pivotal station)
5	25022 – Syngefield
6	FSR hydrograph shape

Table A7.14 Gauging Stations used to derive the Typical Hydrograph Shape in each Reach

Tables A7.14–15 and Figures A7.6–7 identify the highest flood events chosen for comparison at the gauges. The figures present the hydrographs in a non-dimensional manner by dividing flows by their respective flood peaks. The hydrograph that best represents a typical/median flood response has then been selected as the representative design hydrograph shape.

Date	Peak Flow (m^3/s)	Comments
07/02/1990	19.8	
16/12/1986	18.7	
28/01/1995	18.2	
26/08/1986	17.9	Selected for hydrograph shape

Table A7.15 Highest Flood Peaks for Gauging Station 25023

Date	Peak Flow (m^3/s)	Comments
26/08/1986	5.5	Selected for hydrograph shape
22/02/1995	4.9	
17/10/1997	6.2	
02/11/1998	4.6	

Table A7.16 Highest Flood Peaks for Gauging Station 25040

Date	Peak Flow (m^3/s)	Comments
06/02/1990	39.6	
28/01/1995	38.5	
31/01/2009	37.0	
26/08/1986	34.6	Selected for hydrograph shape

Table A7.17 Highest Flood Peaks for Gauging Station 25022

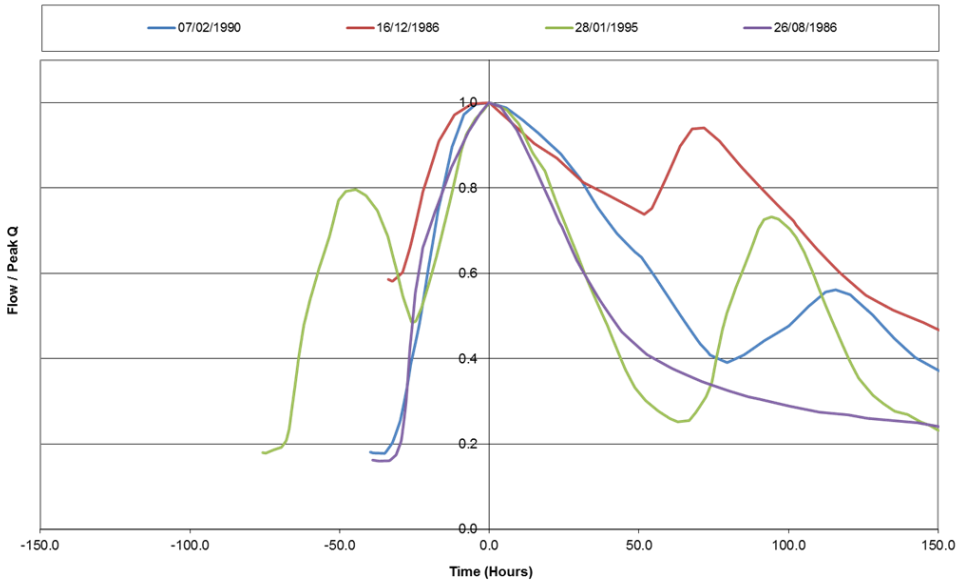


Figure A7.6 Non-dimensional Hydrographs Gauging Station 25023 (Reach 1)

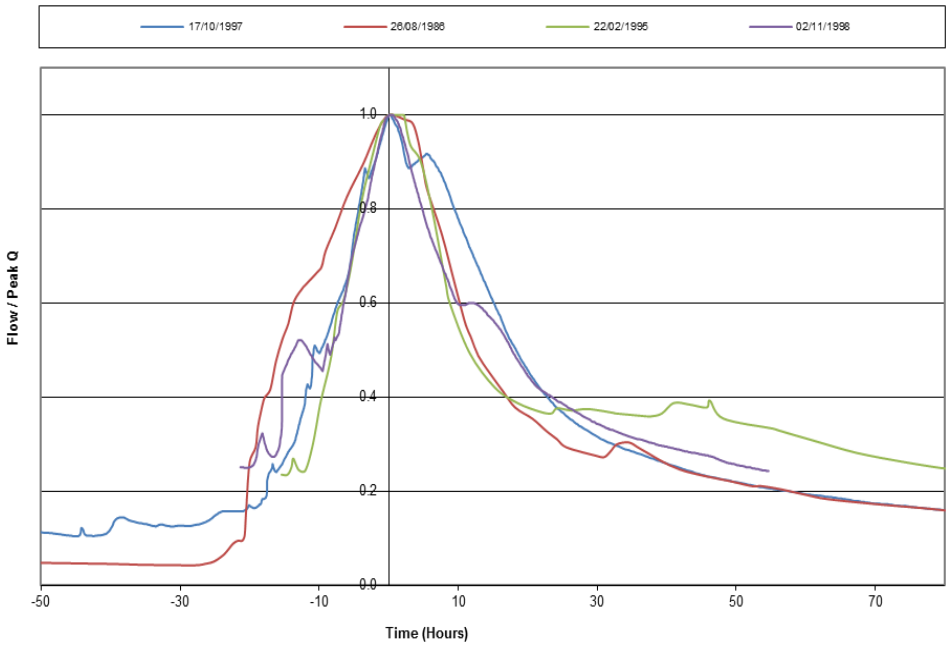


Figure A7.7 Non-dimensional Hydrographs Gauging Station 25040 (Reaches 2-3)

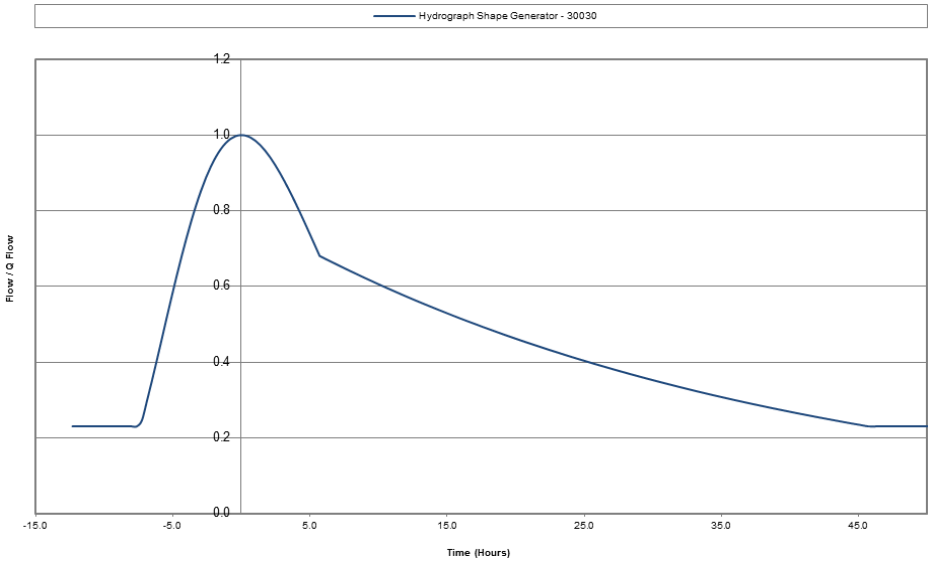


Figure A7.8 Non-dimensional Hydrograph Pivotal Station 30030 (Reach 4)

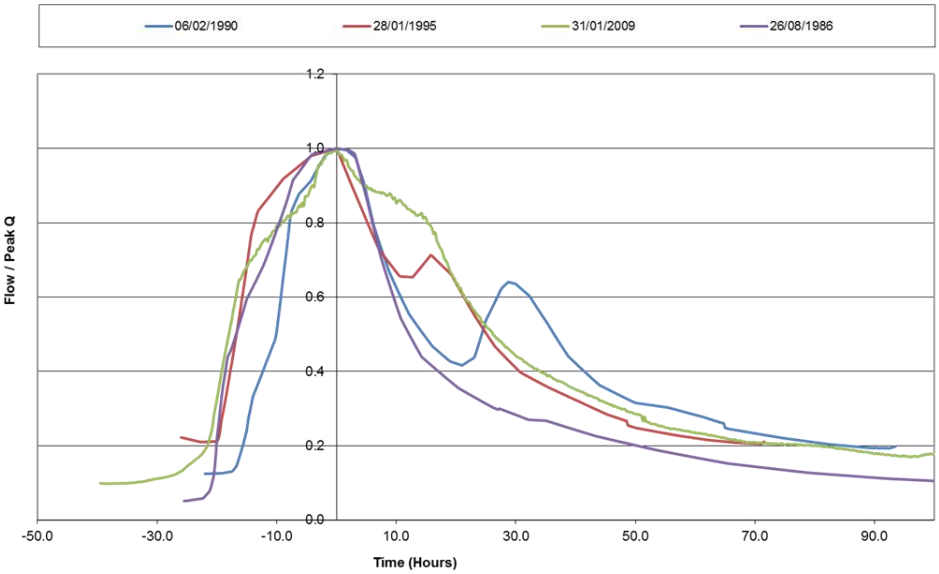


Figure A7.9 Non-dimensional Hydrographs Gauging Station 25022 (Reach 5)

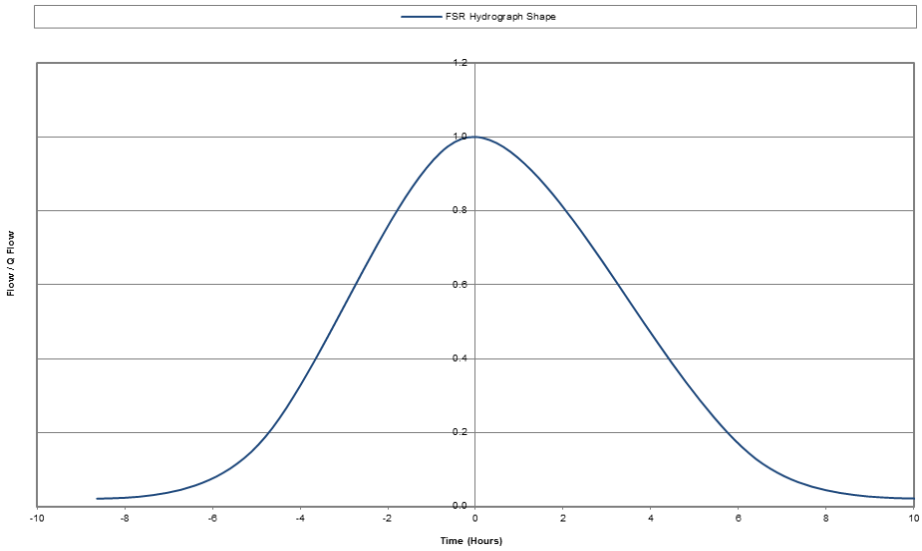


Figure A7.10 Non-dimensional FSR Hydrograph for Reach 6

A7.7 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for each model is discussed in Appendices B10 and B11.

A7.8 Calibration

The calibration and verification of hydraulic models is discussed in Appendices B10 and B11.

A8 Ballyfinboy Catchment

A8.1 Catchment Description

The River Ballyfinboy is a small river which flows into Lough Derg located on the River Shannon in UoM 25/26. The catchment area to its entry into Lough Derg is 193 km^2. The River Ballyfinboy broadly flows from east to west, see Figure A8.1.

The modelled part of the Ballyfinboy catchment is covered by model extent N13.

Tributaries into the River Ballyfinboy are minor and are not part of the model extent.

The only AFA in the catchment is Borrisokane. There are no (Individual Risk Receptors) IRRs in the catchment.

The BFIsoil values along the N13 model extent ranges from 0.698 at the upstream end of the model up to 0.710 downstream near the inflow location to Lough Derg which indicates that there is very little change in the geology underlying the River Ballyfinboy. SAAR ranges from 932 mm at the upstream end of the model extent to 899 mm near the inflow to Lough Derg.

The catchment contains few karstic features (springs, sinkholes and turloughs) as shown on Figure 3.3 in Chapter 3 of the main report. It is expected that the small amount of karstic features in the vicinity of the N13 model extent should have little effect on the design hydrology of N13. In any case, QMED is derived from gauged data and therefore should account for these karstic features in the vicinity of the Ballyfinboy River.

The URBEXT values vary very little along the N13 model extent and the catchment can be classed as primarily rural with the exception of the AFA, Borrisokane. URBEXT reaches a maximum of 1.99 in the vicinity of Borrisokane and gradually decreases as one travels further downstream towards the inflow to Lough Derg.

A8.2 Catchment Geology

The geology of the Ballyfinboy catchment consists of Quaternary subsoils over predominantly Carboniferous limestone bedrock from which much of the overlying glacial deposits are derived. The other predominant subsoil within the Ballyfinboy catchment is peat.

The peat deposits are underlain by Carboniferous limestone and are most extensive within the vicinity of current watercourses.

Limestone till deposits occur across the entire catchment area. The deposits are underlain by pale grey massive limestone of the Waulsortian mudbank in the central and far northwest of the catchment, by the dark grey argillaceous and cherty limestone of the Marine basinal facies in the centre of the catchment and limestone and shale of the Marine shelf and ramp facies to the south of the catchment, all of which are described as locally important bedrock aquifers. The limestone till across these areas is described as moderately permeable subsoil overlain by well-drained soil.

Much of the central area of the catchment is underlain by cherty limestone and calcareous shale of the karstified Marine shelf facies which forms a regionally and locally important aquifer of low to extreme vulnerability. Here the limestone till is described as moderately permeable subsoil overlain by poorly drained gley soil (blue grey clay soil that forms in heavily waterlogged areas).

Carboniferous limestone bedrock forms isolated surface outcrops within the surrounding limestone till across the catchment area with significant surface outcrops of karstified Marine shelf facies occurring to the west and southwest of Borrisokane.

Glacial fluvial limestone sands and gravels occur in the central southern and south eastern area of the catchment. The sands and gravels are described as high permeability subsoils overlain by well drained soils.

The far south east and north east tips of the catchment area are underlain by Devonian and Silurian sandstones from which the overlying till is derived. These tills are described as low to moderate permeability subsoils.

A8.3 Hydrometric Stations in the Ballyfinboy Catchment

The gauging stations in the catchment (within the N13 model extent) are tabulated in Table A8.1. They are also shown on Figure A8.1.

Model	Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments
N13	25025	Ballyhooney	1957 - present	Level and Flow	A1	No	1, 2
	25113	Cloghjordan	N/A	N/A	N/A	N/A	3
	25120	Cullenwaine	N/A	N/A	N/A	N/A	3
	25132	Borrisokane	N/A	N/A	N/A	N/A	3
	25326	Ballyfinboy Castle	N/A	N/A	N/A	N/A	3

Table A8.1 Ballyfinboy Catchment Gauging Stations

Table A8.1 Quality comments:

1. A notable step change was observed in the daily mean flow series (DMF) for 25025 from November 1985 and an upward trend observed in the Amax series from this time. The “RBD Shannon Data Summary.xls” spreadsheet splits the record up in a range from 1957 to 1985 and one from 1985 to present, but does not indicate any drainage works within the catchment. However, the step change in 1985 suggests a change in catchment response in that year and so the Amax series has been taken from 1985 to estimate QMED and for further flood frequency analysis.
2. According to the FSU classification, 25025 is considered an A1 gauging site. However, based on the check gaugings available for this site a quality classification of B would be more appropriate as the highest check gauging is around QMED and all other check gaugings are considerably lower. Plotting the check gaugings reveals that there is also

a large scatter in the check gaugings which raises some uncertainty about the accuracy of the higher AMAX values for this site.

3. Staff gauge only (no recorder).

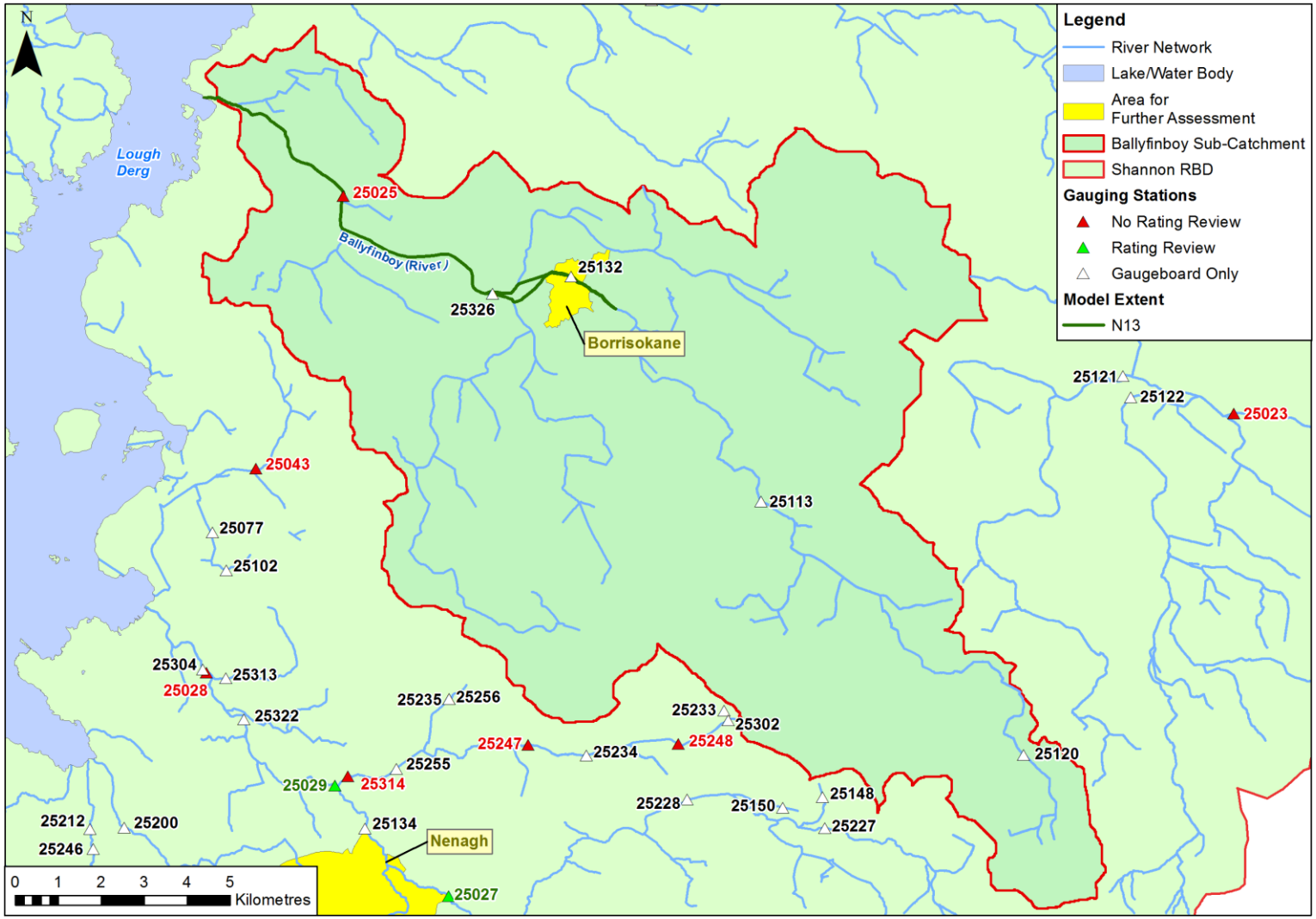


Figure A8.1 Ballyfinboy Catchments Model Extent

A8.4 Catchment River Reaches

River reaches are defined in the context of the River Shannon CFRAM design hydrology analysis as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. Based on the available gauged data, the small variation in the SAAR catchment descriptor and the uniform geology across the N13 model extent (illustrated by the small variation in BFIsoil), a single reach was considered appropriate. The reach extent is summarised in Table A8.2 below, and shown on Figure A8.1.

Reach	Description
Entire N13 river reach	N13 model extent starts at HEP node 25_3530_2a just upstream of Borrisokane AFA and ends at the inflow into Lough Derg (refer to Figure A8.1)

Table A8.2 River Reaches in the Catchment

N13 Model Extent - Ballyfinboy River		
Catchment Descriptor	**Lower Limit**	**Upper Limit**
AREA	37.0 (25_3670_7)	193.3 (25_1853_3)
BFIsoil	0.70 (25_3530_9)	0.72 (25_1855_1)
SAAR	874 (25_3670_7)	932 (25_3530_5)
FARL	1.00 (25_3589_1)	1.00 (25_3670_8)
DRAIND	0.50 (25_3670_7)	0.58 (25_1853_3)
S1085	1.71 (25_3670_7)	2.80 (25_3530_5)
ARTDRAIN2	0.00 (25_3530_5)	6.76 (25_3670_7)
URBEXT	0.00 (25_3670_7)	1.99 (25_3530_6)

Table A8.3 Catchment Descriptor Range for the N13 model extent

A8.5 QMED Adjustment Factors

The QMED has been calculated for gauging station 25025 both from recorded annual maximum data and synthetically. The ratio of these two values gives an adjustment factor to refine the QMED estimate at ungauged locations in the same reach. Table A8.4 below gives the QMED adjustment factors at the only flow gauging station in the catchment.

Reach	Gauging Station Number	QMED Observed (m^3/s)	QMED (Urban) Synthetic (m^3/s)	Adjustment Factor (-)	Comment
1	25025	11.4	15.8	0.72	Station 25025 is the only useable gauging station within the catchment of the Ballyfinboy River. All other gauges within this catchment are staff gauges.

Table A8.4 QMED Adjustment Factor for Ballyfinboy Catchment

The QMED adjustment factor is notably low. This may be a consequence of the high permeability of the catchment (BFIsoil~0.70) which is known to cause difficulty to the FSU QMED regression equation. The adjustment factor of 0.72 is the best estimate available in the catchment based on gauged data and has therefore been applied to the entire reach.

A8.6 Flood Frequency Curves

Single site and pooling group analysis was undertaken for gauging station 25025, Ballyhooney. The flood frequency curve is plotted in Figure A8.2. Figure A8.2 shows the at-site AMAX series (made dimensionless by dividing the flows by QMED), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate (on a Gringorton plot). It is observed that the pooled distributions produce lower growth curves than the curve fitted to the at-site data.

It should be noted that a rating review has not been undertaken for gauging station 25025 (Ballyhooney) as part of the Shannon CFRAM Study. According to the FSU classification, station 25025 is considered an A1 gauging site. However, based on the check gaugings available for this site a quality classification of B would be more appropriate as the highest gauged flow is around QMED and all other gauged flows are considerably lower. There is also a large scatter in the check gaugings which generates some uncertainty about the accuracy of the higher AMAX values for this site.

With the uncertainty described above, and the limited number of AMAX years (25 years), it is appropriate that a pooled distribution is selected. Although there is some uncertainty in the highest AMAX values, there are no indications that the at-site data is over predicting the growth factors by large amounts, and a pooled curve close to the at-site data (see Figure A8.2) is preferred over shallower curves. The EV1 and LO pooled curves are closer to the at-site data than the LN2 curve and are therefore preferred. There is only 4% difference in the 1% (1 in 100) AEP growth factor between the EV1 and LO curves. However the L-Moment ratio diagram in Figure A8.3 below shows that the EV1 distribution provides a (much) better fit with the L-Moments for the sites that make up the pooling group than the LO distribution. For this site the pooled EV1 distribution was therefore selected as the most appropriate distribution for the local growth curve.

The use of the EV1 distribution suggests that the highest recorded flood (Nov 2009) has a return period of approximately 200 years (i.e. an AEP of 0.5%). It also suggests that the 20 year (5% AEP) event has been exceeded once in its 25 years of record, which appears to be reasonable.

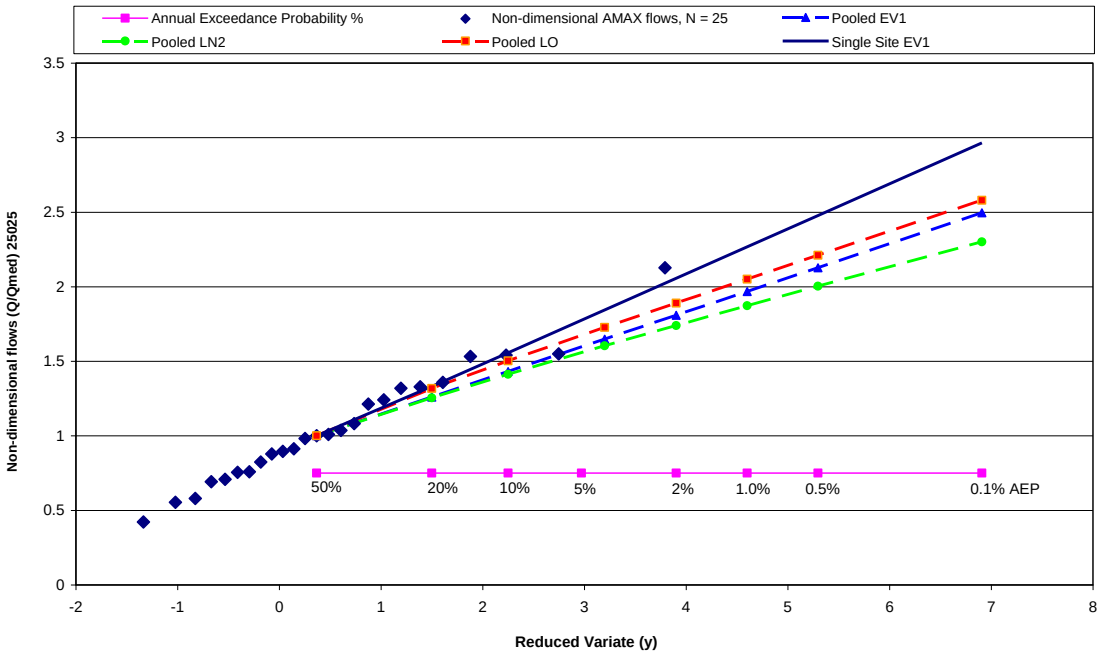


Figure A8.2 25025 Ballyhooney - Growth Curves

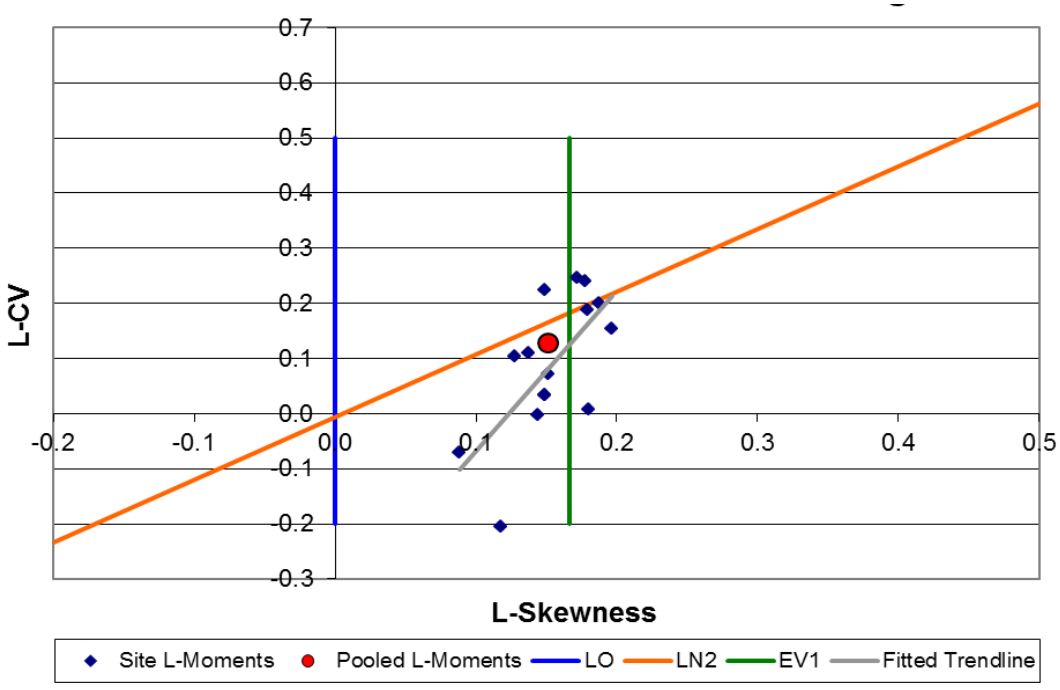


Figure A8.3 25025 Ballyhooney – 2-Parameter L-Moment Ratio Diagram

The pooled EV1 growth factors for Ballyhooney have been applied to the entire modelled river. This was deemed appropriate given that it is the only recorder gauge on the River Ballyfinboy. The selected distribution and resulting growth factors are shown in Table A8.5 and Table A8.6 respectively.

Reach	Station	Single Site or Pooled	Selected Distribution
Entire N13 river reach	25025 – Ballyhooney	Pooled	EV1

Table A8.5 Growth Curve Selected

Annual Exceedance Probability (%)	Growth Factors
50%	1.00
20%	1.26
10%	1.43
5%	1.60
2%	1.81
1%	1.97
0.5%	2.13
0.1%	2.50

Table A8.6 Growth Factors Applied to the Ballyfinboy Catchment

A8.7 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape.

This model extent is gauged. Ballyhooney is located relatively central on the River Ballyfinboy downstream from the Borrisokane AFA. Table A8.7 and Figure A8.4 show the four largest flood events recorded at gauging station 25025 which have digitally available hydrograph records. Figure A8.4 presents the hydrographs in a non-dimensional manner by dividing the flows by their respective flood peak. The hydrograph that best represents the median or typical storm duration has then been selected as the representative design hydrograph shape.

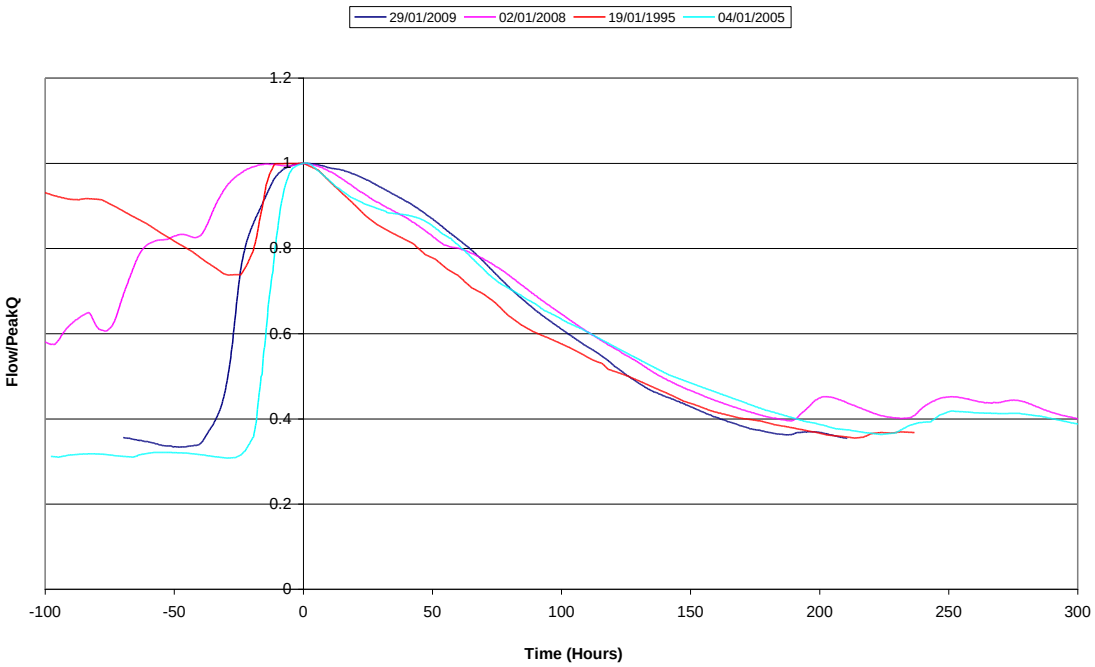


Figure A8.4 Non-dimensional Hydrographs for Gauging Station 25025

Date	Peak Flow (m^3/s)	Comments
29/01/2009	17.5	Selected for hydrograph shape
02/01/2008	16.8	
04/01/2005	15.5	
19/01/1995	17.0	

Table A8.7 Top Four Historic Amax Flows for Gauging Station 25025

The 29/01/2009 historic flood hydrograph was selected as an appropriate shape for the design hydrographs. Of the four hydrographs shown on Figure A8.4 it is shorter than the longest hydrograph (of Jan 2008) but shorter than the other two hydrographs. It is therefore considered to be a good estimate of a median hydrograph. This event was the second highest ever recorded in the AMAX series for the site and occurred recently. The highest event in the AMAX series did not have digitally available hydrograph records and is not included in Table A8.7.

A8.8 Flows and Hydrometric Estimation Points

The peak flow estimation at individual HEPs for each model is discussed in Appendix B13.

A8.9 Calibration

The calibration and verification of hydraulic models is discussed in Appendix B13.

A9 Nenagh Catchment

A9.1 Catchment Description

The general description of the Nenagh catchment (Figure A9.1) is given in Table A9.1.

Attribute	Description
Unit of Management	25/26
Main watercourses	River Nenagh, Ollatrim River, Moyroe Stream and Benedin Stream
Outflow point	River Nenagh into Lough Derg
Total catchment area	326 km^2 (to Lough Derg)
Areas for Further Assessment (AFAs)	Nenagh
Individual Risk Receptors (IRRs)	None
Model Extents*	N14
General topology	Min altitude = 27 m AOD Max altitude = 475 m AOD Rolling hills in the east to flat lowland in the west
Average annual rainfall**	930 mm to 1252 mm.
Soils and geology	Well drained soils predominate with limited poorly drained soils and peat occurring over areas of higher ground and where bedrock is close to the surface. Refer to Figure 3.4 in the Main Report for the distribution of differing soil drainage classes. Subsoils comprise predominantly low to moderate permeability glacial tills over limestone, mudstone and sandstone bedrock. Minor alluvium, lake sediments and glacial sands and gravels occur predominantly along watercourses. Sandstone bedrock is limited to the area between Toomyvara and Dolla while mudstone bedrock forms the higher ground to the south with extensive surface outcrops. Both the sandstone and mudstone are poor aquifers. The remainder of the catchment is underlain by limestone bedrock which is a locally important bedrock aquifer, recorded as karstified in an isolated area north of Nenagh. Refer to Figure 3.5 in the Main Report for the hydrogeological characteristics of the underlying rock formations.
Urban areas	The town of Nenagh is the only significant urban area. Locally, URBEXT values are high on the tributaries running through the town. The highest URBEXT values occur along the Benedin Stream at 29% and the Moyroe Stream at 20%, which both run through the Nenagh AFA. On the River Nenagh the URBEXT values decrease from 1.5% immediately downstream of Nenagh to 1.2% at the outflow to Lough Derg. In Figure B14.1 (Appendix B14) the actual town is shown to be smaller than the AFA extent suggests.

* Specific hydrological details for the models are provided in Appendix B14
** Range of SAAR values taken from the FSU catchment descriptors covering the extent of modelling

Table A9.1 Nenagh Catchment Description

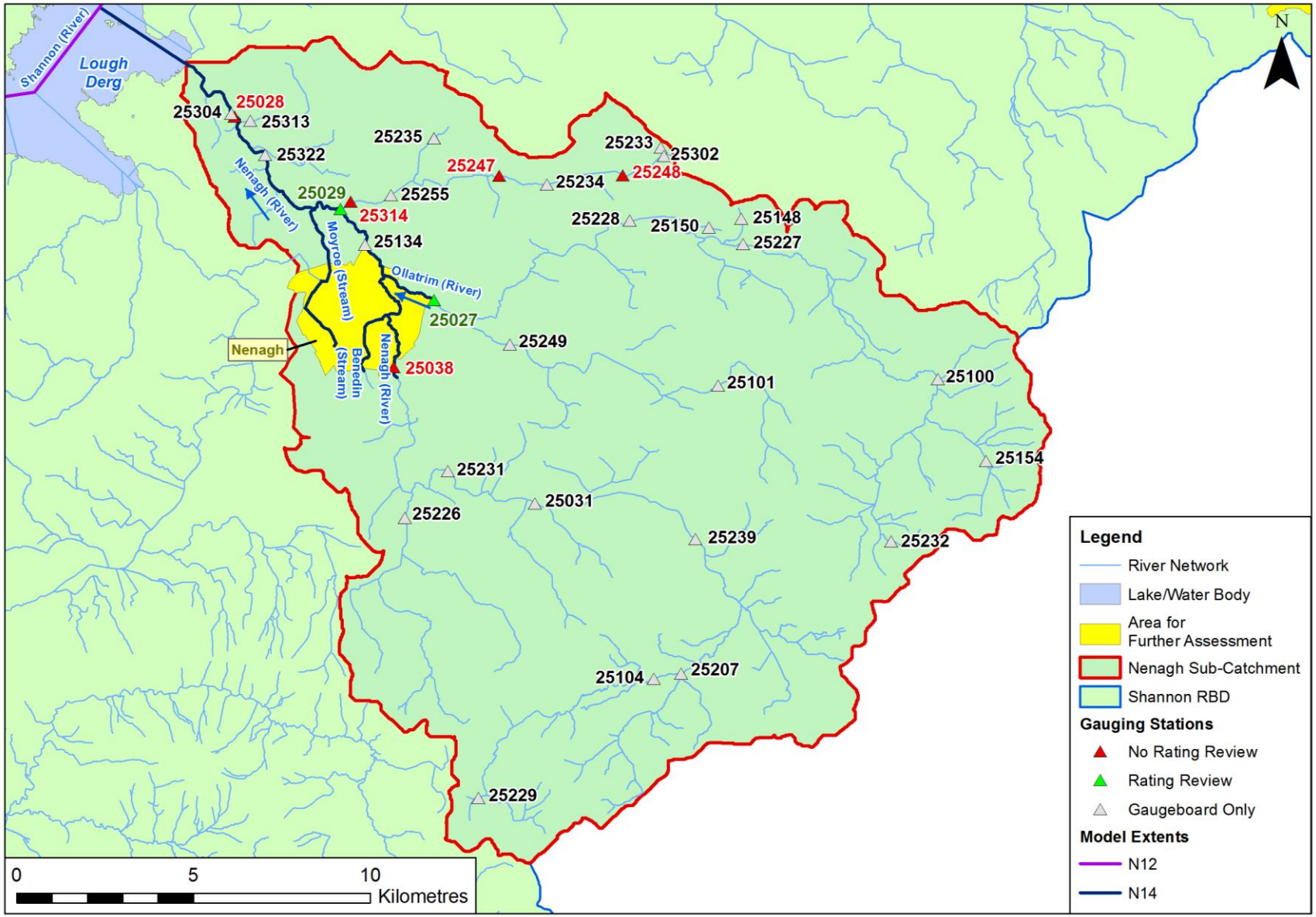


Figure A9.1 Nenagh Catchment Extent

A9.2 Hydrometric Stations in the Nenagh Catchment

Details of the gauging stations in the Nenagh catchment are tabulated in Table A9.2. They are also shown on Figure A9.1. Staff gauges without recorders have not been included.

Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments
25027	Gourdeen	1962 - 2009	Level and flow	A1	Yes	1
25028	Annabeg	1950 - 1955	N/A	N/A	No	2
25029	Clarianna	1972 - 2009	Level and flow	A2	Yes	3
25038	Tyone	1988 - 2012	Level and flow	A2	No	4
25247	Hackstown	1999 - 2001	Level and flow	N/A	No	5
25248	Tooreigh	1999 – 2002	Level and flow	N/A	No	5
25314	Ballyanny	1999 - 2002	Level and flow	N/A	No	5

[1] The rating review at Gourdeen showed that the AMAX flows from 1966 to 1988 can be used with the existing OPW rating, and the AMAX flows from 1989 to present with a revised rating based on hydraulic modelling.

[2] Annabeg – An inactive station with short record from 1950 to 1955. Record is not suitable for flood flow estimation.

[3] Clarianna – The rating review concluded that there was insufficient evidence to revise the existing and historic OPW ratings. The full AMAX series from 1972 (based on the OPW ratings) can be used for flood flow estimation.

[4] Tyone – Flow gauge reportedly active from 1979, but AMAX flows only available from 1988.

[5] These are inactive stations with very short records on a tributary to the River Nenagh outside the N14 model extent, and not relevant for flood flow estimation within the N14 model extent.

Table A9.2 Nenagh Catchment Gauging Stations

A9.3 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A9.2 above. The river reaches are tabulated in Table A9.3 and shown on Figure A9.2. The variation in catchment descriptors for each reach is tabulated in Tables A9.4 to A9.8 below.

Reach	Upstream Node	Downstream Node	Description
1	25_3495_4	25_335_5	Nenagh River - Top of the N14 model extent (on the main stem) to the Nenagh/Ollatrim confluence
2	25_1844_1	25_2140_4	Nenagh River - Nenagh River/Ollatrim River confluence to N14 model downstream end at the outflow to Lough Derg
3	25_3_3	25_3_7	Ollatrim River is a significant tributary of the Nenagh River
4	25_3773_1	25_3773_5b	The Moyroe stream is a small tributary of the Nenagh River which flows through the Nenagh AFA.
5	25_3560_2	25_3560_6	The Benedin tributary is a small tributary of the Nenagh River near the upstream end of the Nenagh River. It is situated within the Nenagh AFA.

Table A9.3 River Reaches in the Catchment

Reach 1 Upper Nenagh		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	135 (25_3495_4)	144 (25_335_5)
BFIsoil	0.60 (all nodes)	0.60 (all nodes)
SAAR (mm)	1232 (25_335_5)	1252 (25_3495_4)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.9 (all nodes)	0.9 (all nodes)
S1085 (m/km)	5.4 (25_335_5)	7.4 (25_3495_4)
ARTDRAIN2 (%)	26 (25_3495_4)	28 (25_335_5)
URBEXT (%)	0.1 (25_3495_4)	1.4 (25_335_5)

Table A9.4 Reach 1 Catchment Descriptor Range

Reach 2 Lower Nenagh		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	265 (25_1844_1)	326 (25_2140_4)
BFIsoil	0.58 (25_1845_1)	0.6 (25_2140_4)
SAAR (mm)	1092 (25_2140_4)	1133 (25_1844_3)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.9 (all nodes)	0.9 (all nodes)
S1085 (m/km)	3.8 (25_2140_4)	5.2 (25_1844_1)
ARTDRAIN2 (%)	37 (25_1844_1)	42 (25_2140_4)
URBEXT (%)	1.0 (25_1844_1)	1.3 (25_1845_3)

Table A9.5 Reach 2 Catchment Descriptor Range

Reach 3 River Ollatrim		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	119 (25_3_3)	120 (25_3_7)
BFIsoil	0.64 (25_3_7)	0.65 (25_3_3)
SAAR (mm)	1019 (25_3_7)	1021 (25_3_3)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.9 (all nodes)	0.9 (all nodes)
S1085 (m/km)	3.9 (25_3_3)	4.1 (25_3_7)
ARTDRAIN2 (%)	47 (25_3_3)	48 (25_3_7)
URBEXT (%)	0.6 (all nodes)	0.6 (all nodes)

Table A9.6 Reach 3 Catchment Descriptor Range

Reach 4 Moyroe Stream (corrected)		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	2.4 (25_3773_1)	8.7 (25_3773_5)
BFIsoil	0.65 (25_3773_4)	0.66 (25_3773_1)
SAAR (mm)	991 (25_3773_5)	1002 (25_3773_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.0 (25_3773_1)	0.5 (25_3773_5)
S1085 (m/km)	0.1 (25_3773_1)	2.8 (25_3773_4)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (25_3773_1)	20 (25_3773_5a)

Table A9.7 Reach 4 Catchment Descriptor Range

The FSU catchment delineation for the Reach 4 (Moyroe Stream) HEPs was found to be inaccurate and was amended using the NDHM digital terrain model. Some of the catchment descriptors in this table (AREA, S1085, URBEXT) were manually adjusted to reflect the corrected catchment outline:

1. AREA – derived for each HEP based on the NDHM digital terrain model, using the Watershed ArcGIS tool in the Spatial Analyst module;

2. S1085 – manually calculated using the FSR definition of the catchment descriptor, using contours plotted from the NDHM dataset;
3. URBEXT – estimated for each HEP as the percentage urban area as delineated on the 1:50,000 scale OSi maps in the catchment to the HEP.

Table A9.7a below shows the original FSU areas, and the revised AREA, S1085 and URBEXT catchment descriptors.

FSU Node	FSU AREA (km^2)	Revised AREA (km^2)	Revised S1085 (m/km)	Revised URBEXT (%)
25_3773_1	2.83	2.39	no change	4.02
25_3773_2	3.49	3.06	no change	8.27
25_3773_3	3.69	3.49	no change	7.90
25_3773_4	3.80	4.30	no change	6.42
25_3773_5	3.96	4.78	no change	7.16
25_3773_6	4.06	0.83	no change	10.65
25_3773_5a	Not available	7.47	2.44	19.61
25_3773_5b	Not available	8.68	2.78	16.89

Table A9.7a Revised Catchment Descriptors Moyroe Stream

The other catchment descriptors were not changed as they are relatively insensitive to the change in catchment extent.

Reach 5 Benedin Stream		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	1.7 (25_3560_2)	3.5 (25_3560_6)
BFIsoil	0.59 (25_3560_6)	0.65 (25_3560_2)
SAAR (mm)	930 (all nodes)	930 (all nodes)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	0.5 (25_3560_2)	0.8 (25_3560_6)
S1085 (m/km)	1.8 (25_3560_2)	2.6 (25_3560_6)
ARTDRAIN2 (%)	0.0 (25_3560_2)	21.3 (25_3560_6)
URBEXT (%)	0.4 (25_3560_2)	29 (25_3560_6)

Table A9.8 Reach 5 Catchment Descriptor Range

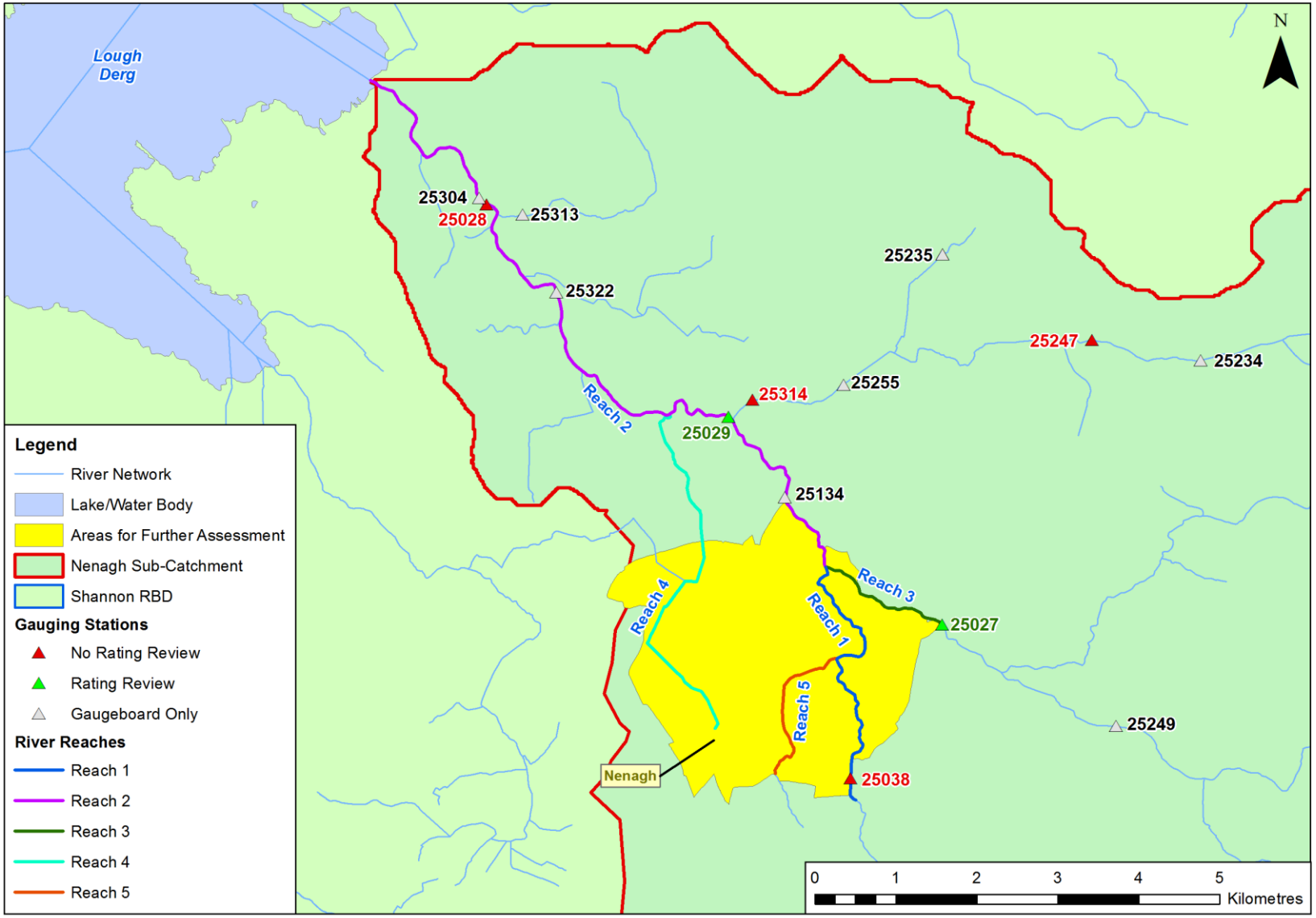


Figure A9.2 Nenagh Catchment River Reaches

A9.4 QMED Adjustment Factors

Table A9.9 below gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED.

Reach	Gauging Station Number	QMED Observed (m^3/s)	QMED (urban) Synthetic (m^3/s)	Adjustment Factor (-)
1	25038	26.1	33.5	0.78
2	25029	56.5	59.2	0.95
3	25027	22.2	20.4	1.09

Table A9.9 Available Gauged QMED Adjustment Factors

The QMED adjustment factors for the ungauged reaches 4 and 5 in the catchment were estimated using multiple pivotal sites in the absence of an adequate single pivotal site. The adjustment factors were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A9.10–A9.11). The use of a single pivotal site was considered but no suitable station was found that was hydrologically similar and sufficiently near to the subject site. The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: $\Pi(\text{Adjustment Factor}^{\text{Weight}})$.

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
10022	CABINTEELY	1	0.93	0.256	1.62
25040	BUNOW	2	0.96	0.248	0.55
22009	WHITE BRIDGE	3	1.40	0.171	1.23
10021	SHANGANAGH	4	1.42	0.169	1.49
9035	CAMMOCK	5	1.52	0.157	1.90
Weighted Geometric Mean					**1.20**

Table A9.10 QMED Adjustment Factor for Reach 4 (Moyroe Stream) based on multiple pivotal sites (Target location 25_3773_5b)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
10022	CABINTEELY	1	1.20	0.274	1.62
8005	SLUICE	2	1.50	0.219	2.28
25040	BUNOW	3	1.75	0.187	0.55
10021	SHANGANAGH	4	1.98	0.166	1.49
9035	CAMMOCK	5	2.11	0.155	1.90
Weighted Geometric Mean					**1.44**

Table A9.11 QMED Adjustment Factor for Reach 5 (Benedin Stream) based on multiple pivotal sites (Target location 25_3560_6)

It is noted that the pivotal station Bunow (25040) has a much lower adjustment factor than the others (for both ungauged reaches 4 and 5). However, it moderates the effect of the other pivotal stations on the adjustment factor for the reaches. This was considered reasonable and this pivotal station was retained. The station's reliability was confirmed and the station is used in the design hydrology for Model N11 (see Chapter A7 in Appendix A).

Table A9.12 shows the final QMED adjustment factor applied to each reach in the catchment, each with a justification for selection.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	0.78	25038	Only station upstream of the Ollatrim/Nenagh River confluence
2	0.95	25029	Only suitable station downstream of the Ollatrim/Nenagh River confluence
3	1.09	25027	Only station on the Ollatrim River
4	1.20	HEP 25_3773_5b	Ungauged watercourse - Used QMED calculator spreadsheet
5	1.44	HEP 25_3560_6	Ungauged watercourse - Used QMED calculator spreadsheet

Table A9.12 Final QMED Adjustment Factors Applied to Each Reach

The soils in the Nenagh catchment are generally well drained. The flows on the River Nenagh are calibrated to gauged data, making an implicit allowance for the permeable geology. Reaches 3 and 4 are ungauged but these are in the less permeable sandstones and mudstones.

A9.5 Flood Frequency Curves

Gauging Station Flood Frequency Curves

Three stations suitable for flood frequency analysis were identified in the catchment: 25038 (Tyone), 25027 (Gourdeen) and 25029 (Clarianna). The flood frequency curves (or growth curves) are plotted in Figures A9.3 to A9.5 below. The flood frequency curve plots for all relevant stations are included in Appendix E. The figures below show the at-site AMAX series (made dimensionless by dividing the flows by QMED, and plotting positions based on the Gringorten formula), a distribution fitted to the AMAX data, and pooling group results plotted against the reduced variate and an AEP scale.

Tyone Gauging Station (25038) on the River Nenagh

Tyone has 25 years of AMAX data (hydrometric years 1988 to 2012), all years of which have been used in the flood frequency analysis for this station. 25 years of acceptable AMAX data suggests single site analysis offers reasonably robust estimates up to return periods of 12-13 years i.e. an AEP of 8% (based on ½N with N=25). The station has not been subject to a rating review.

The Tyone at-site and pooled growth curves are shown on Figure A9.3 below.

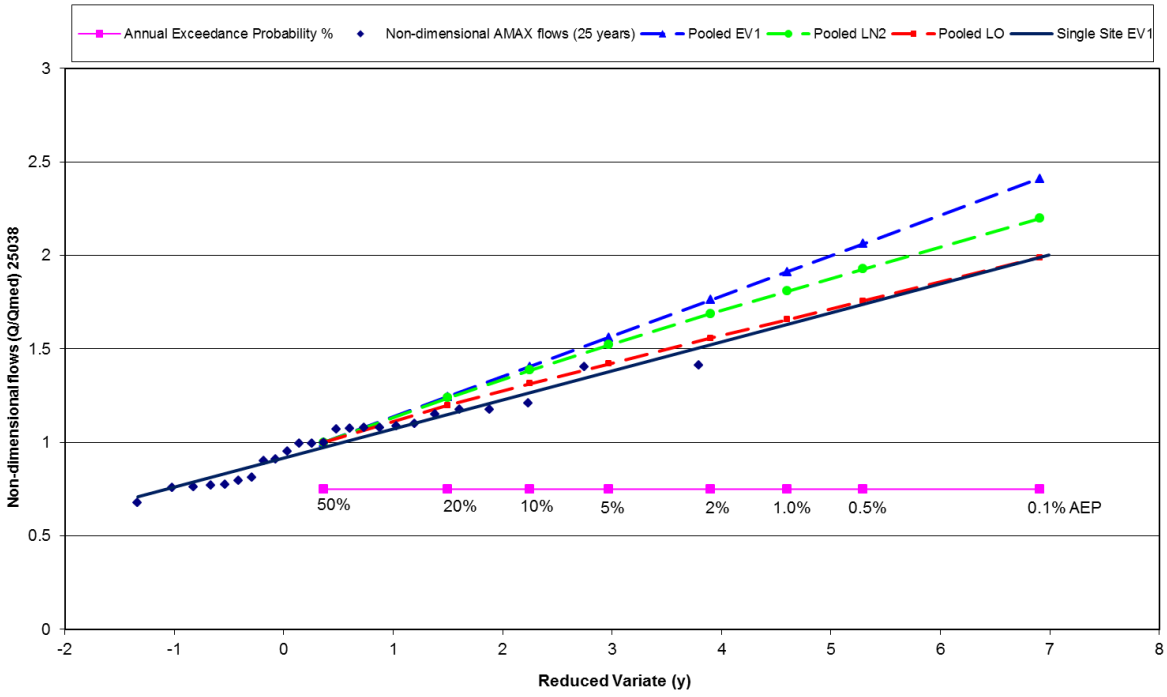


Figure A9.3 25038 Tyone – Flood Frequency Curves

Figure A9.3 shows that although the pooled LO curve is closest to the AMAX data, the growth factors associated with both distributions are believed to be worryingly low (1000-year growth factor of only 1.99). With permeable limestone in the downstream part of the catchment and low permeability sandstone and mudstone in the upstream part there seemed a real risk that basing the growth factors on the short observed AMAX record could result in an underestimation. It was decided that the L-Moment diagram should inform the decision on the best pooled curve as this demonstrates the best fit of the distribution to the pooled data. This showed that the

LN2 distribution had the best fit with the pooling group. The LN2 distribution was therefore selected for this station.

Gourdeen Gauging Station (25027) on the River Ollatrim

This station has been subject to a rating review as part of the CFRAM study. A summary of the rating review process and the findings are provided in Appendix C.

The rating review concluded that AMAX data from hydrometric year 1966 can be used for flood frequency analysis. This gives 43 years of acceptable AMAX data, suggesting that single site analysis offers reasonably robust estimates up to return periods of approximately 21 years, i.e. an AEP of 5% (based on ½N with N=43).

The pooled LN2 distribution shows a good correspondence to the at-site (EV1) curve. It also gives the best fit with the pooled distributions in the L-Moments diagram. Therefore the LN2 distribution was selected for this station.

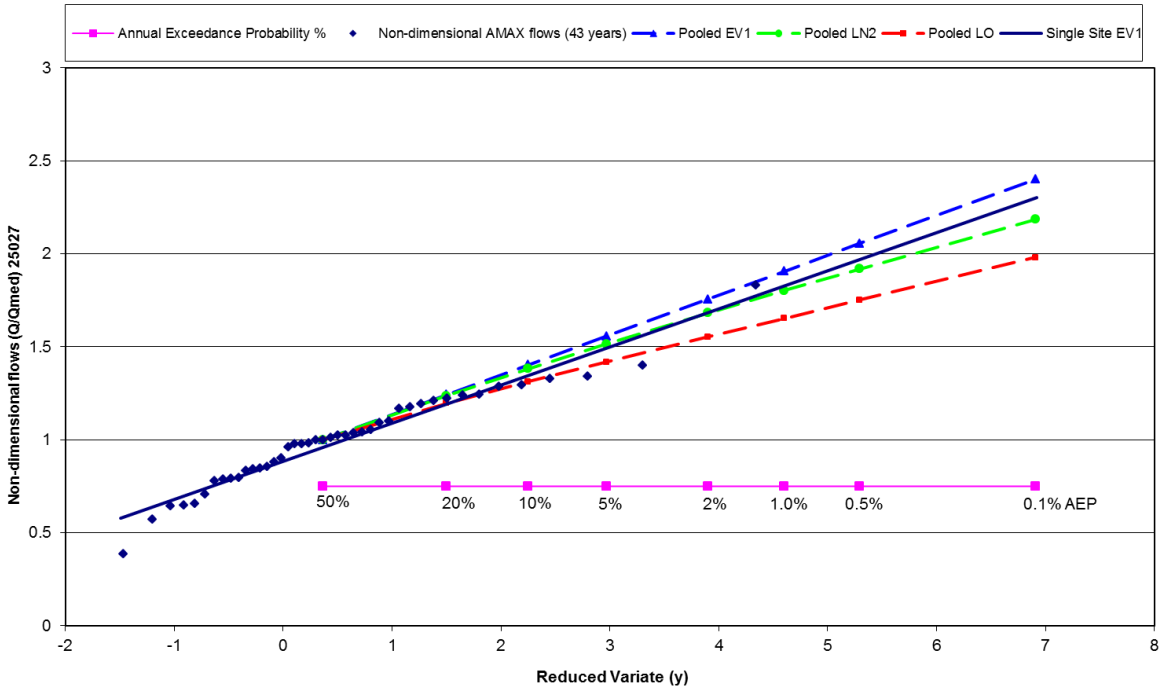


Figure A9.4 25027 Gourdeen – Flood Frequency Curves

Clarianna Gauging Station (25029) on the River Nenagh

This station has been subject to a rating review as part of the CFRAM study. A summary of the rating review process and the findings are provided in Appendix C.

The rating review concluded that the entire AMAX series from 1972 can be used for flood frequency analysis, using the original OPW ratings. This gives 37 years of acceptable AMAX data, suggesting that single site analysis offers reasonably robust estimates up to return periods of 18 years, i.e. an AEP of approximately 6% (based on ½N with N=37). As for the CFRAM study the target return period is 100 years, a pooled distribution is preferred over a single site distribution.

Although the pooled LO curve appears to be closest to the highest AMAX values, similarly to Gourdeen and Clarianna the growth factors associated with this LO distribution are believed to be worryingly low (1000-year growth factor of only 1.82). The EV1 distribution was selected for this station as that distribution shows the best fit with the pooled distributions in the L-Moments diagram. Figure A9.5 shows that the pooled EV1 distribution lies just above the trend line through the entire AMAX series (i.e. the single site EV1 distribution).

A comparison between the three gauging station growth curves in the catchment shows a good similarity between the three sites, as discussed below.

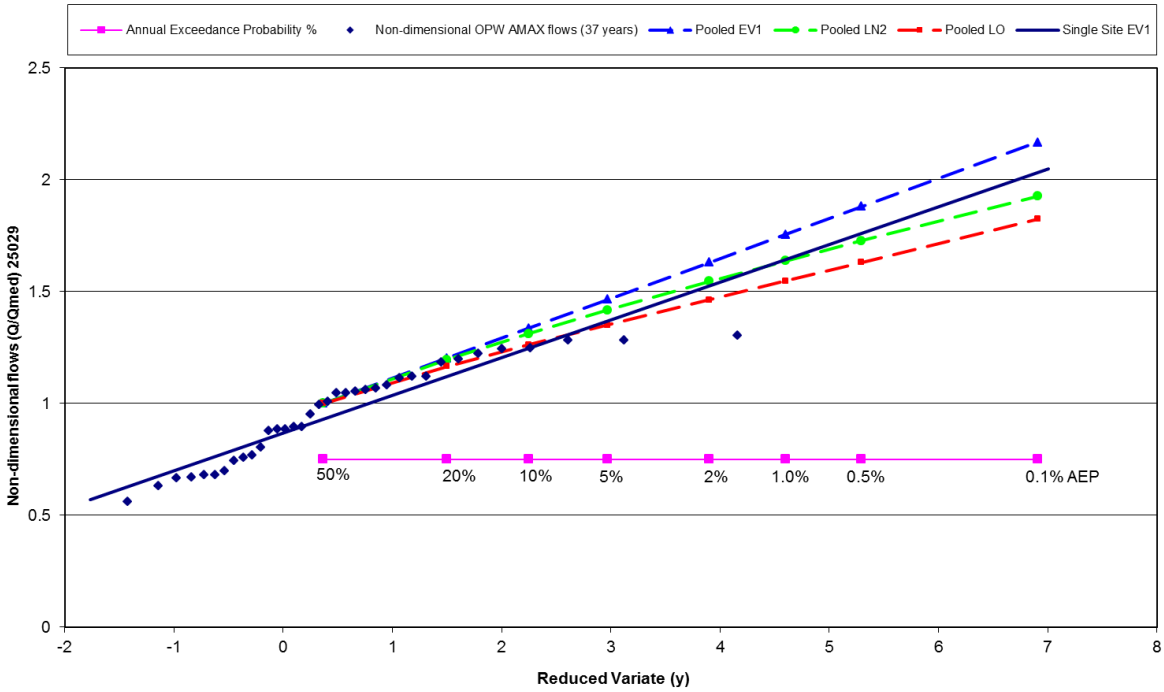


Figure A9.5 25029 Clarianna – Flood Frequency Curves

River Reach Flood Frequency

The growth curve distributions applied to the relevant reaches are shown in Table A9.13. Growth factors generated for a range of AEPs have been detailed in Table A9.14.

Reach	Station / HEP node	Single Site or Pooled	Selected distribution
1	25038 Tyone	Pooled	LN2
2	25029 Clarianna	Pooled	EV1
3	25027 Gourdeen	Pooled	LN2
4	25_3773_5b	Pooled	EV1
5	25_3560_6	Pooled	EV1

Table A9.13 Final Growth Curves Selected

Although pooling in the two ungauged locations (25_3773_5b and 25_3560_6) was undertaken separately, due to the similarity in the catchment descriptors and the small size of the catchments (in comparison to the stations in the pooling database) the exact same pooling groups were found. The growth curves for the two ungauged tributaries are therefore identical. Details of the pooling analysis at all 5 locations can be found in Appendix G.

Annual Exceedance Probability (%)	Growth Factors				
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
50%	1.00	1.00	1.00	1.00	1.00
20%	1.24	1.20	1.24	1.48	1.48
10%	1.39	1.34	1.38	1.79	1.79
5%	1.52	1.46	1.52	2.10	2.10
2%	1.69	1.63	1.68	2.49	2.49
1%	1.81	1.76	1.80	2.78	2.78
0.5%	1.93	1.88	1.92	3.08	3.08
0.1%	2.20	2.17	2.19	3.75	3.75

Table A9.14 Final Growth Factors Applied to the Nenagh Catchment

A comparison of the pooled growth curves for the three gauged locations (Clarianna, Gourdeen and Tyone) shows that the growth factors are very similar (<3% difference for any AEP), with the downstream station (Clarianna in Reach 2) having the lowest growth factors. Given the similarity in catchment descriptors (see Tables A9.4-6) this is reassuring and gives confidence that the pooling for these stations shows a consistent picture for the modelled sections of the Nenagh and Ollatrim rivers.

A9.6 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

Table A9.15 summarises the gauging stations used to produce the typical flood hydrograph shapes for the catchment reaches.

Reach	Gauging Station / HEP Node
1	25038 - Tyone
2	25029 - Clarianna
3	25027 - Gourdeen
4	25_3773_5b (FSR)
5	25_3560_6 (FSR)

Table A9.15 Gauging Stations used to Derive the Typical Hydrograph Shape in each Reach

Tables A9.16–18 and Figures A9.6–8 identify the flood events chosen for comparison at the gauges. The figures present the hydrographs in a non-

dimensional manner by dividing flows by their respective flood peaks. The hydrograph that best represents a typical/median flood response has then been selected as the representative design hydrograph shape.

At station 25038 only the highest three events (from 2000) were selected because of the short record length of the 15-min data used to extract the hydrographs (2000-2009). At stations 25027 and 25029 four events were considered in accordance with our standard approach for sufficiently long flow records as outlined in Section 2.6 of the main report.

Date	Peak Flow (m^3/s)	Comments
08/01/2005	29.3	
10/01/2008	28.0	Selected as it is the median hydrograph shape.
02/11/2000	26.2	

Table A9.16 Highest Flood Peaks for Gauging Station 25038

Date	Peak Flow (m^3/s)	Comments
05/08/1997	166.4	
22/02/1995	156.0	
06/02/1990	148.2	Selected as it is the median hydrograph shape.
25/12/1999	130.2	

Table A9.17 Highest Flood Peaks for Gauging Station 25029

Date	Peak Flow (m^3/s)	Comments
06/02/1990	36.2	Selected as it is the median hydrograph shape
31/01/2009	34.7	
03/11/2000	33.6	
14/01/1984	31.1	

Table A9.18 Highest Flood Peaks for Gauging Station 25027

For Reaches 4 and 5 a suitable pivotal station was sought using the OPW Hydrograph Shape Generator Spreadsheet, but due to the small size of the catchments no representative pivotal station was found. The synthetic hydrograph shapes for these catchments were found to be unrealistically long. It was therefore decided to use FSR. The FSR methodology had previously been used for a hydrological similar catchment in the N10 model domain (Garrycastle, a tributary of the River Shannon with a catchment area of 3 km^2). This had resulted in a realistic hydrograph length, which can be employed to the Moyroe (Reach 4) and Benedin (Reach 5) tributaries due to the similarity in catchment descriptors. The resulting non-dimensional hydrograph used for both reaches is shown in Figure A9.9 below.

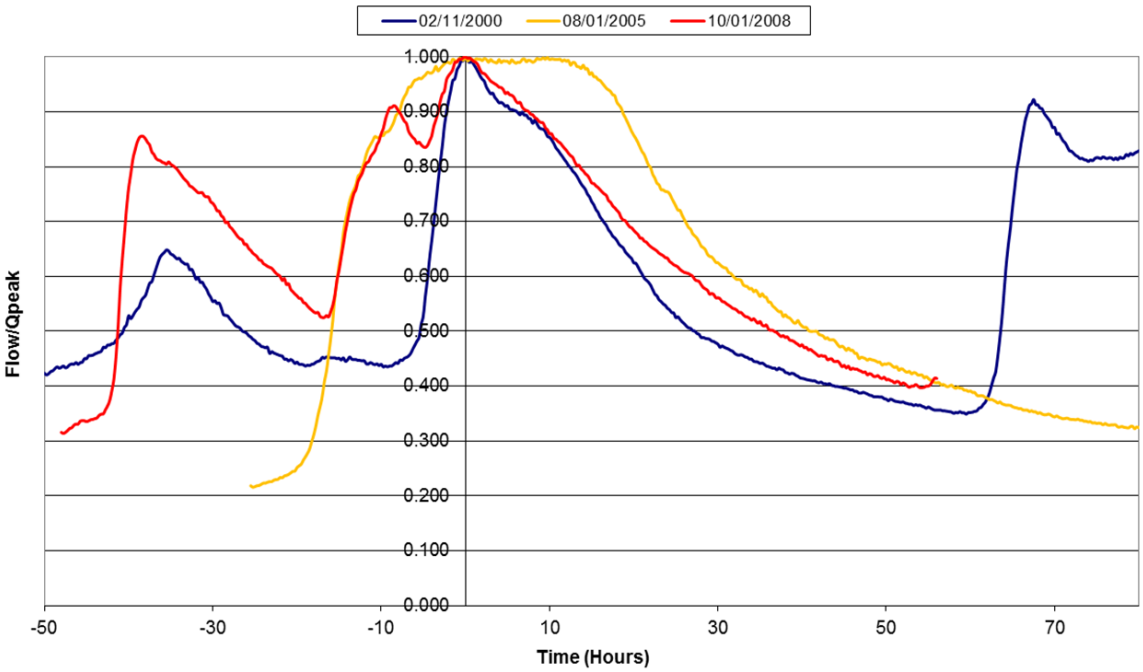


Figure A9.6 Non-dimensional Hydrographs for Gauging Station 25038

For Reach 1 the January 2008 event at Station 25038 was selected as it has the median width at 0.8xQpeak. The first peak (from about -50 to -18 hours) was ignored as a separate event. It is noted that the remaining hydrograph is still double peaked. In accordance with the methodology described in Section 2.6 of the main report events with double peaks were considered in the analysis as any other hydrograph.

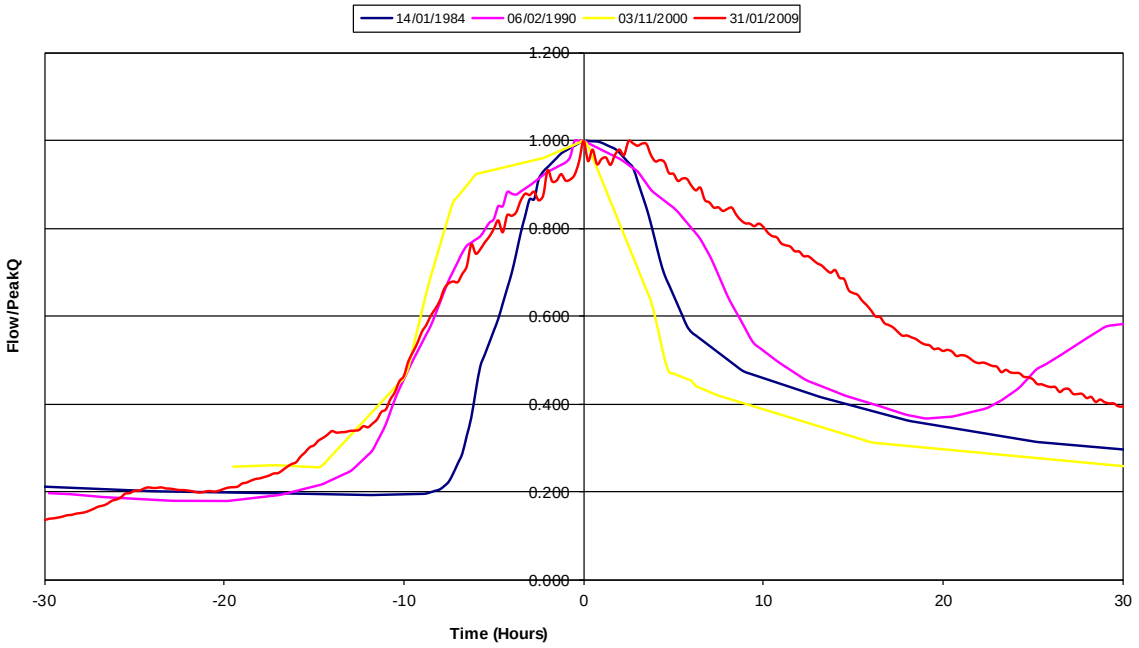


Figure A9.7 Non-dimensional Hydrographs for Gauging Station 25027

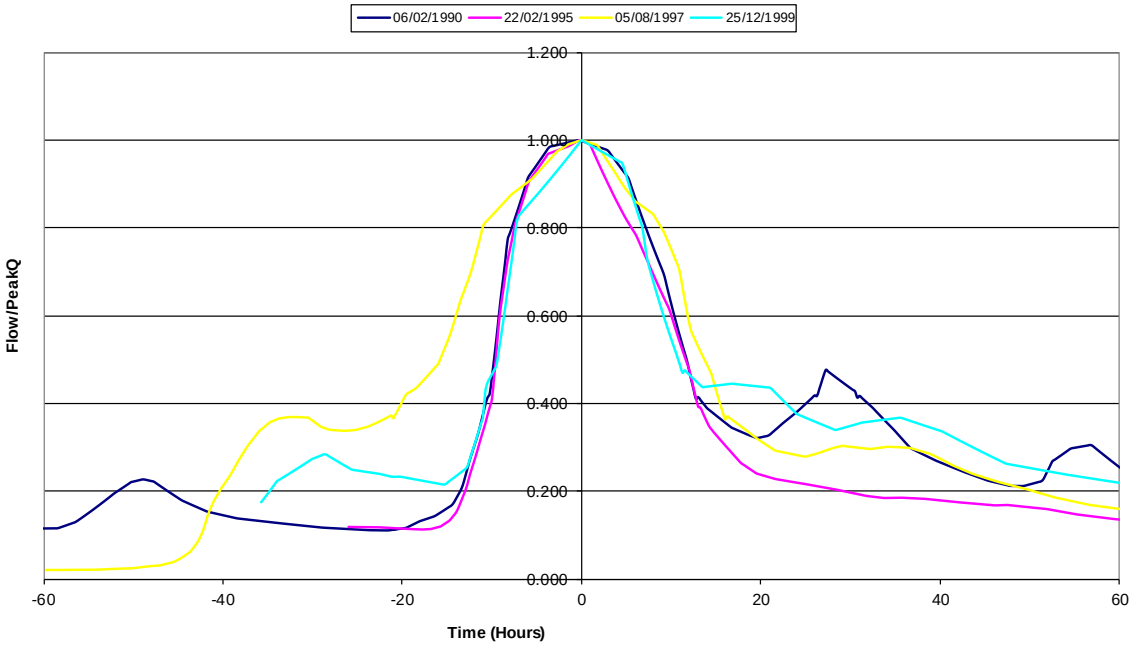


Figure A9.8 Non-dimensional Hydrographs for Gauging Station 25029

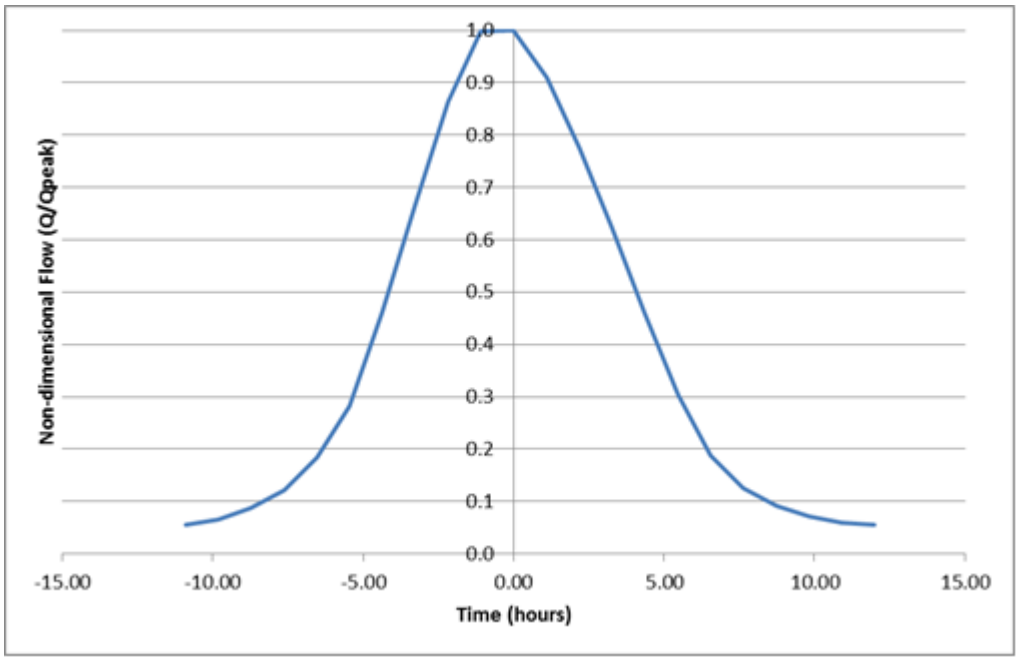


Figure A9.9 Non-dimensional Hydrograph for Reaches 4 (Moyroe Stream) and 5 (Benedin Stream)

A9.7 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for Model N14 is discussed in Appendix B, Chapter B14.

A9.8 Calibration

The calibration and verification of Model N14 is discussed in Appendix B, Chapter B14.

A10 Mulkear Catchment

A10.1 Catchment Description

The general description of the Mulkear catchment (Figure A10.1) is given in Table A10.1.

Attribute	Description
Unit of Management (UoM)	25/26
Main watercourses	River Mulkear River Bilboa (tributary of Mulkear) River Newport (tributary of Kileenagarriff) River Kileenagarriff (tributary of Mulkear) River Thornfield (tributary of Mulkear) River Small (tributary of River Newport) Unnamed tributary of River Newport River Cappamore (Tributary of Mulkear) Cappamore Relief Channel (Tributary of Mulkear) Cappamore Relief Channel North (Tributary of Bilboa) Cappamore East (Tributary of Cappamore)
Outflow point	Confluence with the River Shannon in model extent N16
Total catchment area	656 km^2
Areas for Further Assessment (AFAs)	Cappamore, Newport and a small part of Limerick City
Individual Risk Receptors (IRRs)	None
Model Extents*	N15, part of N16
General topography	Min altitude = 4 mAOD Max altitude = 690 mAOD Ground slopes from the east to west along the River Mulkear and from north east to south west on the River Newport.
Average annual rainfall**	985 mm to 1451 mm.
Soils and geology	Geology: Subsoils comprise predominantly peat and low to moderate permeability glacial tills over mudstone, sandstone and limestone bedrock. Mudstone bedrock (poor aquifer) forms the higher ground to the northeast with extensive surface outcrops. Limestone bedrock occurs to the south and west of the catchment and forms both a locally important and regionally important (karstified) bedrock aquifer. Basic intrusive rocks occur within the limestone and form isolated surface outcrops. Sandstone underlies the rest of the catchment and is a locally important aquifer. Extensive alluvial deposits occur along major watercourses and limited high permeability glacial sands and gravels occur east of Cappamore. Refer to Figure 3.3 in the Main Report for the hydrogeological characteristics of the underlying rock formations. Soils: Well drained soils derived from the underlying sandstone

	and limestone, are predominant with poorly drained soils and peat occurring extensively over areas of higher ground and where the bedrock is close to the surface. Refer to Figure 3.4 in the Main Report for the distribution of differing soil drainage classes.
Urban areas	The URBEXT values within the Mulkear catchment are below 2%, indicating a rural catchment. At the upstream end, URBEXT values range from 0% increasing to 16% at the Cappamore AFA. On the Rivers Newport and Kileenagarriff the URBEXT values do not exceed 0.2%. At the downstream end of the Mulkear the URBEXT value ranges between 0.7% - 1.9%.

* Specific hydrological details for the models are provided in Appendices B15 and B16
** Range of SAAR values taken from the FSU catchment descriptors covering the extent of modelling

Table A10.1 Mulkear Catchment Description

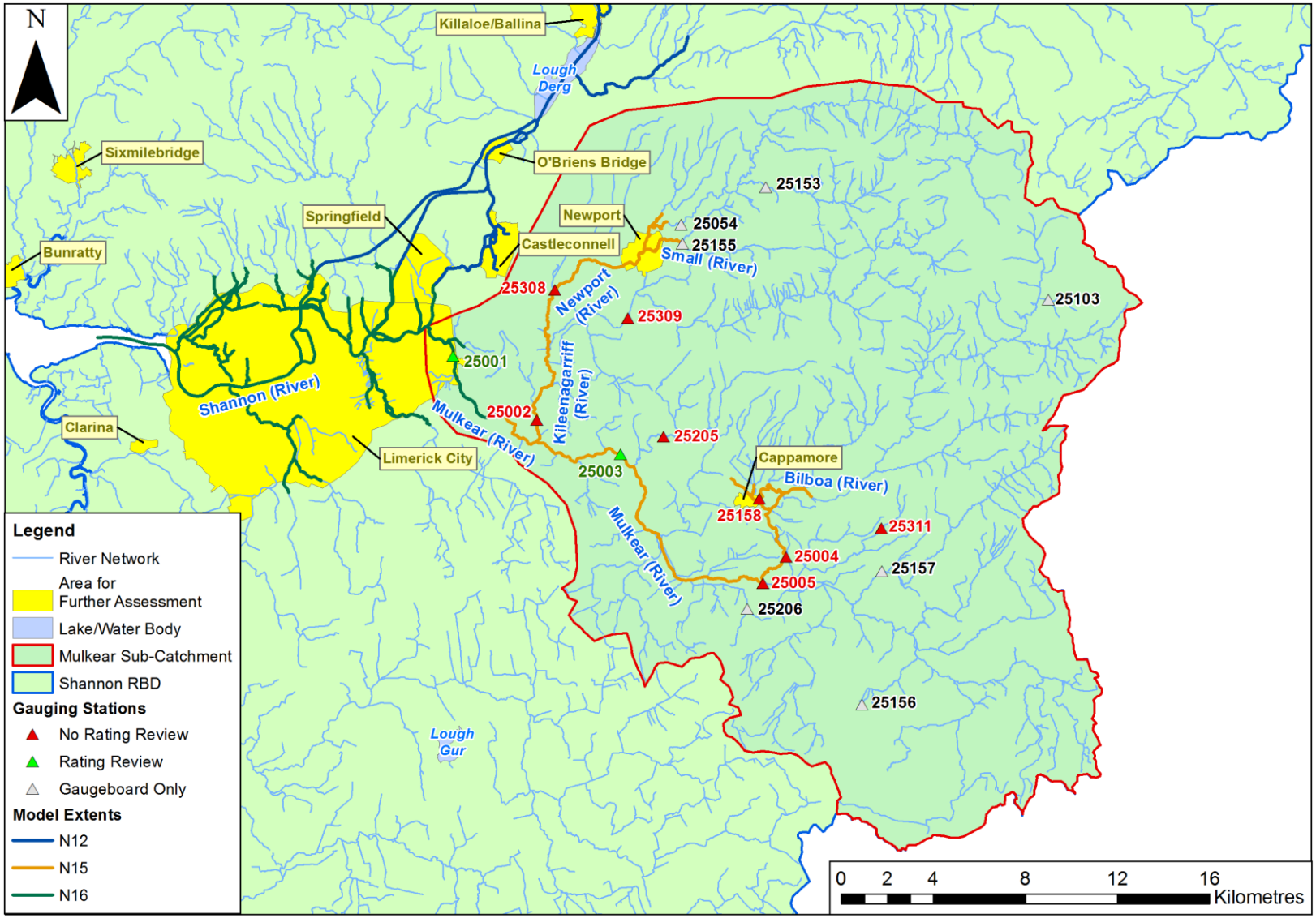


Figure A10.1 Mulkear Catchment with Model Extents

A10.2 Hydrometric Stations in the Mulkear Catchment

Details of the gauging stations in the Mulkear catchment are tabulated in Table A10.2. They are also shown on Figure A10.1. It should be noted that some gauging stations located on minor tributaries not covered by the model extent, namely 25205, 25309 and 25311, were found to be unsuitable for flood estimation and are therefore not included in Table A10.2.

Model	Gauging Station	Name	Record Data Range	AMAX Available	FSU Quality Class or HGF/QMED	CFRAMS Rating Review	Quality Comments
N15	25002	Barrington's Bridge	1953 - present	Level and Flow	A2	No	1
	25003	Abington	1954 - present	Level and Flow	A1 HGF/QMED ~ 0.8	Yes	2
	25004	New Bridge	1970 - present	Level and Flow	HGF/QMED ~ 1.4	No	3
	25005	Sunville	1954 - present	Level and Flow	A2	No	4
	25158	Cappamore	1982 - 1999	Level and Flow	A1	No	5
	25308	Waterpark Bridge	1999 - present	Level and Flow	HGF/QMED ~ 0.9	No	6
N16	25001	Annacotty	1953 - present	Level and Flow	A2 HGF/QMED ~ 1.1	Yes	7

Table A10.2 Mulkear Catchment Gauging Stations

Table A10.2 Hydrometric Data Quality Comments:

1. There is a gap in the AMAX data in 1971. Reason is unclear. Non-standard weir acts as a control.
2. Gauging station is located at the bridge.
3. Gauging station removed due to works in 20/03/1999 and reinstated upstream of newly constructed weir in 26/02/2002.
4. Gauging station not on model extent; included for reference only. AMAX missing data in 1959, 1963, 1964, 1968 and 1984. The bridge acts as a control at medium and high flows.
5. Gauging station is inactive. No records after flood relief works at Cappamore, which are known to have reduced the risk of flooding of the river at this station.
6. Station 25308 has a record from 1999 and a HGF of 0.9xQMED. It appears suitable for QMED estimation but not for flood frequency analysis.
7. Gauge downstream of weir structure. Excavations for flood relief schemes in 1997 and 1999 in the upstream catchment do not appear to have had a significant effect on flood flows.

A10.3 Catchment River Reaches

River reaches are defined as sections of watercourse with similar hydrological characteristics, so that a single QMED adjustment factor and growth curve can be applied. The catchment is split up into river reaches based on the catchment geometry, geology and an assessment of the availability and quality of data at the gauging stations listed in Table A10.2 above. The river reaches are tabulated in Table A10.3 and shown on Figure A10.2. The HEP node numbers are shown on a map in Chapter B15 in Appendix B. The variation in catchment descriptors for each reach is tabulated in Tables A10.4 to A10.11 below.

Reach	Description	Model Extent
1	River Bilboa and the River Mulkear from HEP node 25_496_1 to 25_486_6	N15
2	River Mulkear from HEP node 25_3627_1 to the confluence with the River Kileenagarriff at HEP node 25_2042_3	N15
3	River Small and unnamed tributary to the confluence with River Newport	N15
4	Rivers Newport and Kileenagarriff	N15
5	From the confluence of the River Mulkear with the Kileenagarriff at HEP node 25_3321_1 to the confluence with the River Shannon at HEP node 25_1202_4	N15/N16
6	River Thornfield (tributary of Mulkear, north of station 25001)	N16
7	River Cappamore from HEP node 25_1599 to the confluence with the River Mulkear at HEP node 26_833_2 with tributary Cappamore East. Tributary Cappamore Relief Channel North HEP nodes 25_1602_2a to the Confluence with the River Bilboa at HEP node 25_1602_2.	N15
8	Rivers Newport and Kileenagarriff from River Annagh/Clare confluence HEP node 25_504_2 to outflow into River Mulkear	N15

Table A10.3 River Reaches in the Mulkear Catchment

Reach 1		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	87 (25_496_1)	123 (25_486_6)
BFIsoil	0.57 (25_496_1)	0.61 (25_501_4)
SAAR (mm)	1335 (25_486_6)	1451 (25_496_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.44 (25_496_2)	1.63 (25_486_6)
S1085 (m/km)	6.1 (25_486_6)	7.2 (25_498_1)
ARTDRAIN2 (%)	1.6 (25_496_1)	8.50 (25_486_6)
URBEXT (%)	0.0 (25_496_1)	0.16 (25_502_3 and 25_502_2)

Table A10.4 Reach 1 Catchment Descriptor Range

Reach 2		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	315 (25_3627_1)	413 (25_2042_3)
BFIsoil	0.49 (25_2038_3)	0.52 (25_3627_1)
SAAR (mm)	1101 (25_2042_3)	1145 (25_3627_1)
FARL	0.99 (25_2038_3)	1.00 (25_1991_2)
DRAIND	1.35 (25_2042_3)	1.37 (25_3314_2)
S1085 (m/km)	4.4 (25_2042_3)	8.0 (25_1995_1)
ARTDRAIN2 (%)	3.1 (25_2042_3)	4.0 (25_3627_1)
URBEXT (%)	0.5 (25_1995_1)	0.7 (25_3311_1)

Table A10.5 Reach 2 Catchment Descriptor Range

Reach 3		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	8.6 (25_2623_2)	14.4 (25_2323_6)
BFIsoil	0.52 (25_2323_1)	0.55 (25_2323_6)
SAAR (mm)	1161 (25_2623_4)	1215 (25_2323_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	1.37 (25_2623_4)	1.97 (25_2623_4)
S1085 (m/km)	18.5 (25_2623_4)	34.9 (25_2323_1)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	0.0 (25_2323_1)	0.9 (25_2323_6)

Table A10.6 Reach 3 Catchment Descriptor Range

Reach 4		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	69 (25_469_9)	127 (25_504_2)
BFIsoil	0.54 (25_475_4)	0.55 (25_469_9)
SAAR (mm)	1301 (25_504_2)	1449 (25_469_9)
FARL	0.99 (25_469_9)	1.00 (25_504_2)
DRAIND	1.43 (25_504_2)	1.65 (25_473_4)
S1085 (m/km)	7.7 (25_504_2)	8.5 (25_475_2)
ARTDRAIN2 (%)	0.0 (25_469_9)	2.9 (25_504_2)
URBEXT (%)	0.0 (25_469_9)	0.4 (25_475_4)

Table A10.7 Reach 4 Catchment Descriptor Range

Reach 5		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	636 (25_3321_1)	656 (25_1202_4)
BFIsoil	0.52 (all nodes)	0.52 (all nodes)
SAAR (mm)	1164 (25_1202_4)	1170 (25_3321_1)
FARL	0.99 (all nodes)	0.99 (all nodes)
DRAIND	1.37 (25_527_3)	1.38 (25_3321_1)
S1085 (m/km)	4.0 (25_527_4)	4.3 (25_3321_1)
ARTDRAIN2 (%)	3.8 (25_3321_1)	4.7 (25_3321_1)
URBEXT (%)	0.4 (25_3321_1)	0.7 (25_1202_4)

Table A10.8 Reach 5 Catchment Descriptor Range

Reach 6		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	5.2 (25_3324_1)	6.3 (25_3325_2)
BFIsoil	0.71 (all nodes)	0.71 (all nodes)
SAAR (mm)	985 (25_3324_1)	986 (25_3325_2)
FARL	0.98 (25_3324_1)	0.99 (25_3325_2)
DRAIND	1.54 (25_3324_1)	1.57 (25_3325_2)
S1085 (m/km)	3.8 (25_3324_1)	4.0 (25_3325_2)
ARTDRAIN2 (%)	0.0 (all nodes)	0.0 (all nodes)
URBEXT (%)	1.8 (25_3324_2)	1.9 (25_3324_1)

Table A10.9 Reach 6 Catchment Descriptor Range

Reach 7		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	0.3 (25_838_2a)	9.6 (25_833_2)
BFIsoil	0.45 (25_833_2)	0.54 (25_1602_2a)
SAAR (mm)	991 (25_1602_2a)	1002 (25_1599_1)
FARL	1.00 (all nodes)	1.00 (all nodes)
DRAIND	2.016 (25_1602_2a)	2.43 (25_1599_1)
S1085 (m/km)	30.1 (25_833_2)	55.7 (25_1602_2a)
ARTDRAIN2 (%)	16.5 (25_833_1)	17.6 (25_1599_1)
URBEXT (%)	0.0 (25_1602_2a)	1.6 (25_833_2)

Table A10.10 Reach 7 Catchment Descriptor Range

Reach 8		
Catchment Descriptor	**Lower Limit (HEP node)**	**Upper Limit (HEP node)**
AREA (km^2)	199 (25_505_1)	223 (25_511_2)
BFIsoil	0.54 (all nodes)	0.54 (all nodes)
SAAR (mm)	1299 (25_511_2)	1336 (25_505_1)
FARL	0.99 (all nodes)	0.99 (all nodes)
DRAIND	1.41 (25_507_1)	1.42 (25_505_1)
S1085 (m/km)	6.5 (25_511_2)	7.6 (25_505_1)
ARTDRAIN2 (%)	3.4 (25_505_1)	5.1 (25_511_2)
URBEXT (%)	0.18 (25_511_2)	0.20 (25_505_1)

Table A10.11 Reach 8 Catchment Descriptor Range

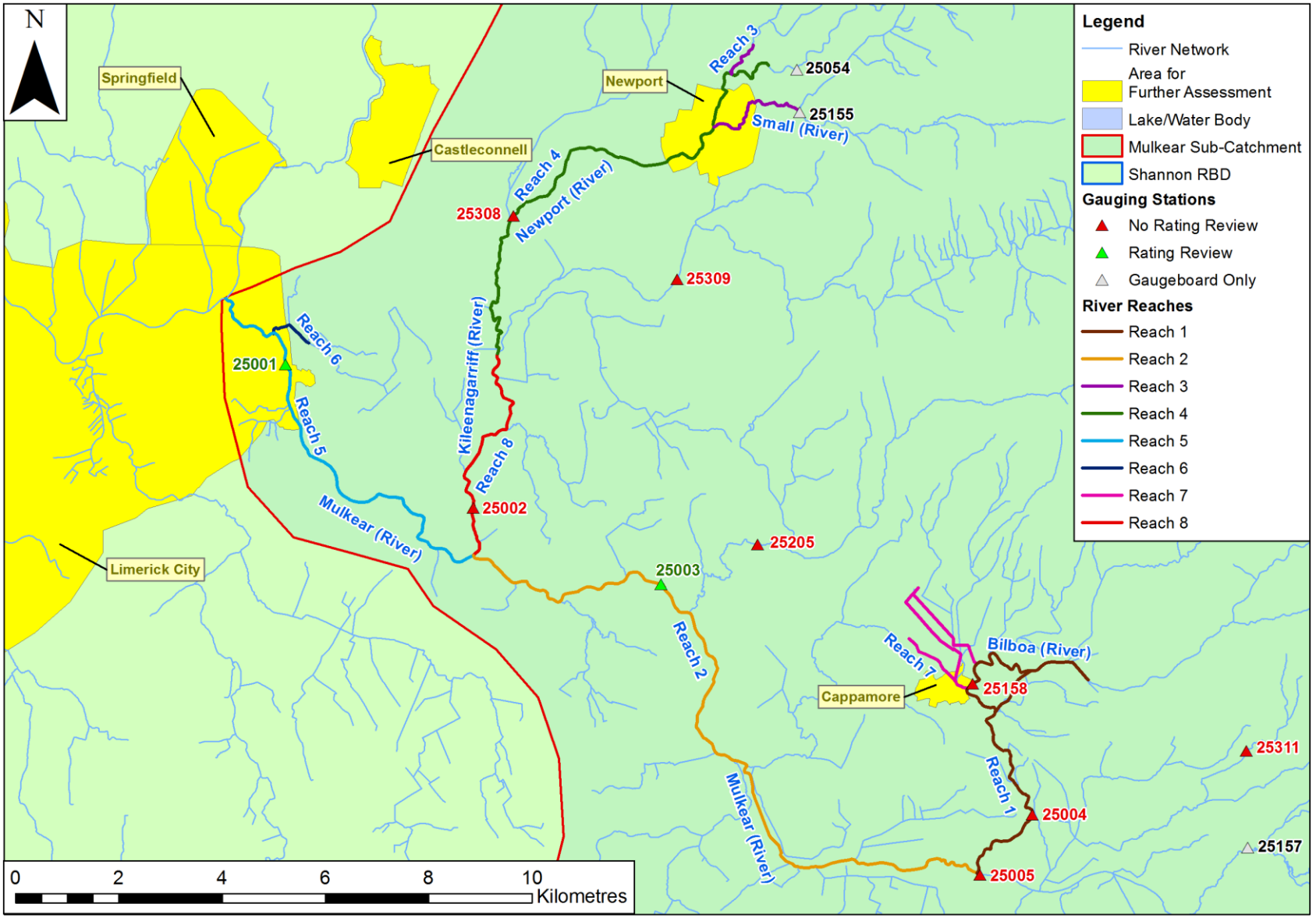


Figure A10.2 Mulkear Catchment River Reaches

A10.4 QMED Adjustment Factors

Table A10.12 below gives the QMED adjustment factors at the available flow gauging stations in the catchment. The table specifies for each gauging station the QMED estimate based on AMAX data and a synthetic estimate based on the FSU regression equation including an urban adjustment (refer to FSU Work Package 2.3). The QMED adjustment factor is the observed QMED divided by the synthetic QMED.

Gauging Station Number	QMED Observed (m^3/s)	QMED (urban) Synthetic (m^3/s)	Adjustment Factor (-)	Reach	Model Extent	Note
25001	126.4	146.1	0.86	5	N15/ N16	1
25002	59.3	65.6	0.90	8	N15	2
25003	73.7	93.7	0.79	2	N15	3
25004	42.8	38.7	1.11	1	N15	2
25005	28.1	37.7	0.75	-	N15	2,4
25308	37.3	34.4	1.08	4	N15	5

Table A10.12 Available QMED Adjustment Factors

Notes:

1. CFRAM rating review highlighted that the AMAX flow series based on the original OPW ratings was reliable for AMAX data from 1977.
2. QMED is based on existing OPW rating.
3. CFRAM rating review modelled rating.
4. Not on model extent (on tributary Dead near confluence with Mulkear)
5. QMED is based on existing OPW rating. It is assumed that flood relief works in the upstream catchment have been designed appropriately without increasing flood risk downstream of the site.

The QMED adjustment factors for the ungauged reaches (or reaches with inadequate high flow monitoring) in the catchment were estimated using multiple pivotal sites in the absence of an adequate single pivotal site. The adjustment factors were estimated using a weighted geometric mean of the five hydrologically most similar gauged sites in the country (see Tables A10.13-15). The use of a single pivotal site was considered but no suitable station was found that was hydrologically similar and sufficiently near to the subject site. The Dij parameter summarises the hydrological similarity between the subject site and the pivotal site and is a function of the AREA, BFIsoil and SAAR catchment descriptors. The weight of a pivotal site is the inverse of Dij divided by the sum of the inverses for all five pivotal sites. The weights add up to 1. The geometric mean is the product of the adjustment factors to the power of the weight, for all five pivotal sites: Π (Adjustment Factor^{Weight}).

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.74	0.315	2.32
22009	WHITE BRIDGE	2	1.24	0.187	1.23
30020	DALGAN	3	1.30	0.179	0.67
25040	BUNOW	4	1.41	0.166	0.55
24022	MAHORE	5	1.53	0.153	1.30
Weighted Geometric Mean					**1.19**

Table A10.13 QMED Adjustment Factor for Reach 3 based on Multiple Pivotal Sites (Target Location HEP 25_2623_4)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
25034	L.ENNELL TRIB	1	0.52	0.389	1.23
10022	CABINTEELY	2	1.22	0.164	1.62
30020	DALGAN	3	1.29	0.155	0.67
25040	BUNOW	4	1.29	0.154	0.55
9011	FRANKFORT	5	1.45	0.138	1.94
Weighted Geometric Mean					**1.10**

Table A10.14 QMED Adjustment Factor for Reach 6 based on Multiple Pivotal Sites (Target Location HEP 25_3325_2)

Station Number	Station Name	Rank	Dij	Weight	Adjustment Factor
6030	BIG	1	0.635	0.361	1.36
8012	BALLYBOGHIL	2	1.405	0.163	0.99
24022	MAHORE	3	1.419	0.162	1.04
8007	ASHBOURNE	4	1.424	0.161	1.00
10022	CABINTEELY	5	1.497	0.153	1.08
Weighted Geometric Mean					**1.51**

Table A10.15 QMED Adjustment Factor for Reach 7 based on Multiple Pivotal Sites (Target Location HEP 25_833_2)

Table A10.16 shows the final QMED adjustment factor applied to each reach in the catchment, each with a justification for selection.

Reach	QMED adjustment factor	Station or HEP Node	Justification
1	1.11	25004	Only gauging station with reliable data for QMED estimation within the reach.
2	0.79	25003	Only gauging station with reliable data for QMED estimation within the reach.
3	1.19	25_2623_4	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
4	1.08	25308	Only gauging station with reliable data for QMED estimation within the reach.
5	0.86	25001	Only gauging station with reliable data for QMED estimation within the reach.
6	1.10	25_3325_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
7	1.51	25_833_2	Ungauged. Based on geometric mean of adjustment factors at 5 pivotal sites.
8	0.90	25002	Only gauging station with reliable data for QMED estimation within the reach.

Table A10.16 Final QMED Adjustment Factors Applied to Each Reach

A10.5 Flood Frequency Curves

Gauging Station Flood Frequency Curves

The only gauging stations considered for flood frequency analysis in the catchment were 25001 (Annacotty) and 25003 (Abington). Other gauging stations with a stage-discharge rating were considered unreliable for flows above QMED.

Annacotty Gauging Station (25001)

The rating at this station has been reviewed as part of the CFRAM study (see Appendix C). The review recommended that only AMAX data from 1977 is used for flood estimation. This gave 33 years of data. Low confidence in the rating above QMED and a relatively short record makes this station less suitable for flood frequency analysis than station 25003 (see below). Applying the existing OPW rating to the AMAX series for 25001 produced a very flat (single site) flood frequency curve with a 1% (1 in 100) AEP growth factor of 1.40.

The growth curve appears to be very flat, as the hydrogeology of the catchment (see Figures 3.3 - 3.5 in the main report) suggests a mixed catchment with some very permeable soils but also areas of impermeably soils. The flat growth curve may indicate that the recorded period has been relatively flood-poor, and some caution needs to be applied to the selection of the growth curve for the river reach that this station is on (Reach 5).

The at-site and pooled growth curves for Station 25001 are flatter than the same growth curves found at Station 25003 (Abington), which are already relatively flat (see below). It was considered appropriate to apply a flood frequency curve derived at Station 25003 to the River Mulkear, as a more reasonable curve than that from Station 25001.

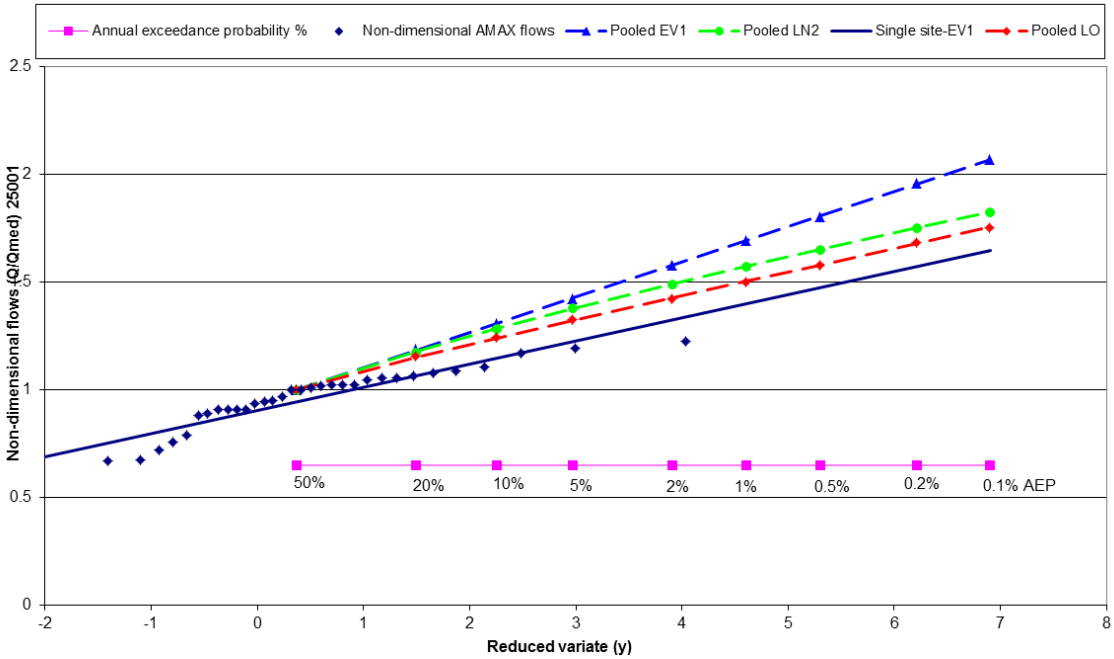


Figure A10.3 25001 Annacotty – Flood Frequency Curves

Abington Gauging Station (25003)

The rating at this station has been reviewed as part of the CFRAM study. Abington has 56 years of AMAX data (from 1954 to 2009). The modelled rating shows a good fit with the check gaugings. This is detailed in the rating review summary in Appendix C.

The Abington at-site and pooled growth curves are shown on Figure A10.3 below.

The at-site growth curve for this station is relatively flat, e.g. the 1% (1 in 100) AEP growth factor is 1.5. Figure 3.5 in the main report shows that the southern part of the catchment to this station contains many recorded karstic features and a regionally important aquifer. Permeable catchments may show a wide range of hydrological responses (which could result in a steeper or flatter growth curve than permeable catchments), and this may be the cause or a contributing factor to the flat growth curve.

The length of the AMAX series suggests single site analysis offers reasonably robust estimates up to return periods of about 28 years i.e. an AEP of approximately 4% (based on ½N with N=56). For lower AEPs (higher return periods) it may be more appropriate to use pooled data. As the at-site AMAX data does not provide evidence that the pooled distributions are inappropriate at Abington, the pooled growth curve is adopted. To acknowledge the importance of local observations, the pooled distribution that is closest to the plotted AMAX data is chosen, which at

Abington is the LO distribution. The LO growth curve lies a bit above the at-site (EV1) growth curve for the range of return periods considered in this study giving slightly more conservative design flows.

As discussed in the section for Station 25001 above the growth curve for this station is considered appropriate not just for the reach that Station 25003 is on (Reach 2) but also for the lower reach of the River Mulkear down to the confluence with the River Shannon (Reach 5).

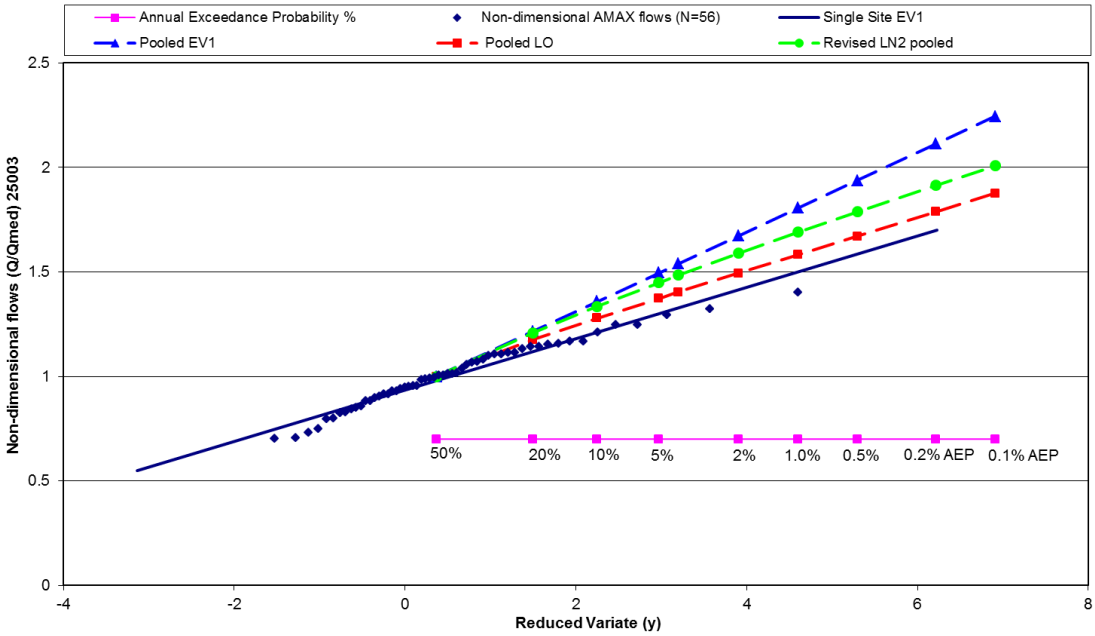


Figure A10.4 25003 Abington – Flood Frequency Curves

Other Gauging Stations (25004 and 25308)

Gauging stations New Bridge (25004) and Waterpark Bridge (25308) were not considered suitable for flood frequency analysis as the data at both stations was not sufficiently reliable for flows greater than QMED, and the record at Waterpark Bridge was too short. Pooling was undertaken at these stations, and the results are shown on Figures A10.5 and A10.6 below. The at-site AMAX series and at-site EV1 distribution have been added for reference only.

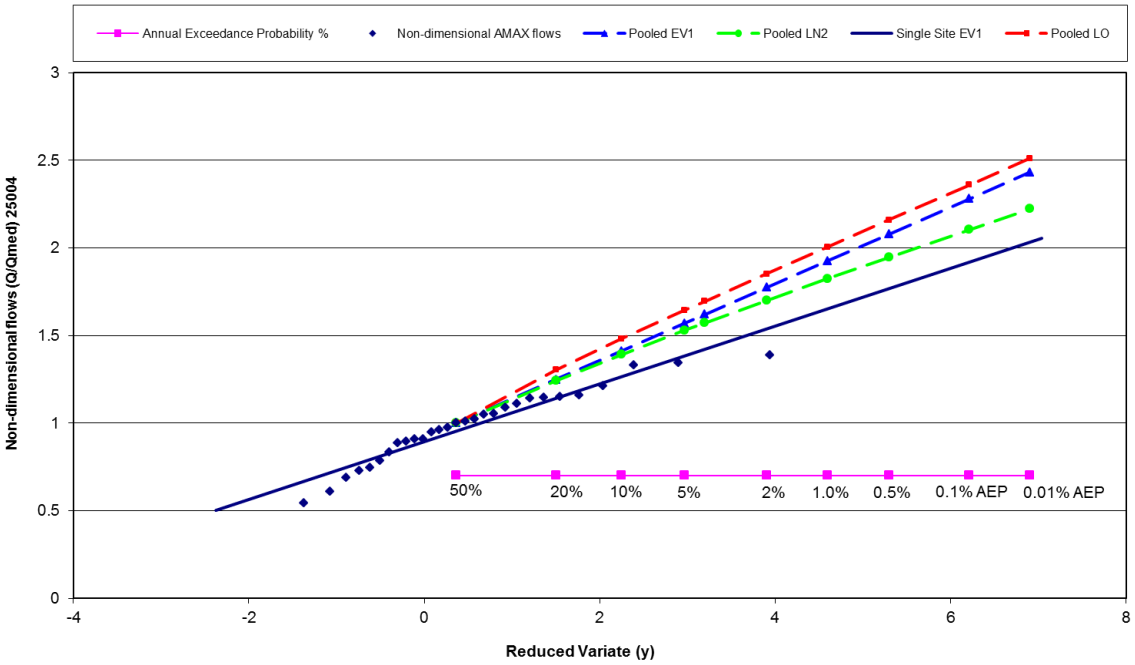


Figure A10.5 25004 New Bridge – Flood Frequency Curves

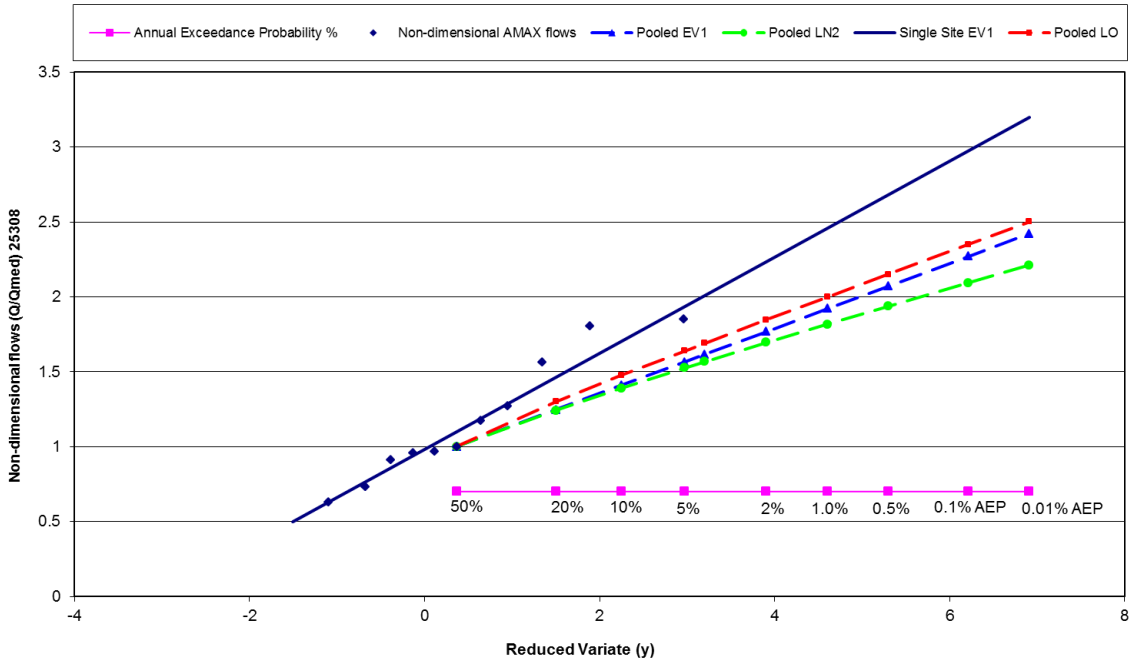


Figure A10.6 25308 Waterpark Bridge – Flood Frequency Curves

River Reach Flood Frequency

The growth curve distributions applied to the relevant reaches are shown in Table A10.17. Growth factors generated for a range of AEPs have been detailed in Table A10.18.

Reach	Station / HEP Node	Single Site or Pooled	Selected distribution
1	25004 - New Bridge	Pooled	LN2
2 and 5	25003 - Abington	Pooled	LO
3, 4 and 8	25308 - Waterpark Bridge	Pooled	EV1
6	25_3329_2	Pooled	LN2
7	25_833_2	Pooled	EV1

Table A10.17 Final Growth Curves Selected

Annual Exceedance Probability (%)	Growth Factors				
	Reaches 1	Reaches 2 and 5	Reach 3, 4 and 8	Reach 6	Reach 7
50%	1.00	1.00	1.00	1.00	1.00
20%	1.24	1.18	1.25	1.20	1.37
10%	1.40	1.28	1.41	1.33	1.62
5%	1.53	1.37	1.57	1.44	1.85
2%	1.71	1.49	1.77	1.57	2.16
1%	1.83	1.58	1.92	1.67	2.39
0.5%	1.96	1.67	2.07	1.76	2.61
0.1%	2.24	1.88	2.42	1.97	3.14

Table A10.18 Final Growth Factors Applied to the Mulkear Catchment

A10.6 Hydrograph Shape

Section 2.6 of the main hydrology report describes the selection of the design hydrograph shape. The design flood hydrograph shape is derived from flood events recorded at flow gauges.

For ungauged reaches, the design hydrograph was generated from data of pivotal stations. The hydrograph shape generated was selected on the basis of the subject and pivotal catchments having hydrological similarities. Table A10.19 summarises the gauged and pivotal stations used to produce the typical flood hydrograph shapes for the catchment reaches.

Reach	HEP Node / Gauging Station	Selected Hydrograph
1	Gauging Station 25004 – New Bridge	Representative shape from gauged flood events
2	Gauging Station 25003 – Abington	Representative shape from gauged flood events
3	River Small – HEP node 25_2323_6 and Unnamed tributary north of the Newport AFA – HEP node 25_2623_4	16013 – Fourmilewater (pivotal site hydrograph shape used, based on gauged N, Tr and C parameters)
4	Gauging Station 25308 – Waterpark Bridge	Representative shape from gauged flood events
5	Gauging Station 25001 – Annacotty	Representative shape from gauged flood events
6	HEP node 25_3325_2	13002 – Foulk's Milk (hydrograph shape adopted from FSR)
7	HEP node 25_833_2	16013 – Fourmilewater (pivotal site hydrograph shape used, based on gauged N, Tr and C parameters)
8	Gauging Station 25002 – Barrington's Bridge	Representative shape from gauged flood events

Table A10.19 Gauging Stations used to derive the Typical Hydrograph Shape in Each Reach

Tables A10.20 – 24 and Figures A10.7, A10.8, A10.11, A10.12 and A10.13 identify the highest flood events chosen for comparison at the gauges. The figures present the hydrographs in a non-dimensional manner by dividing flows by their respective flood peaks. The hydrograph that best represents a typical/median flood response has then been selected as the representative design hydrograph shape. Figures A10.9-10 show the hydrograph shape adopted from pivotal sites and Figure A10.14 shows the hydrograph shape adopted from FSR.

Date	Peak Flow (m^3/s)	Comments
31/01/1983	57.3	
06/08/1986	49.2	Selected for hydrograph shape
27/12/1994	58.1	
01/03/1999	51.7	

Table A10.20 Highest Flood Peaks for Gauging Station 25004

Date	Peak Flow (m^3/s)	Comments
05/11/2000	73.4	
05/03/1998	71.1	Selected for hydrograph shape
01/03/1999	69.8	
03/08/1997	66.7	

Table A10.21 Highest Flood Peaks for Gauging Station 25003

Date	Peak Flow (m^3/s)	Comments
13/09/1960	56.8	Selected for hydrograph shape
23/09/1957	58.1	
21/01/1957	71.1	
20/09/1999	70.2	

Table A10.22 Highest Flood Peaks for Gauging Station 25002

Date	Peak Flow (m^3/s)	Comments
13/09/1990	153.9	
22/02/1995	150.4	
31.01/1983	138.8	
06/08/1986	134.6	Selected for hydrograph shape

Table A10.23 Highest Flood Peaks for Gauging Station 25001

Date	Peak Flow (m^3/s)	Comments
11/12/2008	69.0	Selected for hydrograph shape
05/09/2008	67.2	
06/01/2005	58.2	Not used due to short record
06/12/2007	65.4	

Table A10.24 Highest Flood Peaks for Gauging Station 25308

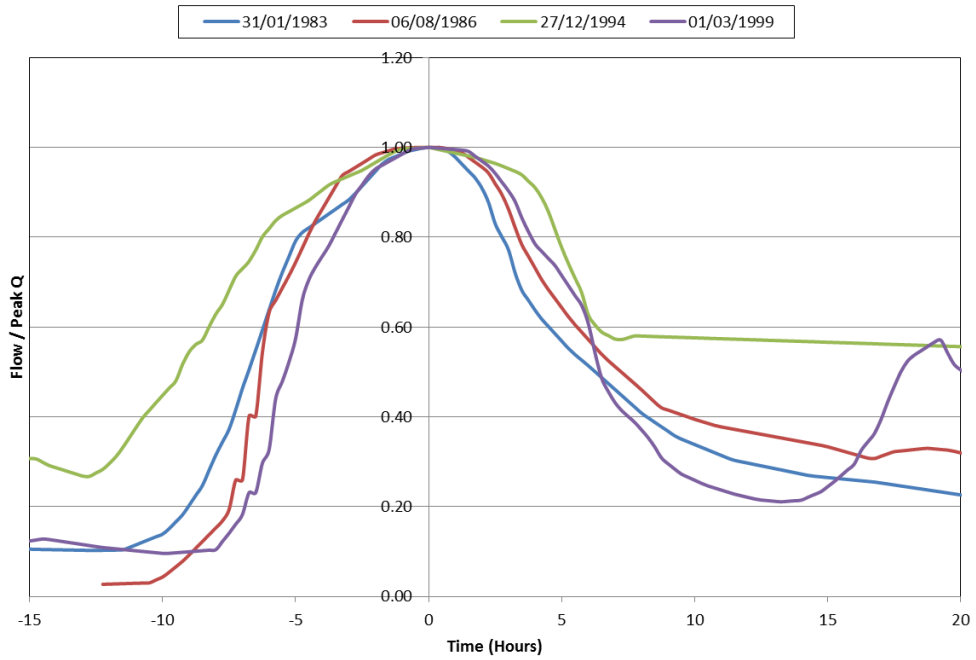


Figure A10.7 Non-dimensional Hydrographs for Gauging Station 25004 – Reach 1

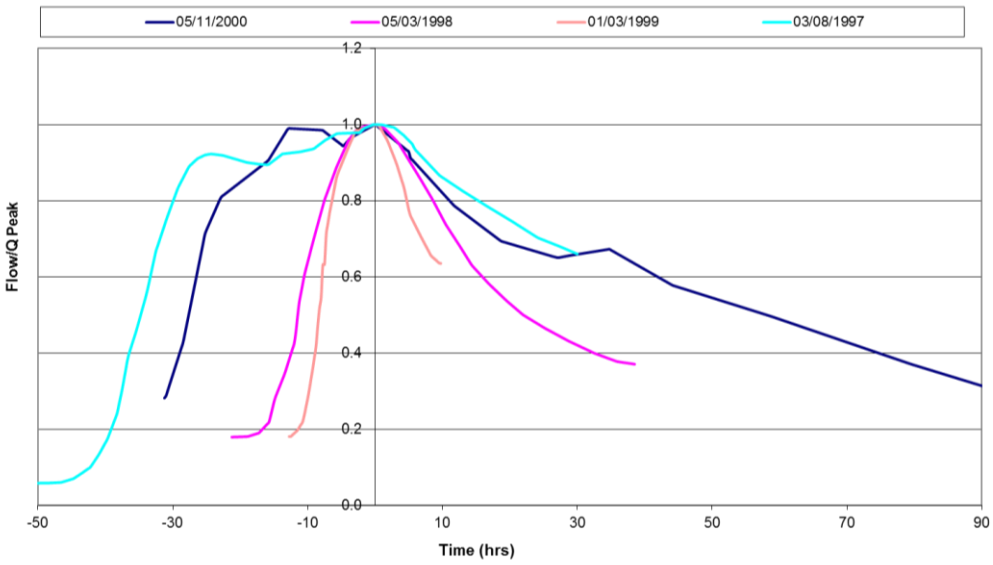


Figure A10.8 Non-dimensional Hydrographs for Gauging Station 25003 – Reach 2 (River Mulkear)

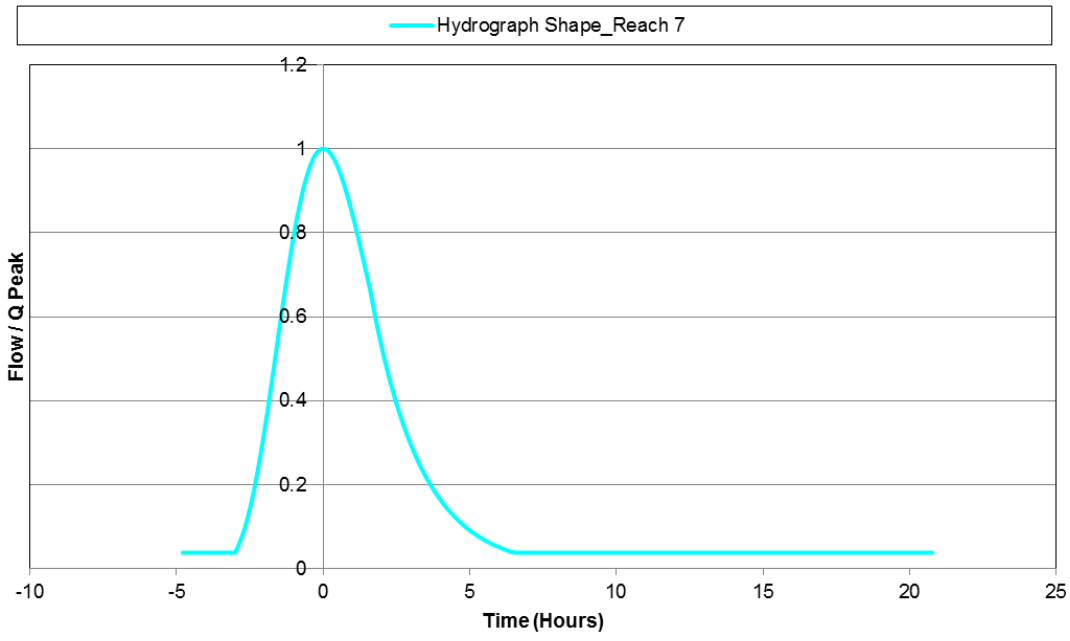


Figure A10.9 Non-dimensional Hydrograph for Reach 7 (HEP 25_833_2)

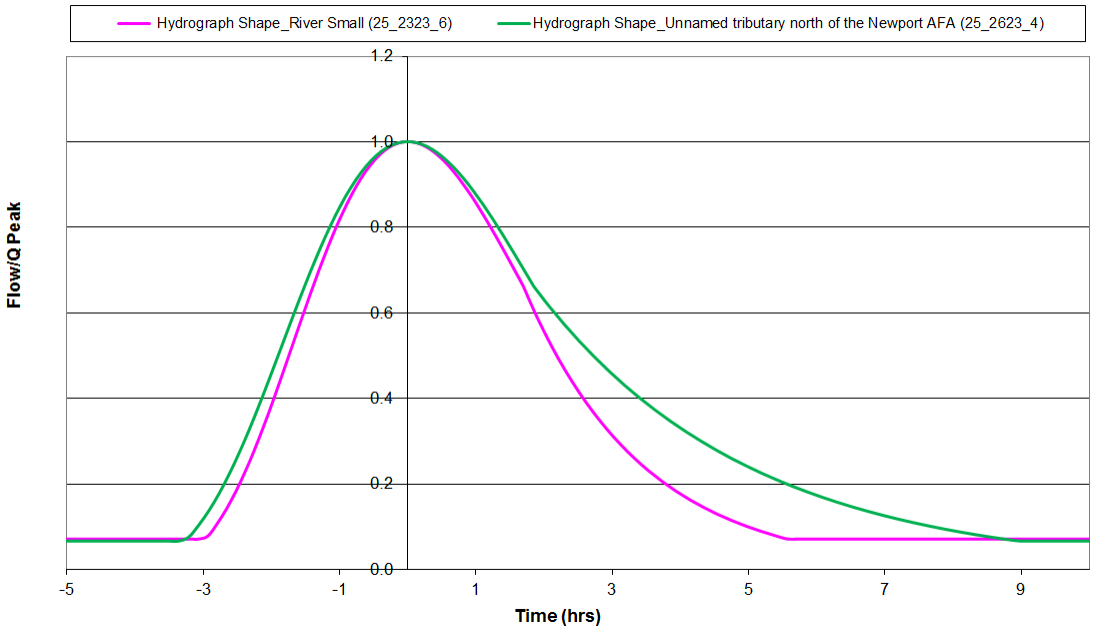


Figure A10.10 Non-dimensional Hydrographs for Reach 3

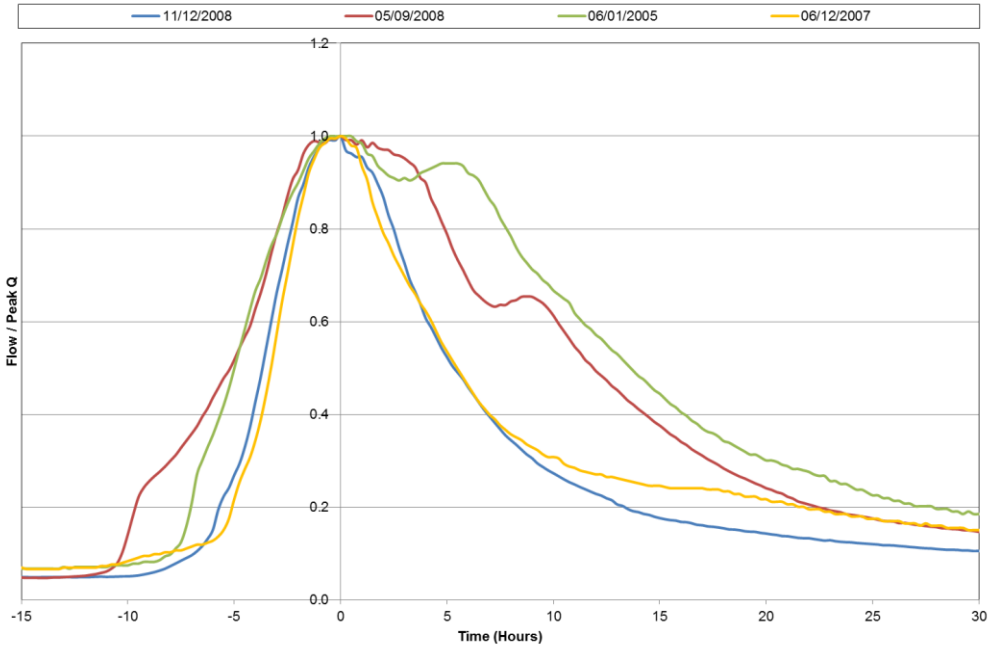


Figure A10.11 Non-dimensional Hydrographs for Gauging Station 25308 for Reach 4 (River Newport)

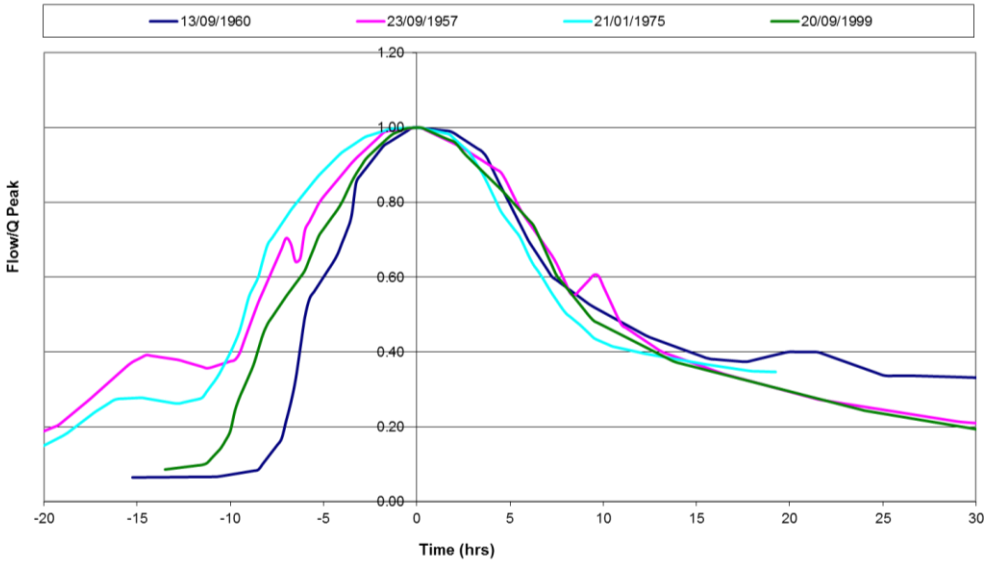


Figure A10.12 Non-dimensional Hydrographs for Gauging Station 25002 for Reach 8

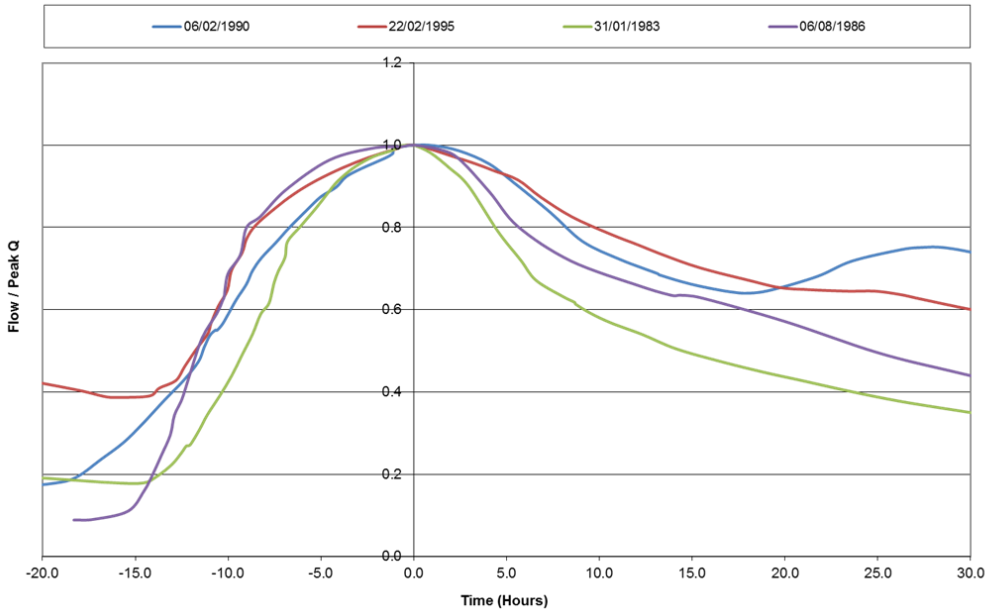


Figure A10.13 Non-dimensional Hydrographs for Gauging Station 25001 - Reach 5

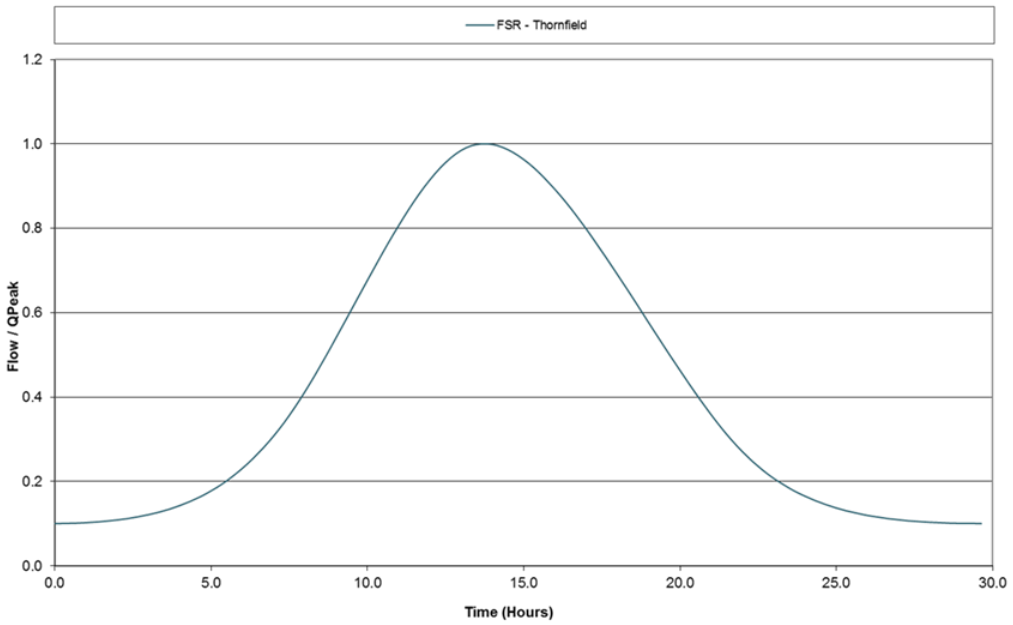


Figure A10.14 Non-dimensional Hydrograph for Reach 6 (HEP 25_3325_2)

A10.7 Flows and Hydrological Estimation Points

The peak flow estimation at individual HEPs for each model covering the Mulkear Catchment is discussed in Chapters B15 and B16 in Appendix B.

A10.8 Calibration

The calibration and verification of the hydraulic models is discussed in Chapters B15 and B16 in Appendix B.

Appendix B Model Specific Hydrological Analysis

Table of Content

B1 Model N01

B2 Model N02

B3 Model N03

B4 Model N04

B5 Model N05

B6 Model N06

B7 Model N07

B8 Model N08

B9 Model N09

B10 Model N10

B11 Model N11

B12 Model N12

B13 Model N13

B14 Model N14

B15 Model N15

B16 Model N16

B1 Model N01

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods, and the preliminary inflow design hydrographs used in the hydraulic modelling as the starting point in the process of ensuring that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B1.1, and shown on Figures B1.1a, B1.1b and B1.1c

Model Attribute	Comment
Rivers included in model	River Shannon River Boyle River Easky River Aghagrania River Ballinamore River Guiltyconeen River Mullaghmore Lisnabrack tributary Drummagh tributary Keenaghban tributary
Areas for Further Assessment (AFA)	Drumshanbo, Leitrim Village, Boyle, Carrick on Shannon

Table B1.1 Model Extent coverage

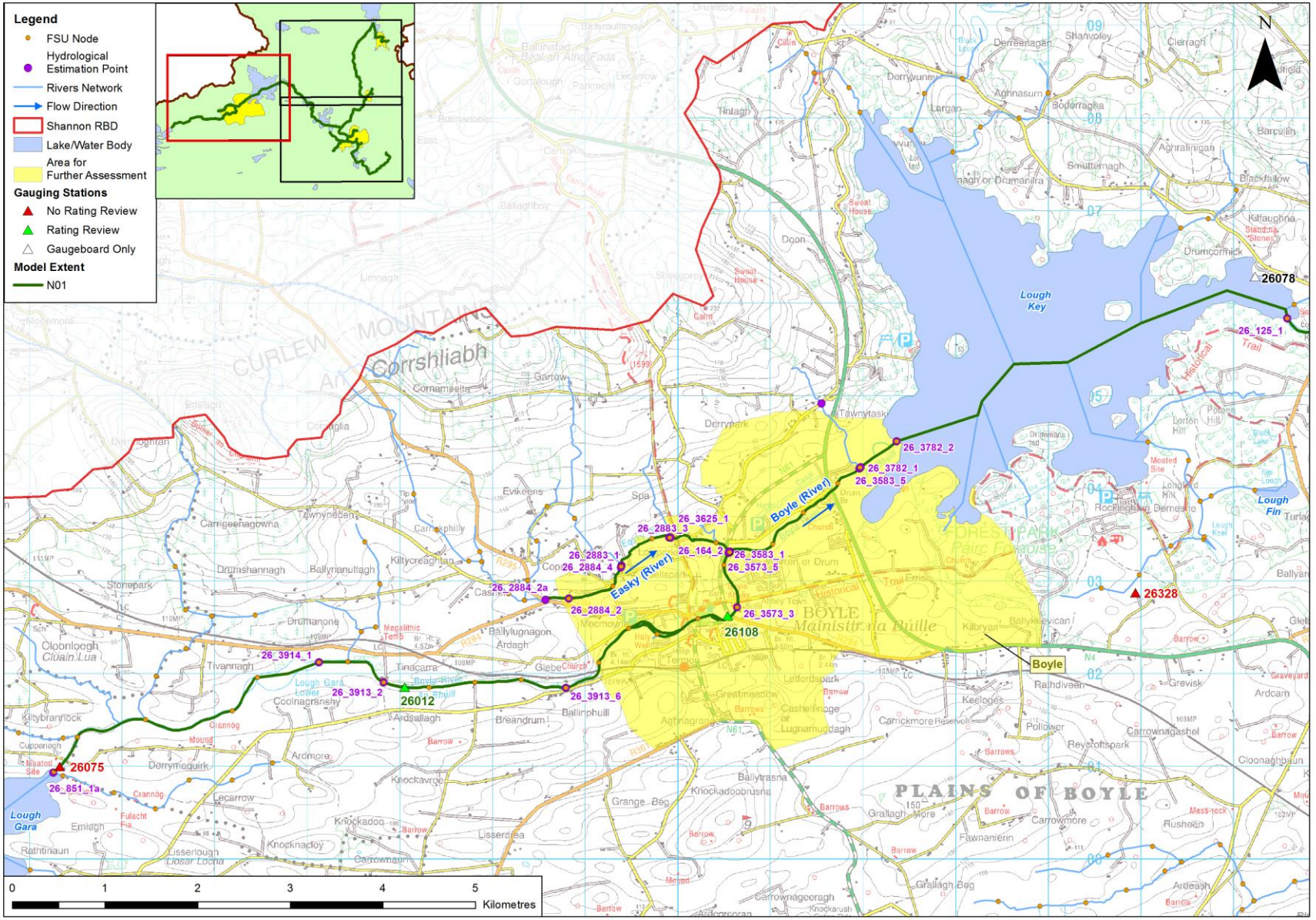


Figure B1.1a N01 Model Extent (West)

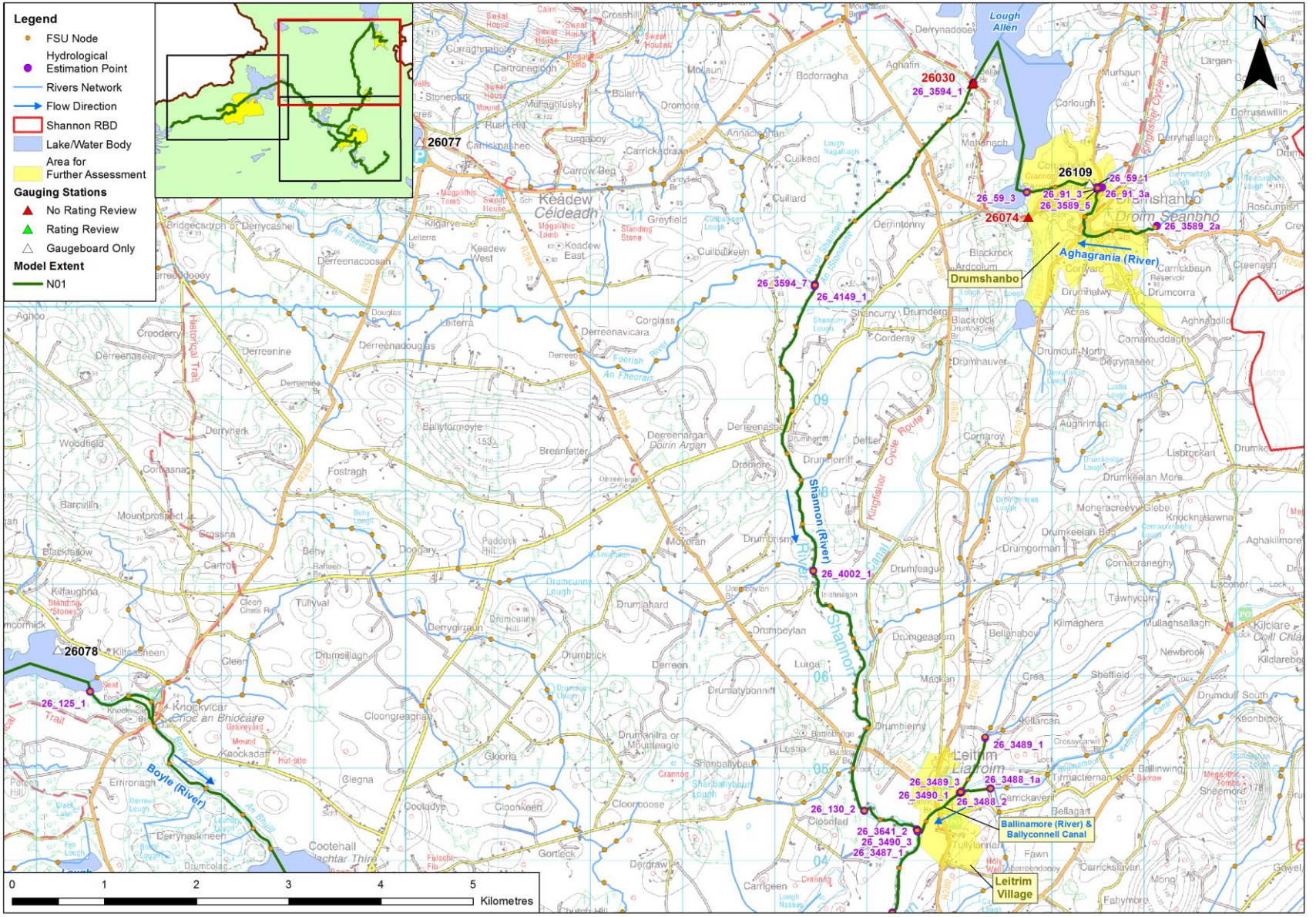


Figure B1.1b N01 Model Extent (North)

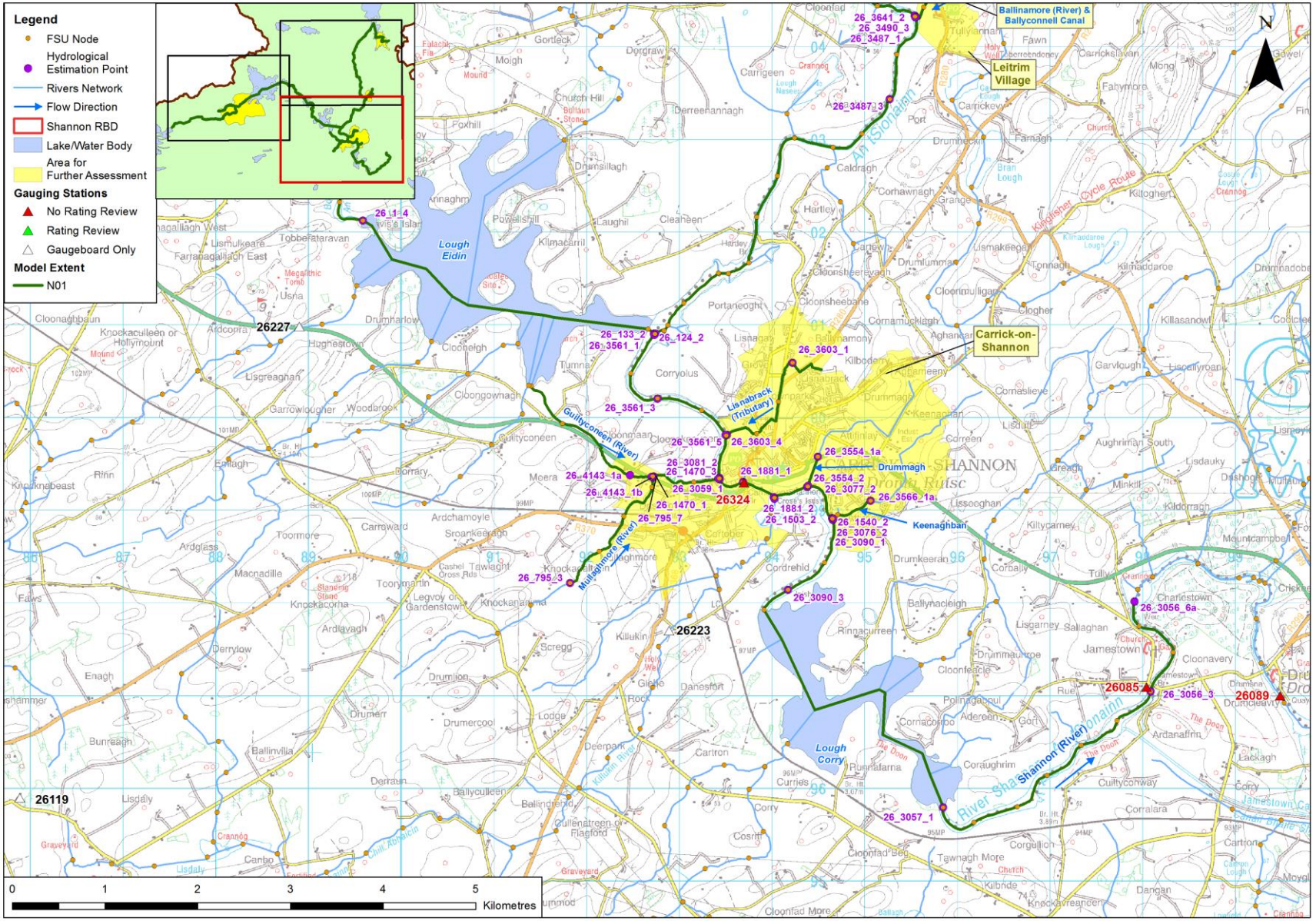


Figure B1.1c N01 Model Extent (South)

B1.1 Hydrology for Hydraulic Model Calibration

There was sufficient hydrometric data coupled with sufficient flood level/extent information available for the calibration and verification against a number of flood events on selected reaches of the model. On the main stem of the River Shannon calibration and verification was undertaken upstream and downstream of Lough Allen and on the River Boyle between Tinacarra (26012) and Boyle Abbey Bridge (26108). The calibration and verification events used are outlined in Tables B1.2 and B1.3.

	Calibration or Verification	Date of Event	Peak Level at 26073 (mAOD-M)
Out-of-bank	Calibration	20/11/2009	47.98
In-bank	Calibration	21/01/2005	47.30
	Calibration	28/05/2002	47.32
	Verification	10/12/2011	47.29

Table B1.2 Calibration and verification events for N01 on the Main Stem River Shannon.

	Calibration or Verification	Date of Event	Peak Flow at 26012 (m^3/s)
Out-of-bank	Calibration	25/11/2009	110.1
In-bank	Calibration	11/12/2007	61.8
	Verification	12/02/2002	61.8

Table B1.3 Calibration and verification events for N01 on the Boyle tributary.

In addition, a high level verification (sense check) of the modelled design extents was undertaken via comparison to the observed flood levels/extents for the following:

1. 10 November 2009 flood for which an approximate exceedance probability of less than 1% (1 in 100) at Carrick on Shannon has been estimated from at-site flood frequency analysis as described in the calibration sheet in Appendix F.
2. 25 December 1999 flood for which an exceedance probability of between 10% (1 in 10) and 50% (1 in 2) has been estimated at Carrick on Shannon.
3. Levels at Jamestown (26085) over a 15-year record have been used to derive the median annual maximum level, equivalent to a rarity of 1 in 2 years (50% AEP).

Refer to the calibration strategy in Appendix F for details on this calibration/verification strategy.

During the calibration modelling it was found that the model calibration could not be successfully completed. For the main stem calibration this appears to be caused by a problem with replicating the Bellantra sluice gate arrangement and/or operation. In the case of the River Boyle the observed flows at the downstream gauge (26108) were much lower than those at the upstream gauge (26012), whilst the hydraulic model did not show any storage losses between the gauges. It is noted that the gauges are only about 4 km apart. As the gauge stage-discharge ratings appear to be reliable for the modelled flows, the most likely cause is the permeable nature of the local geology and the presence of karst features, as shown on Figures 3.3 to 3.5 in the main hydrology report.

A good match was observed between modelled and observed flood extents for the November 2009 flood. The observed flood levels suggest that the event has an annual exceedance probability between 0.1% (1 in 1000) and 1% (1 in 100).

Refer to the hydraulic modelling report for N01 for more details.

B1.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Chapter A1 Appendix A. The target flows at the HEP nodes for model N01 are shown in Tables B1.4 to B1.7.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3594_1	30.6	37.0	41.6	47.4	52.6	57.5	62.4	74.1
26_3594_7	30.6	37.0	41.6	47.4	52.6	57.5	62.4	74.1
26_4149_1	75.1	90.9	102	116	129	141	153	182
26_4002_1	75.1	90.9	102	116	129	141	153	182
26_130_2	75.1	90.9	102	116	129	141	153	182
26_3641_2	75.1	90.9	102	116	129	141	153	182
26_3487_1	75.1	90.9	102	116	129	141	153	182
26_3487_3	75.1	90.9	102	116	129	141	153	182
26_124_2	75.1	90.9	102	116	129	141	153	182
26_3561_1	115	139	156	178	198	216	235	278
26_3561_3	115	139	156	178	198	216	235	278
26_3561_5	115	139	156	178	198	216	235	278
26_3081_2	115	139	156	178	198	216	235	278
26_3059_1	115	139	156	178	198	216	235	278
26_1881_1	115	139	156	178	198	216	235	278
26_1881_2	115	139	156	178	198	216	235	278
26_3077_2	118	143	161	183	203	222	241	286
26_3076_2	118	143	161	183	203	222	241	286
26_3090_1	118	143	161	183	203	222	241	286
26_3090_3	118	143	161	183	203	222	241	286
26_3057_1	113	137	154	176	195	213	231	274
26_3056_3	113	137	154	176	195	213	231	274
26_3056_6a	113	137	154	176	195	213	231	274

Table B1.4 Target Flows (m^3/s) at HEP Locations on the N01 Model Extent (Main Stem-Reaches 2, 3 and 4).

HEP Reference (Continue)	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3589_5	3.95	4.84	5.42	5.98	6.71	7.26	7.80	9.06
26_59_1	4.63	5.67	6.36	7.01	7.87	8.51	9.14	10.62
26_59_3	4.63	5.67	6.36	7.01	7.87	8.51	9.14	10.62
26_91_3	0.68	0.83	0.93	1.03	1.16	1.25	1.34	1.56
26_3488_2	3.48	4.26	4.79	5.28	5.93	6.42	6.90	8.02
26_3489_3	0.39	0.48	0.53	0.59	0.66	0.71	0.77	0.89
26_3490_1	3.87	4.74	5.32	5.87	6.59	7.13	7.67	8.91
26_3490_3	3.87	4.74	5.32	5.87	6.59	7.13	7.67	8.91
26_3603_4	0.48	0.62	0.72	0.81	0.93	1.02	1.11	1.32
26_795_7	2.76	3.61	4.17	4.71	5.41	5.93	6.45	7.65
26_4143_1b	0.06	0.07	0.08	0.09	0.11	0.12	0.13	0.15
26_1470_1	2.82	3.68	4.26	4.80	5.51	6.05	6.58	7.80
26_1470_3	3.01	3.93	4.54	5.12	5.88	6.45	7.01	8.32
26_3554_2	0.88	1.16	1.34	1.51	1.73	1.90	2.06	2.45
26_1540_2	0.64	0.83	0.96	1.09	1.25	1.37	1.49	1.77

Table B1.5 Target Flows (m^3/s) at HEP Locations on the N01 Model Extent (Tributaries to Main Stem) (Reaches 1, 7 and 8).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3914_1	40.0	48.0	53.3	58.4	64.9	69.9	74.8	86.1
26_3913_2	40.2	48.2	53.6	58.6	65.2	70.2	75.1	86.5
26_3913_6	40.6	48.7	54.0	59.2	65.8	70.8	75.8	87.3
26_3573_3	41.7	50.0	55.5	60.7	67.6	72.7	77.8	89.6
26_3573_5	42.6	51.1	56.7	62.1	69.1	74.4	79.6	91.7
26_3583_1	44.1	52.9	58.7	64.3	71.5	76.9	82.3	94.8
26_3782_1	44.1	51.9	57.6	63.0	70.1	75.4	80.7	93.0
26_3782_2	44.1	50.3	55.9	61.2	68.0	73.2	78.3	90.2
26_125_1	38.0	45.6	50.6	55.4	61.6	66.3	70.9	81.7
26_238_1	39.5	47.4	52.6	57.6	64.1	69.0	73.8	85.0
26_1_4	39.5	46.6	51.8	56.7	63.1	67.9	72.6	83.6
26_133_2	39.2	47.0	52.2	57.1	63.5	68.4	73.2	84.3

Table B1.6 Target Flows (m^3/s) at HEP Locations on the N01 Model Extent (Tributary to Main Stem- River Boyle) (Reach 5).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2884_2	4.14	5.21	5.91	6.58	7.46	8.11	8.76	10.3
26_2884_4	4.29	5.39	6.12	6.82	7.72	8.40	9.07	10.6
26_2883_1	5.44	6.83	7.75	8.64	9.78	10.6	11.5	13.5
26_3625_1	6.13	7.70	8.74	9.74	11.0	12.0	13.0	15.2
26_164_2	6.49	8.15	9.25	10.3	11.7	12.7	13.7	16.1

Table B1.7 Target Flows (m^3/s) at HEP Locations on the N01 Model Extent (Tributary to River Boyle) (Reach 6)

B1.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B1.4 to B1.7, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, three separate runs were undertaken for each AEP; the first run aimed to match the target flows in the main stem and minor tributaries at Carrick on Shannon (Reach 8); the second run aimed to obtain the target flows on the tributaries; River Boyle, Aghagrania River and Ballinamore River/Ballyconnell Canal; and the third run aimed to obtain the target flows on the Easky River (tributary to River Boyle). For modelling purposes the tributaries are defined as the River Boyle down to HEP 26_133_2, River Easky down to HEP node 26_164_2, Aghagrania River down to HEP 26_59_3, Ballinamore River/Ballyconnell Canal down to HEP node 26_3490_3, Guiltyconeen River down to HEP node 26_1470_3, Mullaghmore River down to HEP node 26_4143_1b, Lisnabrack tributary down to HEP node 26_3603_4, Drummagh tributary down to HEP node 26_3554_2 and Keenaghban tributary down to HEP node 26_1540_2.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the adjustment factor, growth curves and hydrograph shape specified in Chapter A1 Appendix A. The QMED adjustment factor, growth curve and hydrograph shape are specified in Chapter A1 Appendix A. The HEPs are shown in Figure B1.1 a,b,c. Tables B1.8 to B1.11 present the peak values of the preliminary lateral inflows inserted into the model in the reach immediately upstream of the HEP in the hydraulic model for the main stem and tributary runs.

Preliminary design inflow hydrographs are shown in Figures B1.2 to B1.6 for the 1% AEP design runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3594_1	30.6	37.0	41.6	47.4	52.6	57.5	62.4	74.1
26_3594_7	44.5	53.8	60.5	69.0	76.5	83.7	90.8	108
26_3561_1	39.9	48.2	54.2	61.8	68.6	74.9	81.3	96.5

Table B1.8 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N01 Model Extent (Main Stem – Reaches 2, 3, and 4)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3630_11	3.48	4.26	4.79	5.28	5.93	6.42	6.90	8.02
26_3489_1	0.39	0.48	0.53	0.59	0.66	0.71	0.77	0.89
26_91_3a	0.68	0.83	0.93	1.03	1.16	1.25	1.34	1.56
26_3589_2a	3.95	4.84	5.42	5.98	6.71	7.26	7.80	9.06
26_3603_1	0.48	0.62	0.72	0.81	0.93	1.02	1.11	1.32
26_4143_1a	0.06	0.07	0.08	0.09	0.11	0.12	0.13	0.15
26_795_3	2.76	3.61	4.17	4.71	5.41	5.93	6.45	7.65
26_1470_1	0.19	0.25	0.28	0.32	0.37	0.40	0.44	0.52
26_1881_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26_3554_1a	0.88	1.16	1.34	1.51	1.73	1.90	2.06	2.45
26_3566_1a	0.64	0.83	0.96	1.09	1.25	1.37	1.49	1.77

Table B1.9 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N01 Model Extent (Tributaries to Main Stem) (Reaches 1, 7 and 8)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_851_1a	40.0	48.0	53.3	58.4	64.9	69.9	74.8	86.1
26_3914_1	1.62	1.94	2.15	2.36	2.62	2.82	3.02	3.48
26_3573_3	2.44	2.92	3.25	3.55	3.95	4.25	4.55	5.24

Table B1.10 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N01 Model Extent (Tributary to Main Stem - River Boyle) (Reach 5)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2884_2a	4.14	5.21	5.91	6.58	7.46	8.11	8.76	10.3
26_2884_2	0.15	0.18	0.21	0.23	0.26	0.29	0.31	0.36
26_2884_4	1.15	1.44	1.64	1.82	2.06	2.25	2.43	2.84
26_2883_1	0.48	0.61	0.69	0.77	0.87	0.95	1.03	1.20
26_2883_3	0.21	0.26	0.29	0.33	0.37	0.40	0.44	0.51
26_3625_1	0.36	0.45	0.52	0.57	0.65	0.71	0.76	0.90

Table B1.11 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N01 Model Extent (Tributary to River Boyle) (Reach 6)

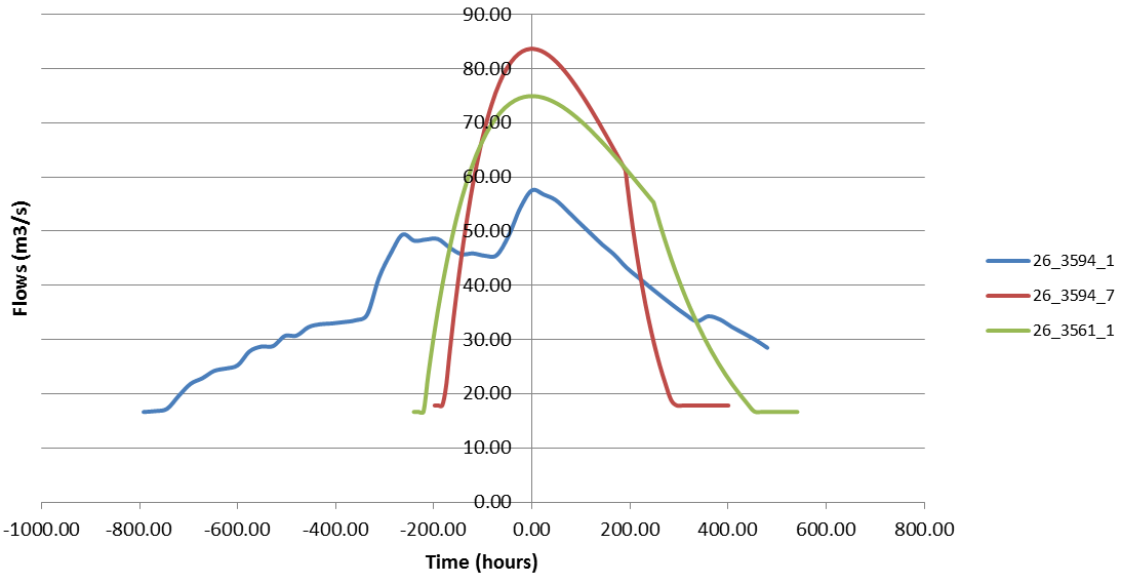


Figure B1.2 N01 Preliminary Design Inflow Hydrographs for 1% AEP (Reaches 2, 3, and 4)

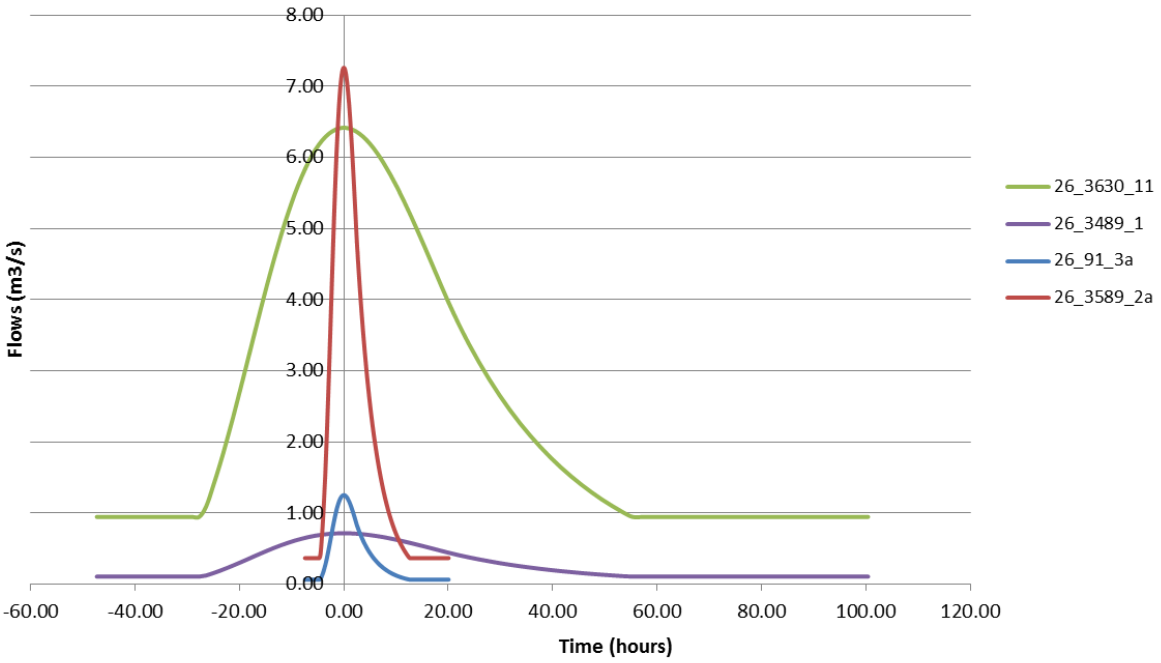


Figure B1.3 N01 Preliminary Design Inflow Hydrographs for 1% AEP (Reaches 1 and 7)

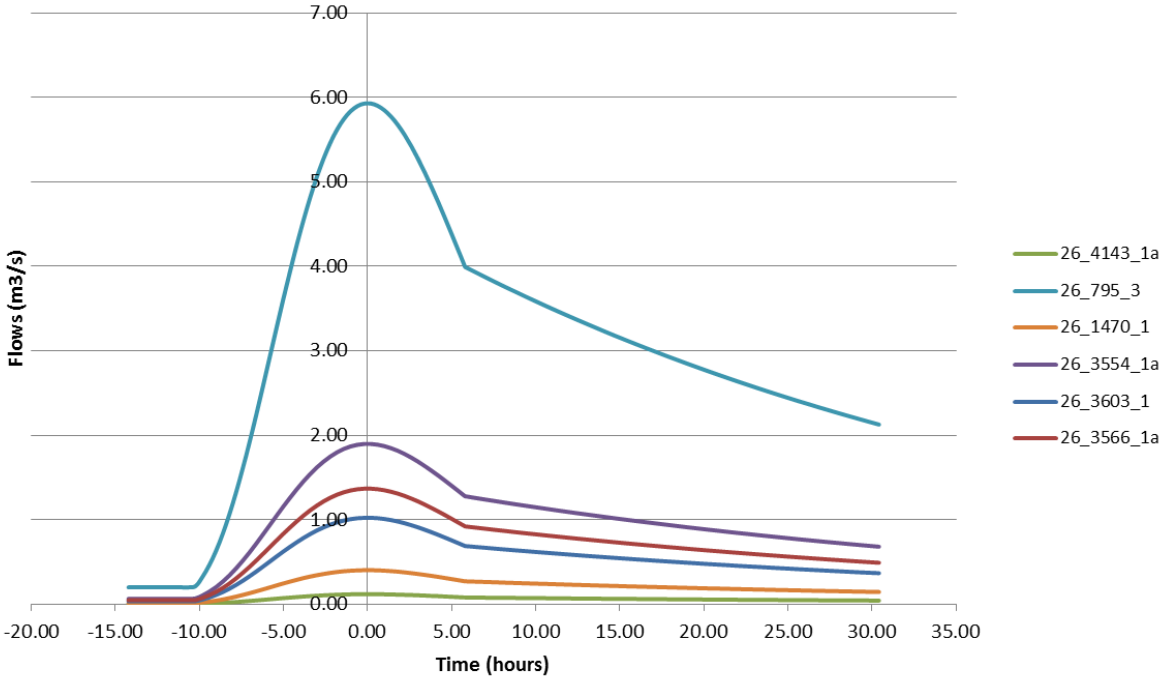


Figure B1.4 N01 Preliminary Design Inflow Hydrographs for 1% AEP (Reach 8)

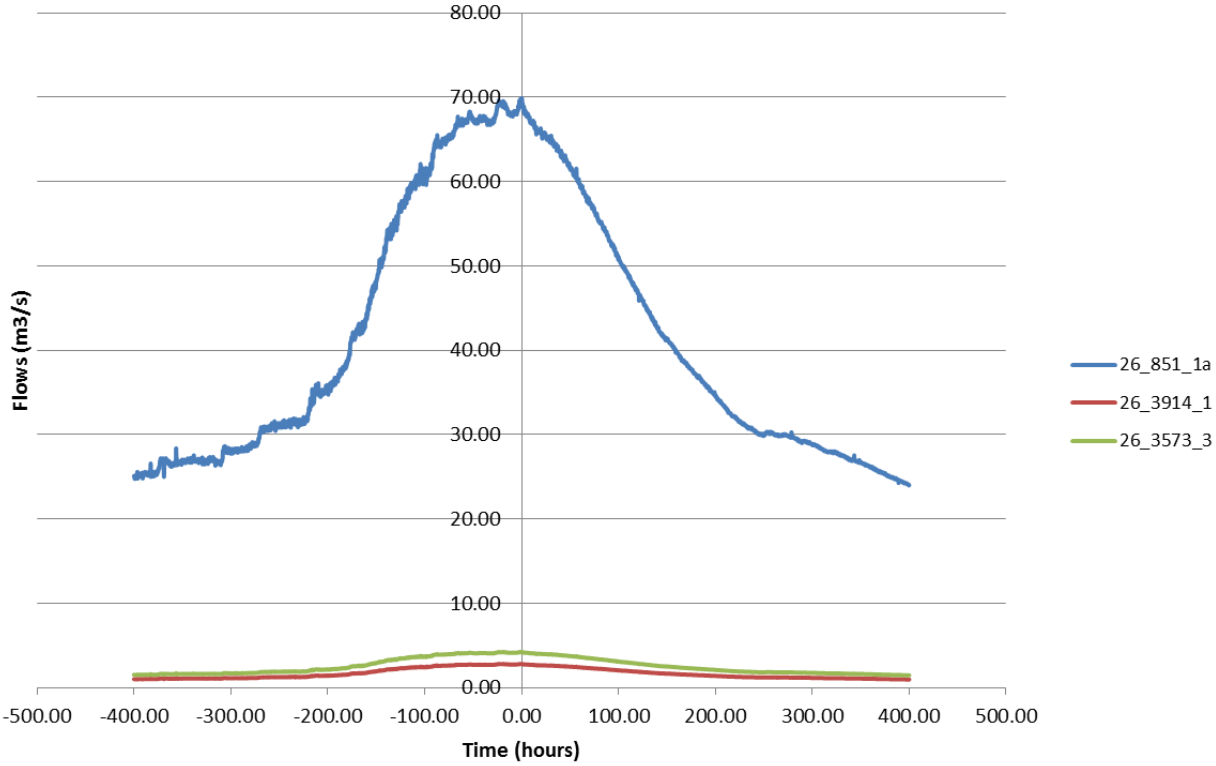


Figure B1.5 N01 Preliminary Design Inflow Hydrographs for 1% AEP (Reach 5)

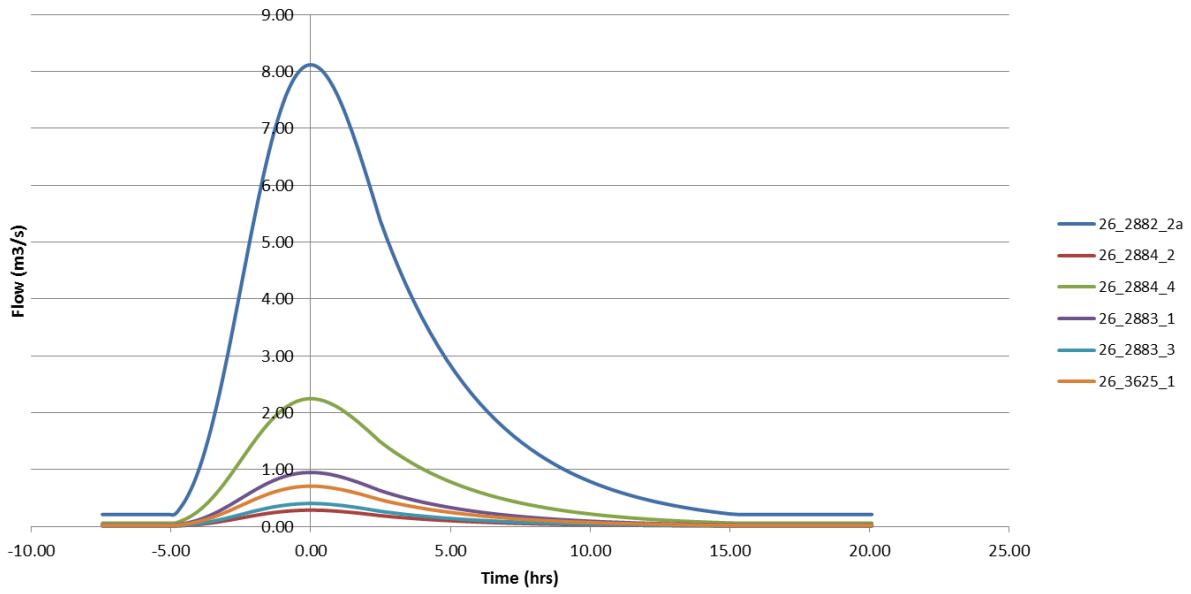


Figure B1.6 N01 Preliminary Design Inflow Hydrographs for 1% AEP (Reach 6)

B1.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B1.8 to B1.11 for calibrating the model to the HEP target flows presented in Tables B1.4 to B1.7.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N01.

B2 Model N02

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods, and the preliminary inflow design hydrographs used in the hydraulic modelling as the starting point in the process of ensuring that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B2.1, and shown on Figures B2.1a and B2.1b

Model Attribute	Comment
Rivers included in model	River Shannon River Camlin River Camlin South River Rinn River Eslin River Knockmartin River Carrickglass Demesne River Ardnacassagh River Farranyoogan River Clookeen River Fallan River Cappagh River Shannagh River Ballyminion (tributary to Farranyoogan)
Areas for Further Assessment (AFA)	Longford, Mohill, Dromod, Cloondara

Table B2.1 Model Extent coverage

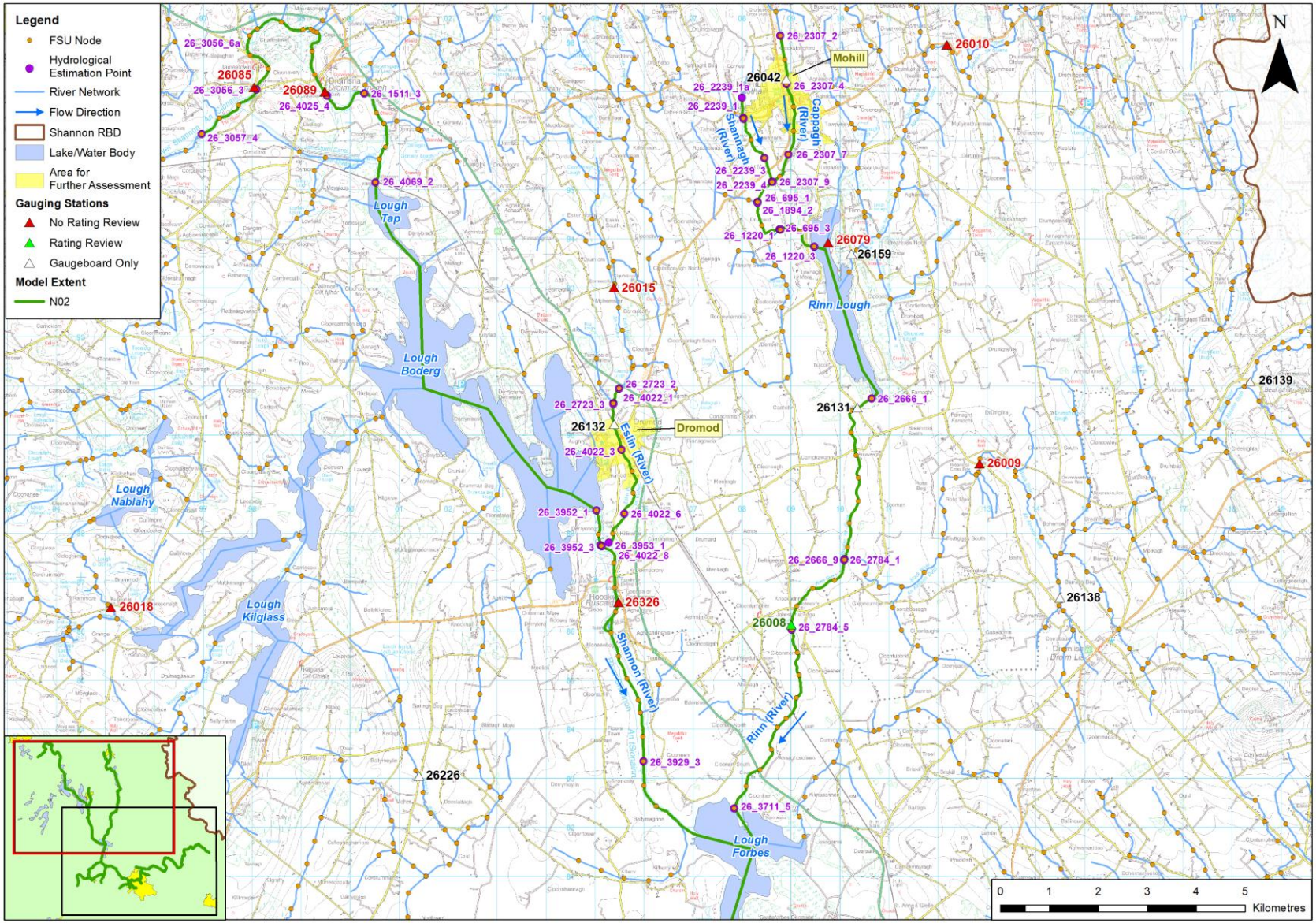


Figure B2.1a N02 Model Extent (North)

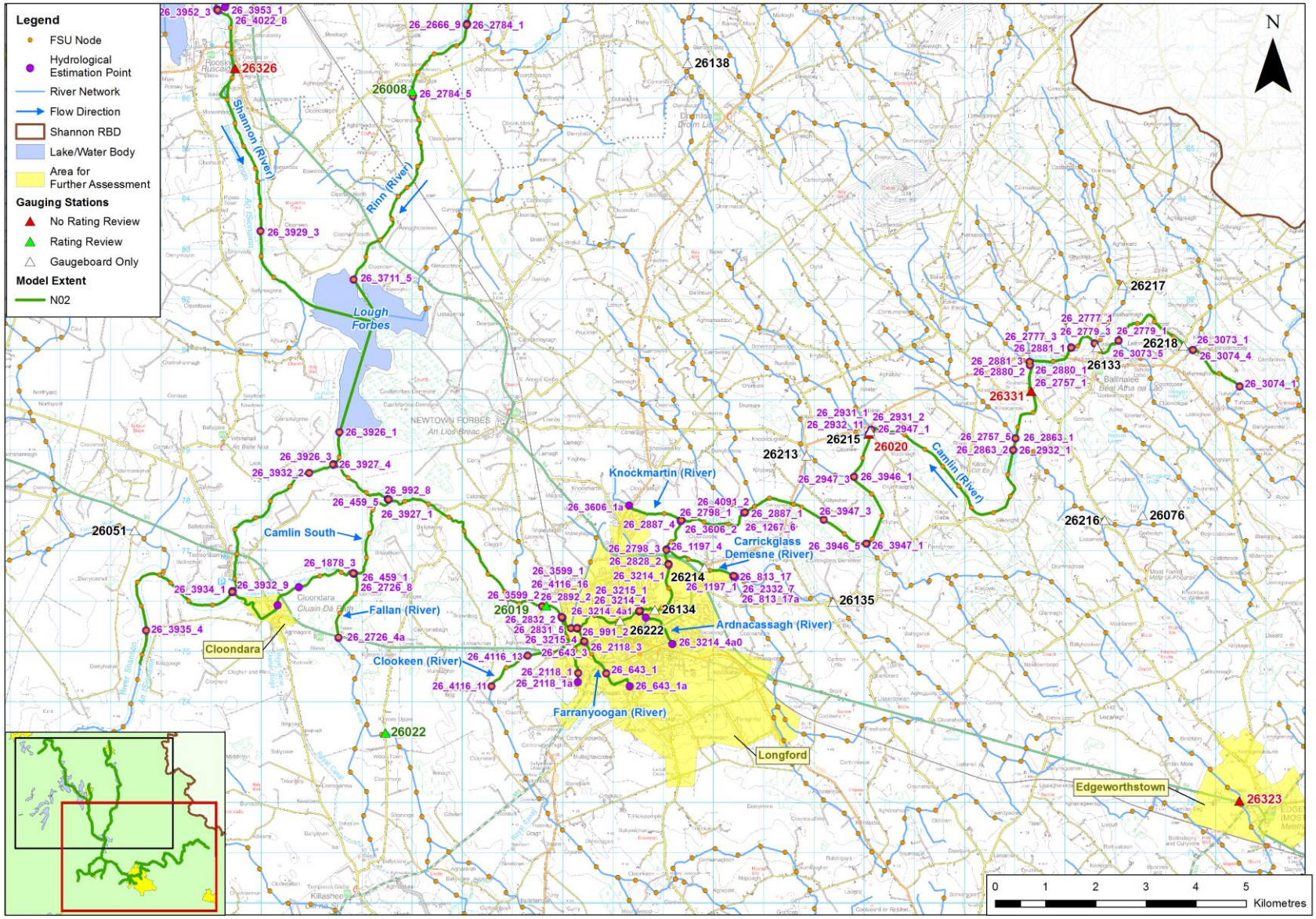


Figure B2.1b N02 Model Extent (South)

B2.1 Hydrology for Hydraulic Model Calibration

There was insufficient gauged data available to calibrate or verify the N02 model.

B2.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Chapter A1 Appendix A. The target flows at the HEP nodes for model N02 are shown in Tables B2.3 to B2.6.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3056_3	113	137	154	175	194	212	230	273
26_4025_4	114	138	155	176	196	214	232	275
26_1511_3	117	142	159	181	201	220	239	283
26_4069_2	117	142	159	181	201	220	239	283
26_3952_1	117	142	159	181	201	220	239	283
26_3952_3	117	142	159	181	201	220	239	283
26_3953_1	122	148	166	190	211	230	250	296
26_3929_3	122	148	166	190	211	230	250	296
26_3926_1	135	164	184	210	233	254	276	327
26_3926_3	135	164	184	210	233	254	276	327
26_3934_1	163	198	222	253	281	307	333	395
26_3935_4	170	205	231	263	292	319	346	411

Table B2.3 Target Flows (m^3/s) at HEP Locations on the N02 Model Extent (Main Stem) (Reach 4).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2723_3	6.08	7.37	8.22	9.04	10.1	10.9	11.7	13.5
26_4022_1	6.19	7.50	8.37	9.20	10.3	11.1	11.9	13.8
26_4022_3	6.39	7.74	8.64	9.50	10.6	11.4	12.3	14.2
26_4022_6	6.50	7.88	8.79	9.67	10.8	11.6	12.5	14.5
26_4022_8	6.50	7.88	8.79	9.67	10.8	11.6	12.5	14.5
26_2307_4	2.17	2.97	3.50	4.00	4.66	5.15	5.64	6.8
26_2307_7	2.98	4.08	4.80	5.50	6.40	7.07	7.75	9.3
26_2307_9	3.25	4.44	5.24	6.00	6.98	7.72	8.45	10.1
26_1894_2	4.66	6.38	7.52	8.61	10.0	11.1	12.1	14.6
26_695_1	5.42	7.42	8.74	10.0	11.6	12.9	14.1	16.9
26_695_3	5.48	7.49	8.83	10.1	11.8	13.0	14.2	17.1
26_1220_1	7.55	10.3	12.2	13.9	16.2	17.9	19.6	23.6
26_1220_3	7.55	10.3	12.2	13.9	16.2	17.9	19.6	23.6
26_2239_1	0.91	1.25	1.47	1.68	1.96	2.17	2.37	2.85
26_2239_3	1.63	2.23	2.63	3.01	3.50	3.87	4.24	5.09
26_2239_4	1.78	2.43	2.87	3.28	3.82	4.22	4.62	5.55
26_2666_9	12.5	15.4	17.3	19.1	21.5	23.3	25.1	29.2
26_2784_1	22.2	27.3	30.8	34.0	38.3	41.4	44.6	51.9
26_2784_5	22.9	28.3	31.8	35.2	39.6	42.8	46.1	53.7
26_3711_5	23.8	29.3	33.0	36.5	41.0	44.4	47.8	55.7

Table B2.4 Target Flows (m^3/s) at HEP Locations on the N02 Model Extent (Tributaries to the Main Stem) (Reaches 13, 14 and 15).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3074_4	5.49	6.65	7.42	8.15	9.11	9.8	10.5	12.2
26_3073_1	6.43	7.79	8.69	9.55	10.7	11.5	12.3	14.3
26_3073_5	6.53	7.91	8.82	9.70	10.8	11.7	12.5	14.5
26_2779_1	7.74	9.37	10.5	11.5	12.8	13.8	14.8	17.2
26_2779_3	8.03	9.73	10.9	11.9	13.3	14.4	15.4	17.8
26_2777_1	8.94	10.8	12.1	13.3	14.8	16.0	17.2	19.8
26_2777_3	9.22	11.2	12.5	13.7	15.3	16.5	17.7	20.5
26_2881_1	9.77	11.8	13.2	14.5	16.2	17.5	18.7	21.7
26_2881_3	9.77	11.8	13.2	14.5	16.2	17.5	18.7	21.7

26_2880_1	10.2	12.4	13.8	15.2	16.9	18.3	19.6	22.6
26_2880_2	10.2	12.4	13.8	15.2	16.9	18.3	19.6	22.6
26_2757_1	10.5	12.8	14.2	15.7	17.5	18.9	20.2	23.4
26_2757_5	10.5	12.8	14.2	15.7	17.5	18.9	20.2	23.4
26_2863_1	11.4	13.8	15.3	16.9	18.8	20.3	21.8	25.2
26_2863_2	11.4	13.9	15.5	17.0	19.0	20.5	22.0	25.4
26_2932_1	12.5	15.1	16.9	18.6	20.7	22.3	24.0	27.7
26_2932_11	12.5	15.1	16.9	18.6	20.7	22.3	24.0	27.7
26_2931_1	12.5	15.1	16.9	18.6	20.7	22.3	24.0	27.7
26_2931_2	12.5	15.1	16.9	18.6	20.7	22.3	24.0	27.7
26_2947_1	12.6	15.3	17.1	18.8	20.9	22.6	24.2	28.0
26_2947_3	12.7	15.4	17.2	18.9	21.1	22.7	24.4	28.2
26_3946_1	13.3	16.1	17.9	19.7	22.0	23.7	25.5	29.5
26_3946_5	13.3	16.1	17.9	19.7	22.0	23.7	25.5	29.5
26_3947_1	14.0	17.0	18.9	20.8	23.2	25.1	26.9	31.1
26_3947_3	14.2	17.2	19.2	21.1	23.6	25.5	27.3	31.6
26_4091_2	15.0	18.2	20.3	22.3	24.9	26.8	28.8	33.3
26_2887_1	15.6	18.9	21.1	23.2	25.9	27.9	29.9	34.6
26_2887_4	15.6	18.9	21.1	23.2	25.9	27.9	29.9	34.6
26_2798_1	15.7	19.0	21.2	23.3	26.0	28.1	30.1	34.8
26_2798_3	15.7	19.0	21.2	23.3	26.0	28.1	30.1	34.8
26_2828_2	18.6	22.5	25.1	27.6	30.8	33.2	35.6	41.2
26_3214_1	18.6	22.5	25.1	27.6	30.9	33.3	35.7	41.3
26_3214_4	19.1	23.1	25.8	28.3	31.6	34.1	36.6	42.3
26_3215_1	19.5	23.6	26.3	28.9	32.3	34.8	37.3	43.2
26_3215_4	19.5	23.6	26.3	28.9	32.3	34.8	37.3	43.2
26_2832_2	19.5	23.6	26.3	28.9	32.3	34.8	37.3	43.2
26_2892_2	19.5	23.6	26.3	28.9	32.3	34.8	37.3	43.2
26_3599_1	21.7	26.3	29.4	32.3	36.1	38.9	41.7	48.2
26_3599_2	22.0	26.6	29.7	32.6	36.5	39.3	42.2	48.8
26_992_8	22.3	27.1	30.2	33.2	37.1	40.0	42.9	49.6
26_3927_1	25.2	30.6	34.1	37.5	41.8	45.1	48.4	56.0
26_3927_4	25.2	30.6	34.1	37.5	41.8	45.1	48.4	56.0

Table B2.5 Target Flows (m^3/s) at HEP Locations on the N02 Model Extent (Tributary – River Camlin) (Reach 9).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2726_8	7.43	8.99	10.0	11.0	12.3	13.3	14.2	16.5
26_3606_2	0.84	1.15	1.36	1.55	1.81	2.00	2.19	2.63
26_813_17	2.03	2.46	2.74	3.01	3.37	3.63	3.89	4.50
26_1197_1	5.37	6.51	7.26	7.98	8.91	9.61	10.3	11.9
26_1197_4	5.51	6.67	7.44	8.18	9.13	9.85	10.6	12.2
26_3214_4a1	0.60	0.82	0.97	1.11	1.29	1.42	1.56	1.87
26_643_1	0.37	0.51	0.60	0.68	0.79	0.88	0.96	1.16
26_643_3	0.48	0.66	0.78	0.89	1.04	1.14	1.25	1.51
26_991_2	0.99	1.35	1.60	1.83	2.13	2.35	2.58	3.09
26_2118_1	0.30	0.41	0.48	0.55	0.65	0.71	0.78	0.94
26_2118_3	0.46	0.62	0.74	0.84	0.98	1.08	1.19	1.43
26_4116_13	4.92	5.96	6.65	7.31	8.16	8.80	9.44	10.9
26_4116_16	5.02	6.08	6.78	7.45	8.32	8.98	9.63	11.1

Table B2.6 Target Flows (m^3/s) at HEP Locations on the N02 Model Extent (Tributaries to River Camlin and Camlin South) (Reaches 10, 11 and 12).

B2.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B2.3 to B2.6, an initial set of inflow hydrographs were produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, four separate runs were undertaken for each AEP. One run to match the target flows in the main stem and three further independent run to match flows in the 1st order tributaries (Rivers Camlin, Camlin South and Fallan, Rinn and Eslin) 2nd order tributaries (Rivers Shannagh, Knockmartin, Carrickglass Demesne, Ardnacassagh, Farranyoogan) and 3rd order tributaries (Rivers Shannagh and Ballyminion). The only exception to this was the River Fallan (2nd order tributary) which was modelled with the River Camlin and Camlin South (1st order tributaries). For modelling purposes the tributaries are defined as the River Camlin down to node 26_992_8, River Rinn down to node 26_3711_5, River Eslin down to node 26_4022_8, River Knockmartin down to node 26_3606_2, River Carrickglass Demesne down to node 26_1197_4, River Ardnacassagh down to node 26_3214_4a1, River Farranyoogan down to node 26_991_2, River Clookeen down to node 26_4116_16, River Fallan down to node 26_2726_8, River Cappagh down to 26_1220_3, River Farranyoogan down to node 26_2118_3, and River Shannagh down to node 26_2239_4.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the adjustment factor, growth curves and hydrograph shape specified in Chapter A1 Appendix A. The HEPs are shown in Figure B2.1. Tables B2.7 to B2.10 present the peak values of the preliminary lateral inflows inserted into the model in the reach immediately upstream of the HEP in the hydraulic model for the main stem and tributary runs.

Preliminary design inflow hydrographs are shown in Figures B2.2 to B2.6 for the 1% AEP design runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3057_4	113	137	154	175	194	212	230	273
26_1511_3	3.82	4.62	5.20	5.92	6.57	7.18	7.80	9.25
Lake Tap-Bofin	0.27	0.33	0.37	0.42	0.46	0.51	0.55	0.65
26_3952_1	5.36	6.49	7.29	8.31	9.22	10.1	10.9	13.0
26_3926_1	12.8	15.5	17.4	19.8	22.0	24.0	26.1	30.9
26_3926_3	28.2	34.1	38.4	43.7	48.5	53.0	57.6	68.3
26_3934_1	6.23	7.54	8.47	9.66	10.7	11.7	12.7	15.1

Table B2.7 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N02 Model Extent (Main Stem) (Reach 4)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2723_2	6.08	7.37	8.22	9.04	10.1	10.9	11.7	13.5
26_2723_3	0.11	0.13	0.15	0.16	0.18	0.19	0.21	0.24
26_4022_1	0.20	0.24	0.27	0.30	0.33	0.36	0.38	0.44
26_4022_3	0.11	0.14	0.15	0.17	0.19	0.20	0.22	0.25
26_2307_2	2.17	2.97	3.50	4.00	4.66	5.15	5.64	6.78
26_2307_4	0.81	1.11	1.31	1.49	1.74	1.92	2.11	2.53
26_2307_7	0.27	0.37	0.44	0.50	0.58	0.64	0.70	0.84
26_2239_1a	1.44	1.97	2.33	2.66	3.10	3.43	3.75	4.51
26_1894_2	0.73	1.00	1.18	1.35	1.57	1.73	1.90	2.28
26_695_1	0.06	0.08	0.09	0.10	0.12	0.13	0.15	0.17
26_695_3	2.08	2.84	3.34	3.83	4.46	4.93	5.40	6.48
26_2239_1a	0.91	1.25	1.47	1.68	1.96	2.17	2.37	2.85
26_2239_1	0.72	0.98	1.16	1.32	1.54	1.70	1.86	2.24
26_2239_3	0.15	0.20	0.24	0.27	0.32	0.35	0.39	0.46
26_2666_1	12.5	15.4	17.3	19.1	21.5	23.3	25.1	29.2
26_2666_9	9.70	12.0	13.4	14.9	16.7	18.1	19.5	22.7
26_2784_1	0.75	0.93	1.05	1.16	1.30	1.41	1.52	1.77
26_2784_5	0.86	1.06	1.19	1.31	1.48	1.60	1.72	2.00

Table B2.8 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N02 Model Extent (Tributaries to Main Stem) (Reaches 13, 14 and 15)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3074_1	5.49	6.65	7.42	8.15	9.11	9.82	10.5	12.2
26_3074_4	0.94	1.14	1.27	1.40	1.56	1.68	1.80	2.09
26_3073_1	0.10	0.12	0.14	0.15	0.17	0.18	0.19	0.22
26_3073_5	1.20	1.46	1.63	1.79	2.00	2.15	2.31	2.67
26_2779_1	0.30	0.36	0.40	0.44	0.49	0.53	0.57	0.66
26_2779_3	0.91	1.10	1.23	1.35	1.51	1.63	1.74	2.02
26_2777_1	0.28	0.34	0.38	0.42	0.47	0.50	0.54	0.62
26_2777_3	0.54	0.66	0.73	0.80	0.90	0.97	1.04	1.20
26_2881_1	0.44	0.53	0.59	0.65	0.73	0.79	0.84	0.97
26_2880_1	0.34	0.41	0.46	0.50	0.56	0.61	0.65	0.75
26_2757_1	0.82	0.99	1.10	1.21	1.35	1.46	1.57	1.81
26_2863_1	1.13	1.37	1.53	1.68	1.88	2.03	2.17	2.51
26_2932_1	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.30
26_2947_1	0.65	0.79	0.88	0.96	1.08	1.16	1.24	1.44
26_3946_1	0.74	0.89	1.00	1.10	1.22	1.32	1.42	1.64
26_3947_1	0.21	0.26	0.29	0.32	0.36	0.38	0.41	0.48
26_3947_3	0.76	0.92	1.03	1.13	1.26	1.36	1.46	1.69
26_4091_2	0.60	0.73	0.81	0.89	0.99	1.07	1.15	1.33
26_2887_4	0.09	0.11	0.12	0.13	0.15	0.16	0.17	0.20
26_2798_3	2.88	3.49	3.89	4.27	4.77	5.15	5.52	6.38
26_2828_2	0.52	0.63	0.70	0.77	0.86	0.92	0.99	1.15
26_3214_4	0.38	0.46	0.52	0.57	0.64	0.69	0.74	0.85
26_3215_1	2.29	2.77	3.09	3.40	3.80	4.09	4.39	5.08
26_3599_1	0.23	0.28	0.31	0.34	0.38	0.41	0.44	0.51
26_3599_2	0.37	0.44	0.49	0.54	0.61	0.65	0.70	0.81
26_2726_4a	7.43	8.99	10.0	11.0	12.3	13.3	14.2	16.5

Table B2.9 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N02 Model Extent (Tributary to Main Stem – Rivers Camlin, Camlin South and Fallan) (Reaches 9 and 12)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3606_1a	0.84	1.15	1.36	1.55	1.81	2.00	2.19	2.63
26_813_17a	2.03	2.46	2.74	3.01	3.37	3.63	3.89	4.50
26_813_17	3.34	4.05	4.51	4.96	5.54	5.98	6.41	7.41
26_1197_1	0.13	0.16	0.18	0.20	0.22	0.24	0.26	0.30
26_3214_4a0	0.57	0.78	0.92	1.05	1.22	1.35	1.48	1.78
26_643_1a	0.37	0.51	0.60	0.68	0.79	0.88	0.96	1.16
26_643_1	0.11	0.15	0.18	0.21	0.24	0.27	0.29	0.35
26_643_3	0.51	0.70	0.82	0.94	1.09	1.21	1.32	1.59
26_2118_1a	0.30	0.41	0.48	0.55	0.65	0.71	0.78	0.94
26_2118_1	0.16	0.21	0.25	0.29	0.34	0.37	0.41	0.49
26_4116_11	4.92	5.96	6.65	7.31	8.16	8.80	9.44	10.9
26_4116_13	0.10	0.12	0.13	0.15	0.16	0.18	0.19	0.22

Table B2.10 Preliminary Design Hydrograph Peak Inflows (m3/s) at HEP Locations on the N02 Model Extent (Tributaries to River Camlin and Camlin South) (Reaches 10 and11)

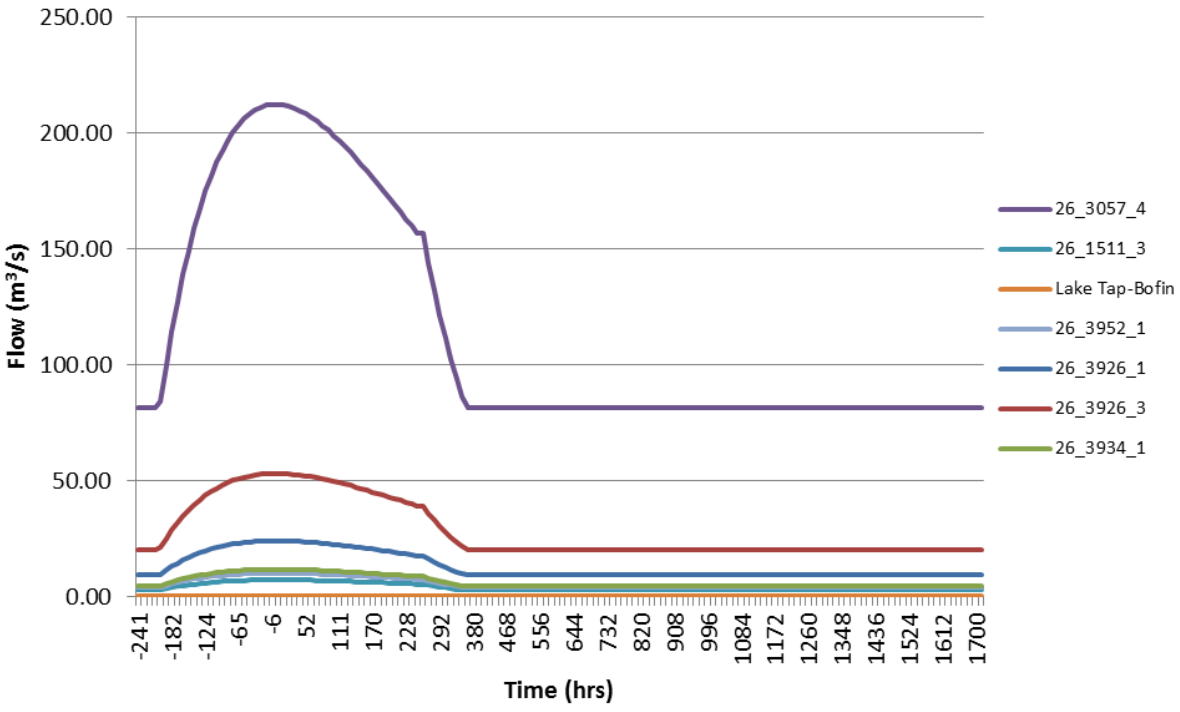


Figure B2.2 N02 Preliminary Design Inflow Hydrographs for 1% AEP (Reach 4)

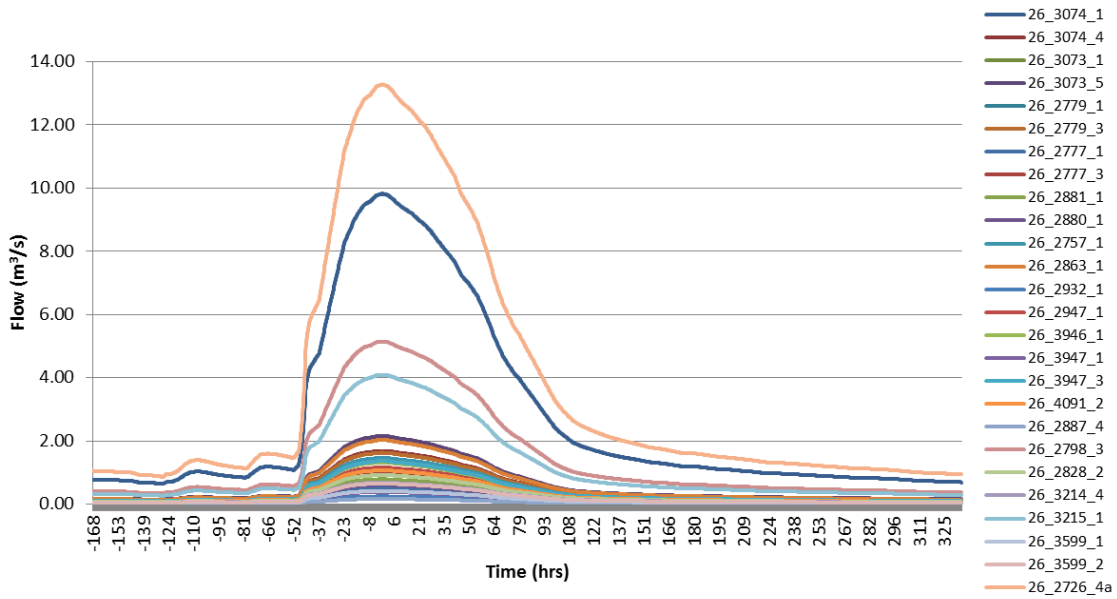


Figure B2.3 N02 Preliminary Design Inflow Hydrographs for 1% AEP (Reaches 9 and 12)

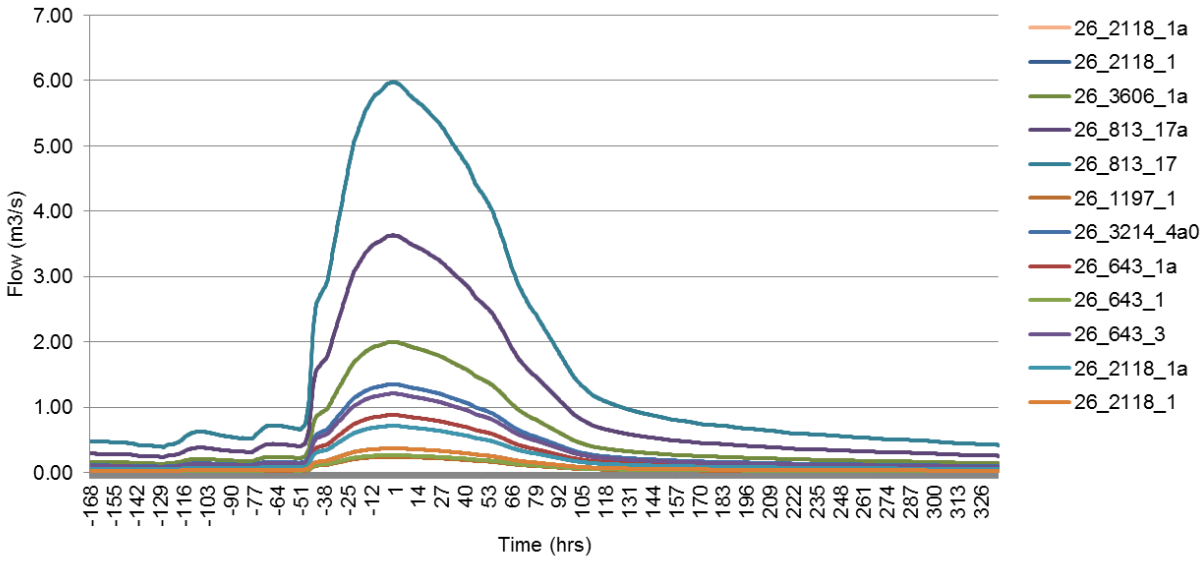


Figure B2.4 N02 Preliminary Design Inflow Hydrographs for 1% AEP (Reaches 10 and 11)

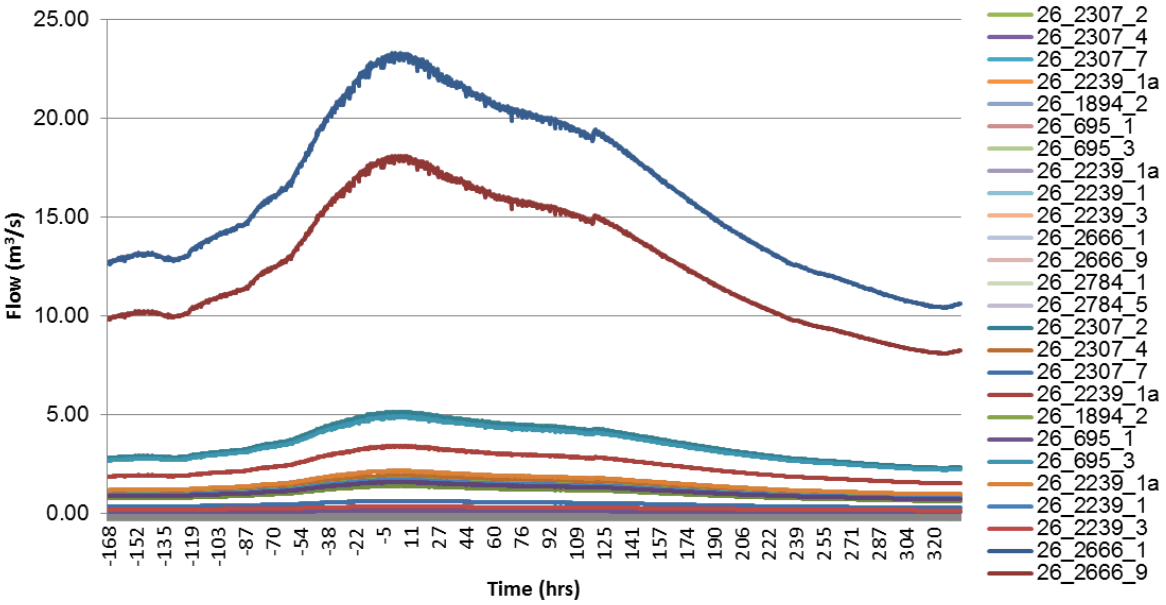


Figure B2.5 N02 Preliminary Design Inflow Hydrographs for 1% AEP (Reaches 13 and 14)

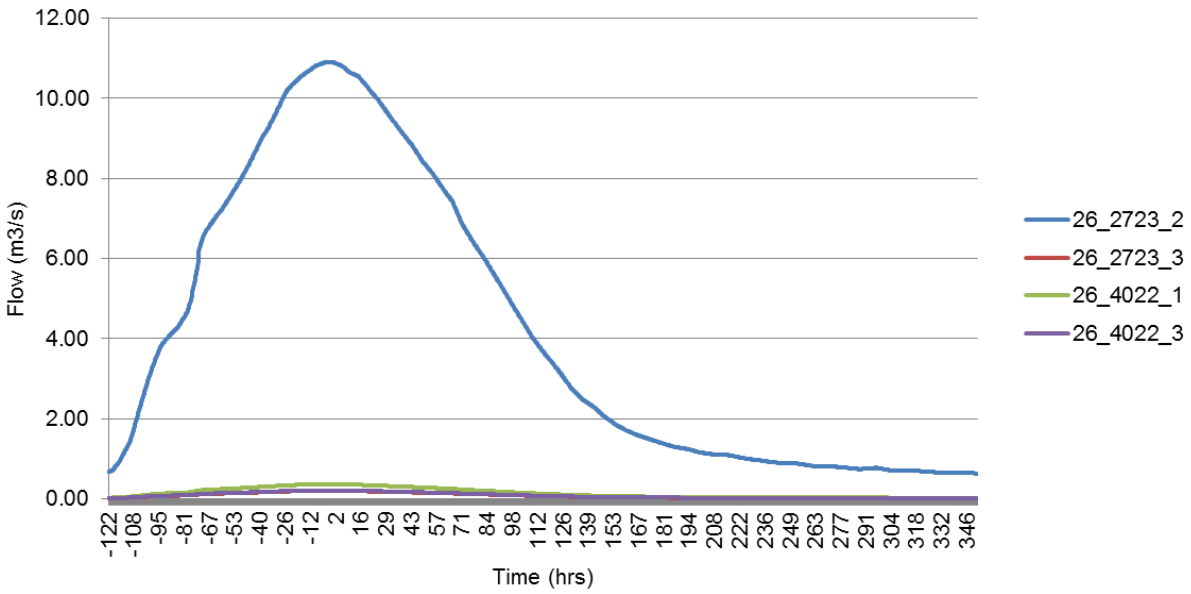


Figure B2.6 N02 Preliminary Design Inflow Hydrographs for 1% AEP (Reach 15)

B2.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B2.7 to B2.10 for calibrating the model to the HEP target flows presented in Tables B2.3 to B2.6.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N02.

B3 Model N03

Model extent N03 comprises the River Inny and its tributaries, River Keelbaun, River Tipper, River Black and its own tributary, River Ballindadny. There are three AFAs located within this model extent, Ballymahon, Abbeyshrule and Edgeworthstown. The model extent of N03 is shown on Figure B3.1 on the next page.

The estimation of QMED adjustment factors, growth curve and hydrograph shapes are all documented in Appendix A, Chapter 4. The model calibration and design inflow hydrographs are summarised below.

B3.1 Calibration

Limited historic data for verification and calibration is available for this model. Gauging stations 26021 (Ballymahon) and 26220 (Shrule Bridge) were identified for use in the calibration, see Appendix F. Table B3.1 summarises the flow and level gauging stations considered for the calibration/verification process.

Calibration and verification on the River Inny was completed at the AFA Ballymahon between the two stations. No observed data was available for calibration in Abbeyshrule and Edgeworthstown.

Station	Data Length	Type	Comment
26021 Ballymahon	1965 - present	Level and Flow	CFRAM rating review site
26220 Shrule Bridge	2009 - present	Level and Flow	No high flow rating

Table B3.1 Gauging Stations used for Calibration/Verification

Out-of-bank calibration of the model between Stations 26021 and 26220 was carried out in accordance with the calibration sheet for this model (see Appendix F) by applying observed flows recorded at Ballymahon (26021) to the upstream end of the truncated model for the 20/11/2009 flood event, making an allowance for the laterally contributing subcatchment between the two stations by scaling the 2-year lateral design inflows proportionally using the ratio of the gauged event peak flow and QMED at the upstream gauging station. The modelled water levels were compared with the gauged levels at Station 26220. The inflow hydrographs used for this calibration event are shown in Figure B3.2.

General verification at AFA Ballymahon was undertaken by comparing the flood extent with 1954 historical flood maps and indicative records of re-occurring flooding.

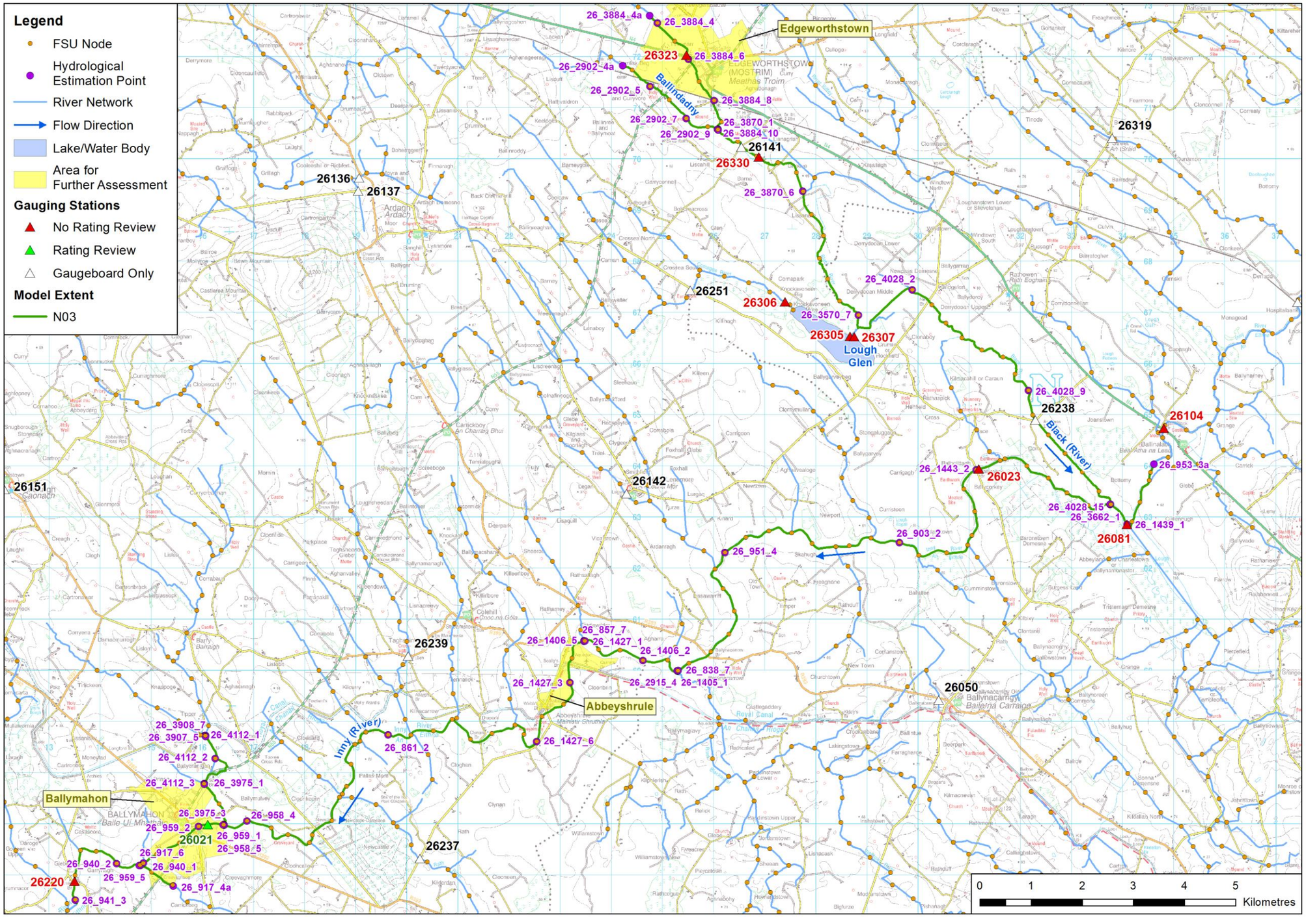


Figure B3.1 Model Extent [1]

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The results of the calibration process are discussed in the hydraulic modelling report for N03.

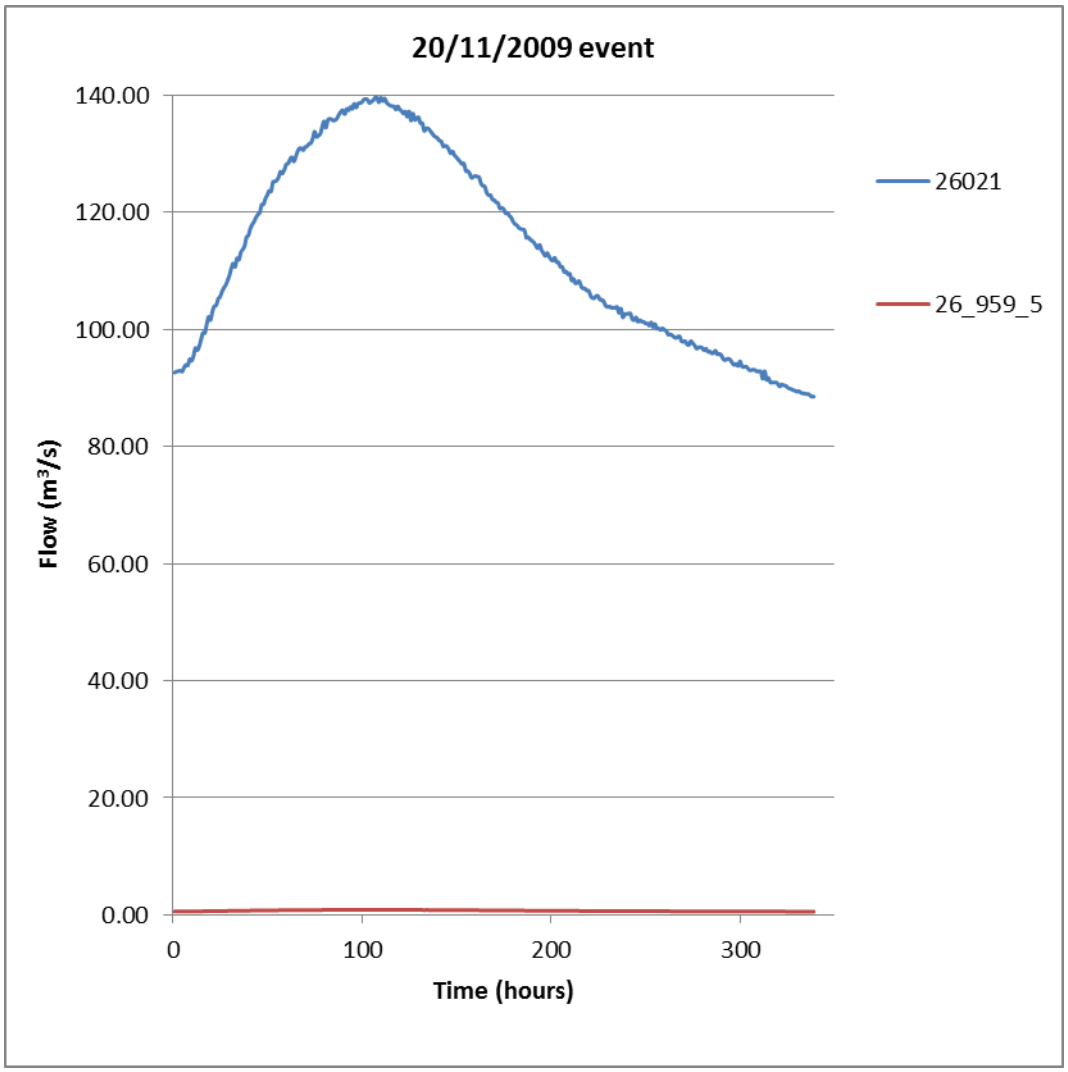

Figure B3.2 Inflow hydrograph for the Nov 2009 Event

B3.2 Target Flows

The target flows are the total peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A, Chapter A2. The target flows at all HEP nodes for model N03 are shown in Tables B3.2, B3.3 and B3.4 below.

To be able to model the critical events on the tributary independently from the critical events on the main stem, three separate runs were undertaken for each AEP. One run was to obtain the target flows in the main stem, one run was to obtain the target flows on 1st order tributaries, and another run was to obtain the target flows on one 2nd order tributary.

The main stem run covered the River Inny. The 1st order tributary run was undertaken for the River Black, the River Tipper and the River Keelbaun, while the 2nd order tributary run was for a tributary of the River Black, the River Ballindadny.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_1439_1	45.96	56.87	63.24	69.12	76.57	82.10	87.60	100.29
26_3662_1	51.35	63.53	70.66	77.22	85.55	91.73	97.86	112.04
24_1443_2*	51.35	63.53	70.66	77.22	85.55	91.73	97.86	112.04
24_903_2*	51.35	63.53	70.66	77.22	85.55	91.73	97.86	112.04
26_951_4	52.87	65.41	72.75	79.51	88.08	94.44	100.76	115.36
26_838_7	56.72	70.17	78.04	85.30	94.49	101.32	108.09	123.75
26_1405_1*	56.72	70.17	78.04	85.30	94.49	101.32	108.09	123.75
26_1406_2*	56.72	70.17	78.04	85.30	94.49	101.32	108.09	123.75
26_1406_5*	56.72	70.17	78.04	85.30	94.49	101.32	108.09	123.75
26_1427_1*	56.72	70.17	78.04	85.30	94.49	101.32	108.09	123.75
26_1427_3*	56.72	70.17	78.04	85.30	94.49	101.32	108.09	123.75
26_1427_6*	56.72	70.17	78.04	85.30	94.49	101.32	108.09	123.75
26_861_2	63.23	78.23	87.01	95.09	105.34	112.95	120.51	137.97
26_958_4	65.95	81.60	90.75	99.18	109.87	117.81	125.69	143.90
26_958_5	67.18	83.12	92.44	101.03	111.92	120.01	128.03	146.58
26_959_1	69.20	85.61	95.22	104.06	115.28	123.61	131.88	150.98
26_959_2	71.33	88.25	98.14	107.26	118.83	127.41	135.93	155.63
26_959_5	72.51	89.72	99.78	109.05	120.81	129.53	138.20	158.22
26_940_1	73.28	90.67	100.84	110.21	122.09	130.91	139.66	159.90
26_940_2*	73.28	90.67	100.84	110.21	122.09	130.91	139.66	159.90
26_941_3*	73.28	90.67	100.84	110.21	122.09	130.91	139.66	159.90

* Target flow estimate increased to match upstream flow estimate

Table B3.2 Target Flows at HEP Locations on the N03 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_3884_4	0.96	1.35	1.60	1.85	2.17	2.41	2.65	3.20
26_3884_6	1.54	2.16	2.57	2.97	3.48	3.87	4.25	5.13
26_3884_8	1.99	2.79	3.32	3.83	4.49	4.98	5.48	6.62
26_3884_10	2.18	3.05	3.64	4.20	4.92	5.46	6.00	7.25
26_3870_1	3.70	5.19	6.18	7.13	8.36	9.28	10.19	12.32
26_3870_6	4.56	6.41	7.63	8.80	10.32	11.45	12.58	15.21
26_3570_7	7.59	10.65	12.68	14.63	17.15	19.04	20.92	25.28
26_4028_2	12.81	17.99	21.42	24.71	28.97	32.16	35.34	42.71
26_4028_9*	12.81	17.99	21.42	24.71	28.97	32.16	35.34	42.71
26_4028_15*	12.81	17.99	21.42	24.71	28.97	32.16	35.34	42.71
26_4112_2	2.71	3.45	3.95	4.43	5.04	5.50	5.96	7.03
26_4112_3	2.80	3.57	4.09	4.58	5.22	5.69	6.17	7.27
26_3975_1	3.73	4.76	5.44	6.10	6.94	7.58	8.21	9.68
26_3975_3	4.12	5.25	6.01	6.73	7.67	8.37	9.07	10.69
26_917_6	1.04	1.33	1.52	1.70	1.94	2.12	2.30	2.71

* Target flow estimate increased to match upstream flow estimate

Table B3.3 Target Flows at HEP Locations on the N03 Model Extent (1st Order Tributaries)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_2902_5	1.10	1.55	1.84	2.12	2.49	2.76	3.03	3.67
26_2902_7	1.50	2.11	2.51	2.90	3.39	3.77	4.14	5.00
26_2902_9	1.73	2.44	2.90	3.34	3.92	4.35	4.78	5.78

Table B3.4 Target Flows at HEP Locations on the N03 Model Extent (2nd Order Tributary)

B3.3 Preliminary Design Flows

To obtain the target flows shown in Tables B3.2, B3.3 and B3.4, an initial set of inflow hydrographs was produced and run through the model.

The inflow hydrographs shown in Figures B3.3 to B3.7 were derived using the procedure outlined in Chapter 2 and the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A2. Tables B3.5, B3.6 and B3.7 below summarise the preliminary peak inflows at each HEP. The HEPs used are shown on Figure B3.1.

Preliminary design inflow hydrographs of the main stem run and tributary runs are shown in Figures B3.3 to B3.7 for the 1% AEP flows.

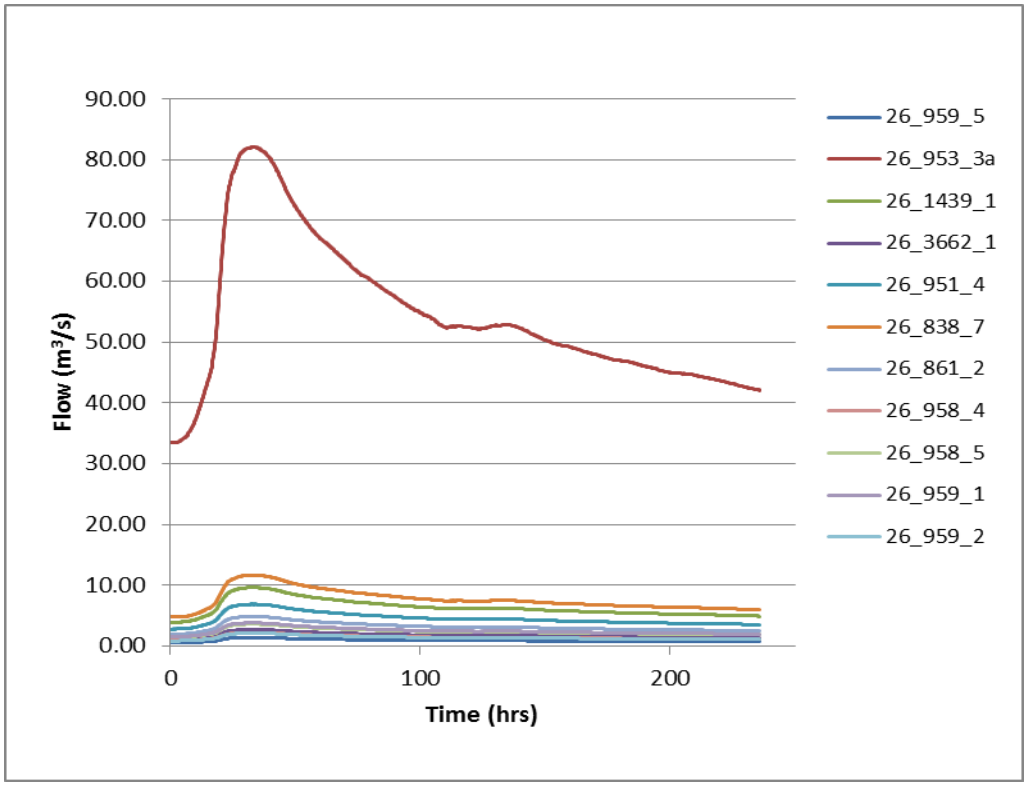

Figure B3.3 Preliminary Design Inflow Hydrographs for Main Stem Reach 1 of 1% AEP

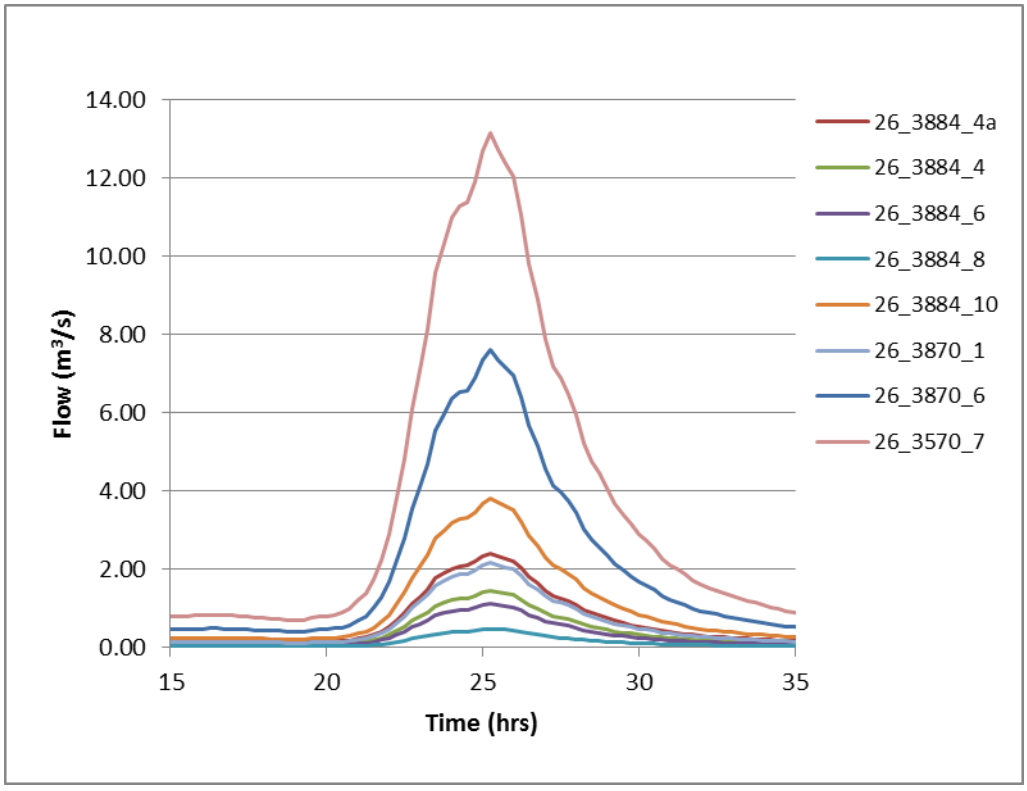

Figure B3.4 Preliminary Design Inflow Hydrographs for 1st Order Tributary Reach 2 of 1% AEP

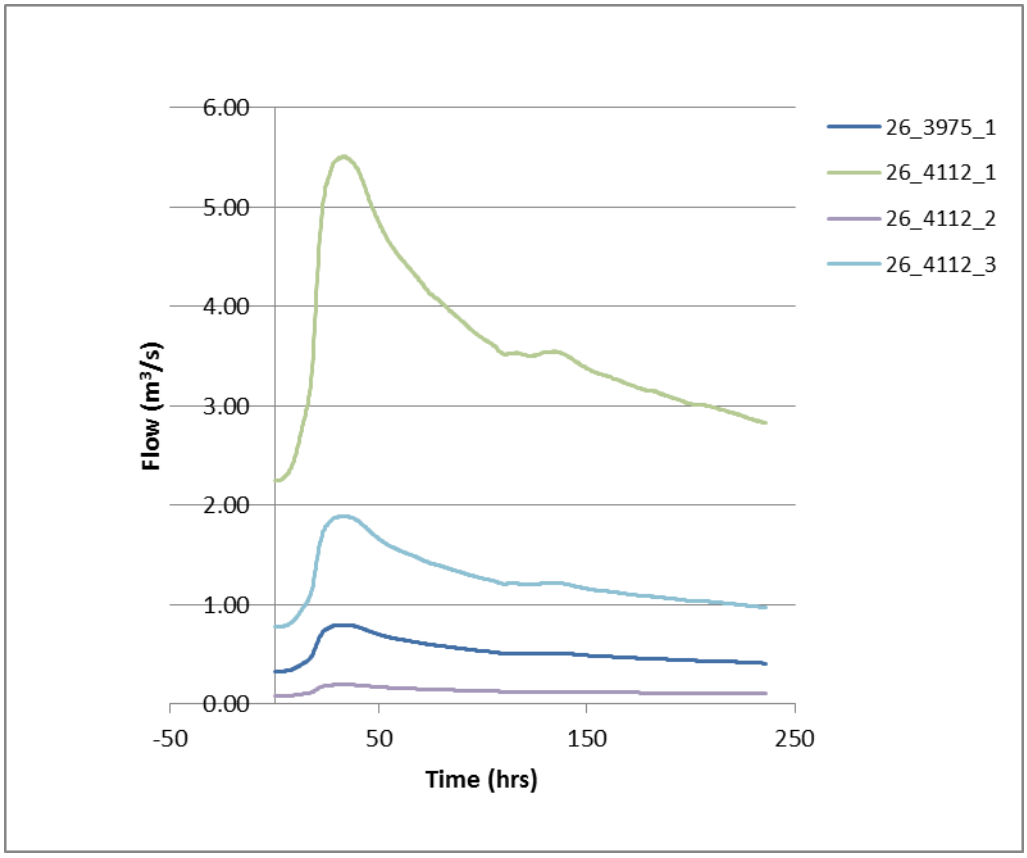

Figure B3.5 Preliminary Design Inflow Hydrographs for 1st Order Tributary Reach 3 of 1% AEP

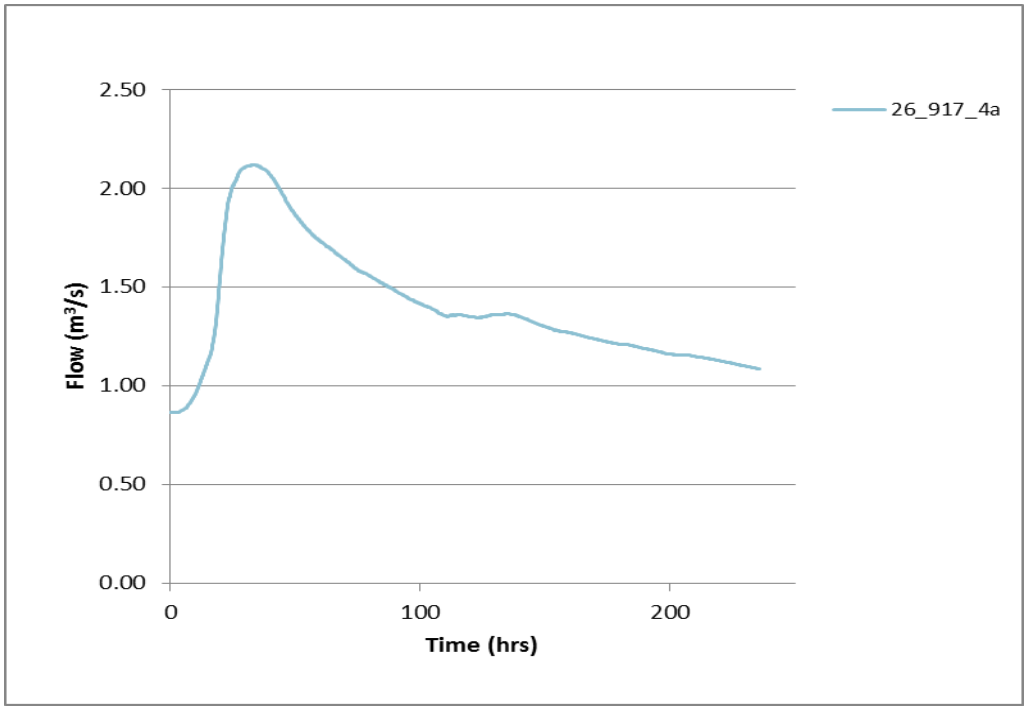

Figure B3.6 Preliminary Design Inflow Hydrograph for 1st Order Tributary Reach 4 of 1% AEP

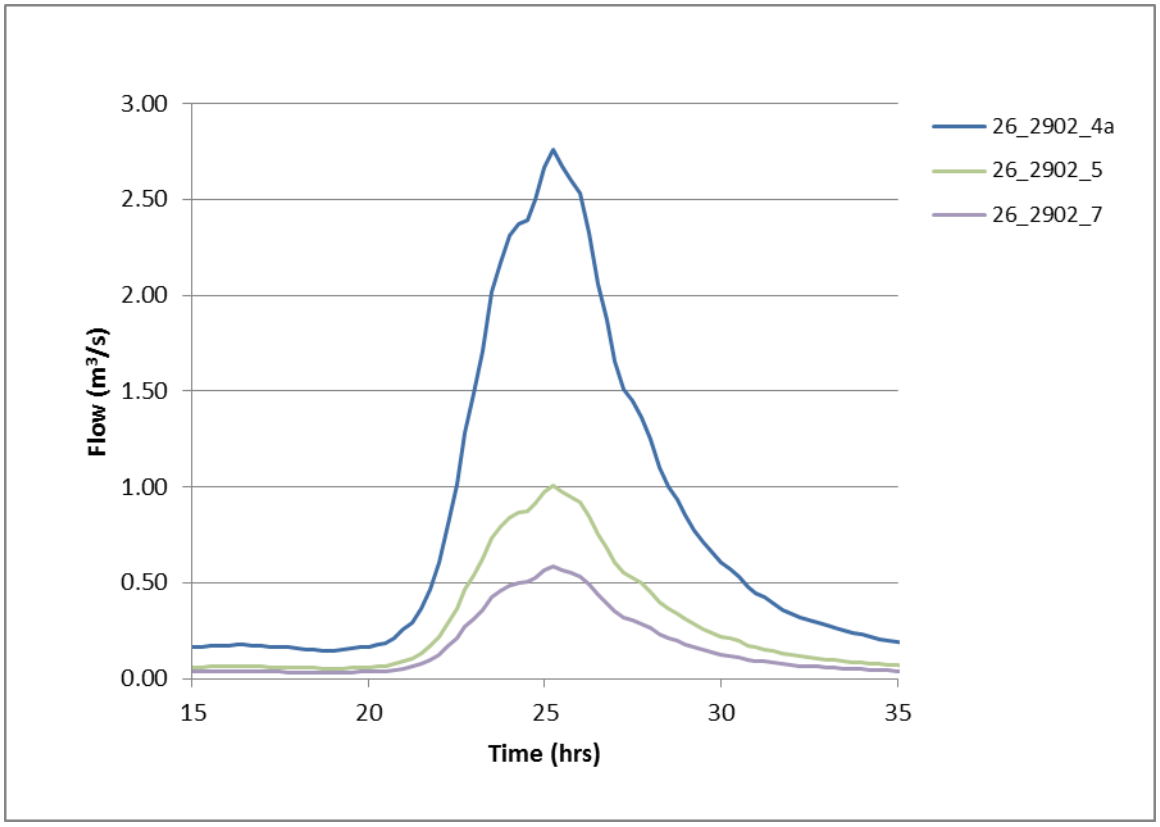

Figure B3.7 Preliminary Design Inflow Hydrographs for 2nd Order Tributary Reach 5 of 1% AEP

HEP reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_953_3a	45.96	56.87	63.24	69.12	76.57	82.10	87.60	100.29
26_1439_1	5.39	6.67	7.41	8.10	8.98	9.62	10.27	11.76
26_3662_1	1.52	1.88	2.09	2.28	2.53	2.71	2.89	3.31
26_951_4	3.85	4.76	5.30	5.79	6.41	6.88	7.34	8.40
26_838_7	6.52	8.06	8.96	9.80	10.85	11.64	12.42	14.22
26_861_2	2.72	3.36	3.74	4.09	4.53	4.85	5.18	5.93
26_958_4	1.23	1.52	1.69	1.85	2.05	2.20	2.35	2.69
26_958_5	2.02	2.50	2.78	3.03	3.36	3.60	3.84	4.40
26_959_1	2.13	2.63	2.93	3.20	3.55	3.80	4.06	4.64
26_959_2	1.19	1.47	1.63	1.79	1.98	2.12	2.26	2.59
26_959_5	0.77	0.95	1.06	1.16	1.28	1.38	1.47	1.68

Table B3.5 Preliminary Design Peak Inflows (m^3/s) at HEP Locations on the N03 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_3884_4a	0.96	1.35	1.60	1.85	2.17	2.41	2.65	3.20
26_3884_4	0.58	0.81	0.97	1.12	1.31	1.46	1.60	1.93
26_3884_6	0.45	0.63	0.75	0.86	1.01	1.12	1.23	1.49
26_3884_8	0.19	0.27	0.32	0.37	0.43	0.48	0.52	0.63
26_3884_10	1.52	2.14	2.54	2.93	3.44	3.82	4.19	5.07
26_3870_1	0.87	1.22	1.45	1.67	1.96	2.17	2.39	2.89
26_3870_6	3.02	4.25	5.05	5.83	6.84	7.59	8.34	10.08
26_3570_7	5.23	7.34	8.74	10.08	11.82	13.12	14.42	17.42
26_4112_1	2.71	3.45	3.95	4.43	5.04	5.50	5.96	7.03
26_4112_2	0.09	0.12	0.14	0.15	0.17	0.19	0.21	0.24
26_4112_3	0.93	1.18	1.35	1.52	1.73	1.89	2.04	2.41
26_3975_1	0.39	0.50	0.57	0.64	0.72	0.79	0.86	1.01
26_917_4a	1.04	1.33	1.52	1.70	1.94	2.12	2.30	2.71

Table B3.6 Preliminary Design Peak Inflows (m^3/s) at HEP Locations on the N03 Model Extent (1^{st} Order Tributary)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_2902_4a	1.10	1.55	1.84	2.12	2.49	2.76	3.03	3.67
26_2902_5	0.40	0.56	0.67	0.77	0.91	1.01	1.11	1.34
26_2902_7	0.23	0.33	0.39	0.45	0.53	0.58	0.64	0.78

Table B3.7 Preliminary Design Peak Inflows (m^3/s) at HEP Locations on the N03 Model Extent (2^{nd} Order Tributary)

B3.4 HEP Calibration and Final Design Hydrographs

The hydraulic model uses the preliminary design inflows presented in Table B3.5, B3.6 and B3.7 for calibrating the model to the HEP target flows presented in Table B3.2, B3.3 and B3.4.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. To this end the inflow hydrographs were scaled up where needed until the target flows were reached.

Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N03.

B4 Model N04

Model N04 comprises of the River Hind, its tributary the River Jiggy and two tributaries of the Jiggy, the River Ballinagard and River Loughnaneane. There is one Area for Further Assessment (AFA) located within this hydraulic model extent (Roscommon). The Ballinagard and Loughnaneane tributaries flow into the Jiggy just east of the town centre of Roscommon. The River Jiggy flows downstream into the River Hind to the south of Roscommon as shown in Figure B4.1. Out of the eight gauging stations within the hydraulic model extent only one has good quality data with a sufficiently long data record (Ballymurray, number 26016). This has been used for the flood frequency analysis in the catchment.

The estimation of a QMED adjustment factor, growth curve and hydrograph shape are all documented in Appendix A3. The model calibration and design inflow hydrographs are summarised below.

B4.1 Calibration

There was insufficient gauged data available to calibrate the N04 model. The only reliable gauging station, 26016 (Ballymurray), is located on the River Hind, approximately 7 km downstream of Roscommon. Therefore, calibration within Roscommon could not be undertaken reliably.

The effects of the November 2009 historical flood event on Roscommon were described in the River Jiggy Flood Study Report (RCC, August 2010). The report specifies locations that are known to have flooded during the November 2009 event. The modelled flood outlines have been verified using this event. Refer to the Calibration Strategy in Appendix F for more details on the calibration/verification strategy. Refer to the hydraulic modelling report for model N04 for more details on the results of the verification using the November 2009 information.

B4.2 Target Flows

The target flows are the total flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A3. The target flows at the HEP nodes for model N04 are shown in Tables B4.1 and B4.2 below. It should be noted that only the nodes that were found to be suitable for comparing the modelled total flows with the target flows have been tabulated. Some HEP nodes are excluded from the tables as the modelled total flows in some nodes are affected by localised 2D flow patterns at nearby confluences and can therefore not be meaningfully compared with the target flows.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2143_1	3.03	4.34	5.18	5.98	7.02	7.80	8.58	10.38
26_2143_4	3.03	4.34	5.18	5.98	7.02	7.80	8.58	10.38
26_876_1	3.64	5.21	6.22	7.18	8.44	9.37	10.31	12.47
26_876_3	4.03	5.77	6.88	7.95	9.34	10.38	11.41	13.81
26_2432_1	4.03	5.77	6.88	7.95	9.34	10.38	11.41	13.81
26_2432_3	4.03	5.77	6.88	7.95	9.34	10.38	11.41	13.81
26_2981_1	6.47	9.26	11.05	12.77	15.00	16.66	18.32	22.17
26_2981_2	6.47	9.26	11.05	12.77	15.00	16.66	18.32	22.17
26_3598_7	8.92	12.77	15.24	17.61	20.67	22.97	25.26	30.57

Table B4.1 Target Flows at HEP Locations on the N04 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_728_1	1.26	1.80	2.15	2.49	2.92	3.25	3.57	4.32
26_728_11	1.26	1.80	2.15	2.49	2.92	3.25	3.57	4.32
26_3148_1	1.92	2.75	3.28	3.79	4.45	4.94	5.44	6.58
26_2111_5	1.07	1.53	1.83	2.11	2.48	2.76	3.03	3.67
26_843_4	2.39	3.42	4.08	4.72	5.54	6.16	6.77	8.19

Table B4.2 Target Flows at HEP Locations on the N04 Model Extent (Tributaries)

B4.3 Preliminary Design Flows

To obtain the target flows shown in Tables B4.1 and B4.2, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, two separate runs were undertaken for each AEP, one run to obtain the target flows in the main stem, one run to obtain the target flows on the tributaries. For modelling purposes the tributaries are defined as the River Jiggy down to node 26_728_11, the Loughnaneane tributary, the Ballinagard tributary and the short modelled section of the River Hind down to node 26_843_5.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 and using the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A3. The QMED adjustment factor, growth curve and hydrograph shape are specified in Appendix A3. The HEPs are shown on Figure B4.1. Tables B4.3 and B4.4 summarise the preliminary peak inflows at each HEP for the main stem and tributary runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3148_1	1.54	2.20	2.63	3.04	3.57	3.97	4.36	5.28
26_728_1	1.01	1.45	1.73	1.99	2.34	2.60	2.86	3.46
26_2143_1	0.47	0.67	0.80	0.93	1.09	1.21	1.33	1.61
26_2111_2	0.61	0.87	1.04	1.20	1.41	1.57	1.73	2.09
26_876_3	0.45	0.64	0.77	0.89	1.04	1.16	1.27	1.54
26_843_4	1.94	2.78	3.31	3.83	4.50	5.00	5.49	6.65
26_2981_1	0.50	0.72	0.85	0.99	1.16	1.29	1.42	1.71
26_3585_4	0.47	0.67	0.80	0.93	1.09	1.21	1.33	1.61
26_2980_1	1.98	2.83	3.38	3.91	4.59	5.10	5.61	6.79

Table B4.3 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N04 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3148_1	1.92	2.75	3.28	3.79	4.45	4.94	5.44	6.58
26_728_1	1.26	1.80	2.15	2.49	2.92	3.25	3.57	4.32
26_2111_2	1.07	1.53	1.83	2.11	2.48	2.76	3.03	3.67
26_843_4	2.39	3.42	4.08	4.72	5.54	6.16	6.77	8.19

Table B4.4 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N04 Model Extent (Tributaries)

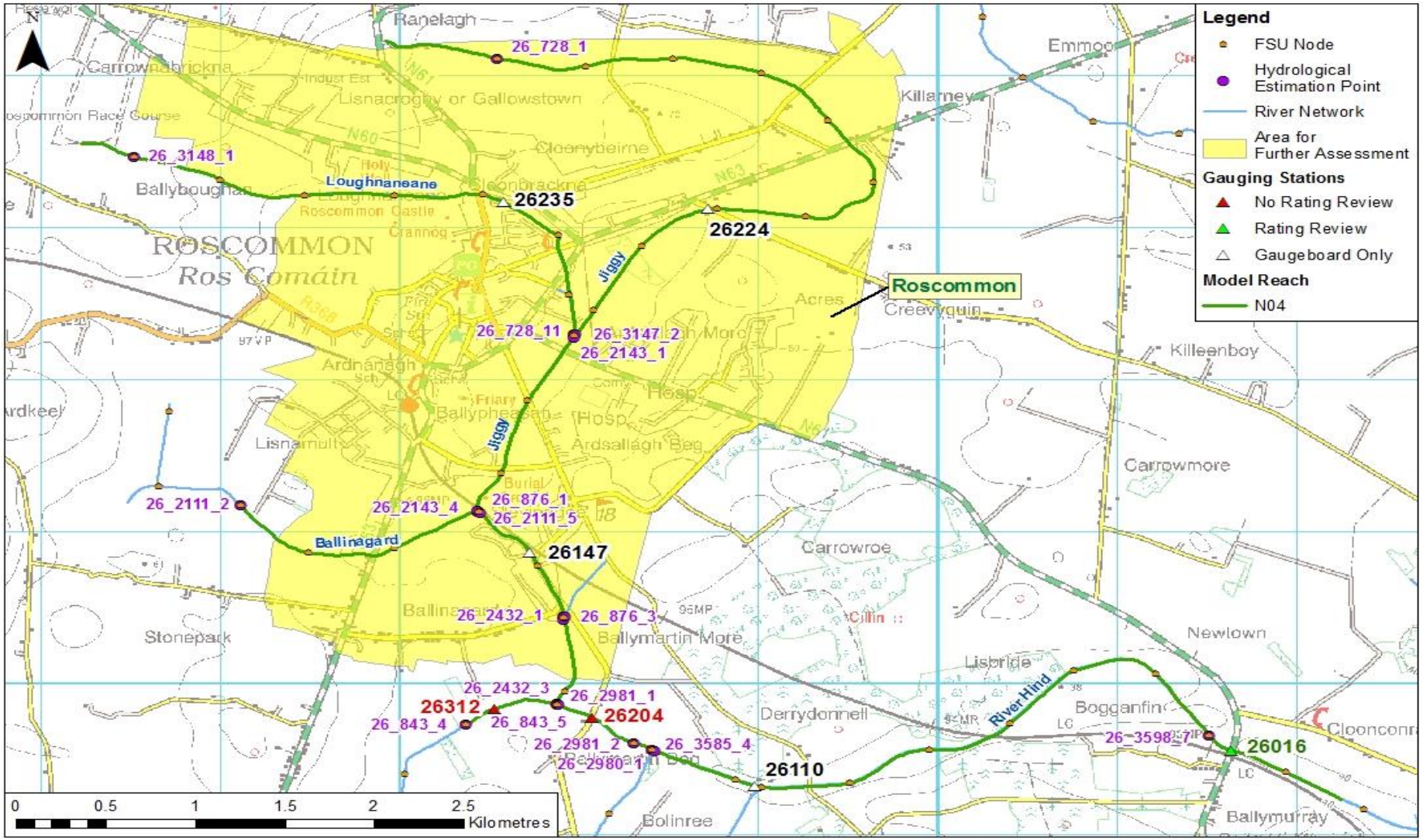

Figure B4.1 N04 Model Extent [1]

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B4.4 Final Design Hydrographs

The process of establishing the final design flows involves extracting from the hydraulic model the total peak flows at the HEPs along the watercourse and comparing these total modelled flows with the target peak flows anticipated at HEPs from the hydrological analysis detailed in Appendix A3. If the modelled flows at a node are more than 5% different than the hydrological target flows, then the model inflows are adjusted by the right amount for the modelled flows to accord with the target flows. The adjustment is done by scaling the hydrograph up by a factor (i.e. scaling all hydrograph ordinates by the same factor). The adjustment required has to be estimated, and may result in revised modelled flows that still deviate from the target flows. The model is then re-run with adjusted inflows and a further comparison is made. Adjusting any inflow has to also consider the potential routing effects of floodplains on the amended inflow hydrographs. Therefore a few iterations may be required until the modelled flows are within 5% of the target flows.

The N04 model was run with the initial design inflows for the full range of AEPs. There were discrepancies in excess of 5% mainly on the main stem but also on some tributaries resulting in a significant reduction in peak flows. This was most apparent at the HEP node immediately downstream of confluences (i.e. HEP nodes 26_2143_1, 26_876_3 and at the bottom of the model at HEP node 26_3585_4). Flows were increased at HEP nodes 26_2143_1, 26_876_3 and 26_3585_4 on the main stem and at HEP node 26_728_1 in the tributary run for some design events. A few iterations were required to obtain a good comparison between the target peak flows and the modelled peak flows.

To obtain a good match of the peak modelled flows on the River Jiggy around node 26_728_11 just upstream of its confluence with the Loughnaneane tributary, for flood events with AEPs below 50% the flows at node 26_728_1 were increased considerably above the target flows based on the hydrological analysis at that node. This is a consequence of the considerable flood routing that occurs in the reach. As a consequence peak flows around the upstream node (26_728_1) are up to 20% higher than the target flows for the lowest AEPs (0.5% and 0.1%). As the match in flows is good in the downstream part of this reach (nearest to Roscommon), this potential overestimate is considered acceptable in the upstream part of the reach.

On the Loughnaneane tributary, the hydrological methods used to derive the target flows do not take account of the large turlough situated on that watercourse (FARL is 1.00 and the BFIsoil values at locations along the watercourse are lower than elsewhere on the modelled reaches). This turlough causes flood routing. The hydrological methods were used to estimate the total flows upstream of the turlough, and the routing effect of the turlough was schematised in the 2D domain of the hydraulic model. Therefore no adjustments were made to the final inflows into this reach.

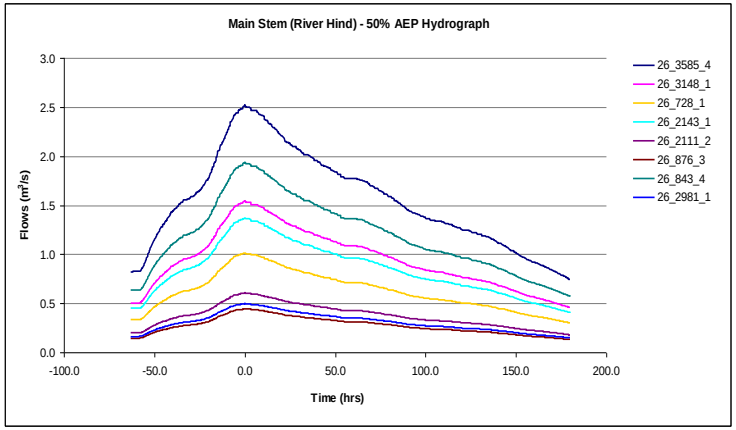
Tables B4.5 and B4.6 summarise the final design hydrograph peak inflows at each HEP location. Figures B4.2 and B4.3 illustrate the final design hydrographs of each return period for the main stem while Figures B4.4 and B4.5 illustrate the final design hydrographs of each return period for the tributaries.

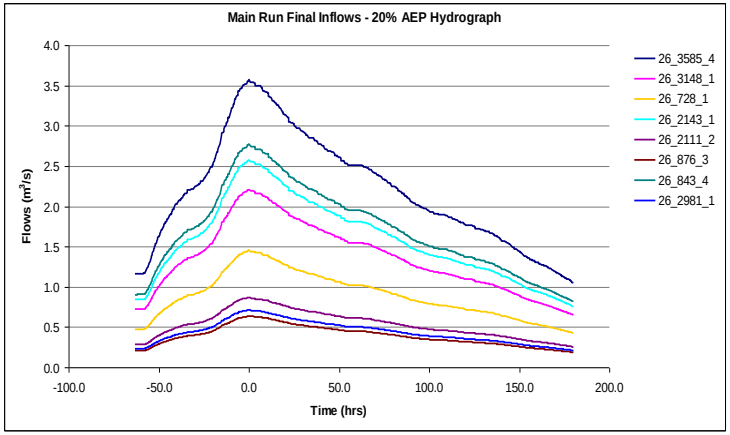
HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3148_1	1.54	2.21	2.64	3.05	3.58	3.97	4.37	5.29
26_728_1	1.01	1.45	1.78	2.00	2.35	2.61	2.87	3.48
26_2143_1	1.37	2.57	3.31	3.93	4.86	5.45	6.03	7.42
26_2111_2	0.61	0.87	1.04	1.20	1.41	1.56	1.72	2.08
26_876_3	0.45	0.64	0.76	0.88	1.03	1.15	1.32	1.73
26_843_4	1.94	2.77	3.31	3.82	4.49	4.99	5.49	6.64
26_2981_1	0.50	0.71	0.85	0.98	1.16	1.28	1.41	1.71
26_3585_4	2.52	3.57	4.30	5.13	6.19	6.72	7.73	9.58

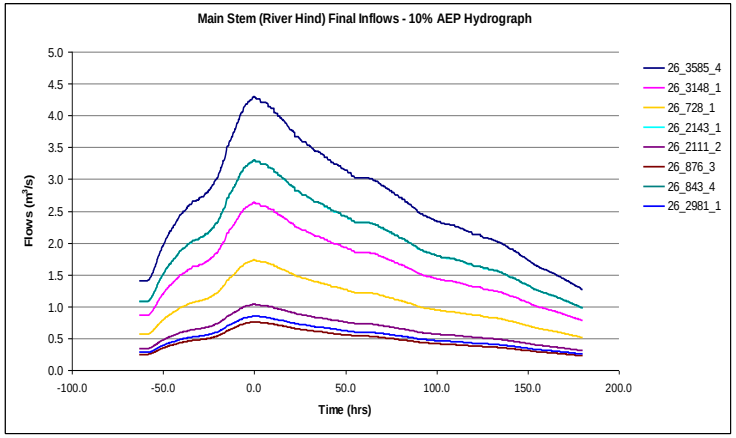
Table B4.5 Final Design Hydrograph Total Peak Inflows (m^3/s) at HEPs on N04 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3148_1	1.92	2.75	3.28	3.79	4.46	4.95	5.44	6.59
26_728_1	1.26	1.96	2.41	3.12	3.45	3.91	4.06	5.02
26_2111_2	1.07	1.52	1.82	2.10	2.47	2.74	3.02	3.95
26_843_4	2.39	3.42	4.08	4.71	5.53	6.15	6.76	8.18

Table B4.6 Final Design Hydrograph Total Peak Inflows (m^3/s) at HEPs on N04 Model Extent (Tributaries)







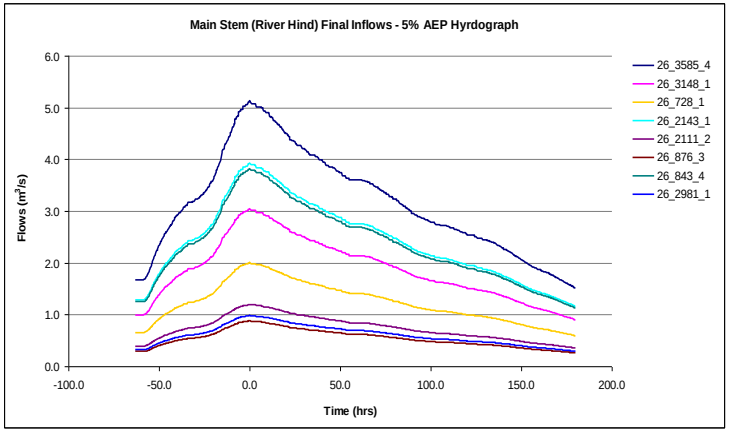
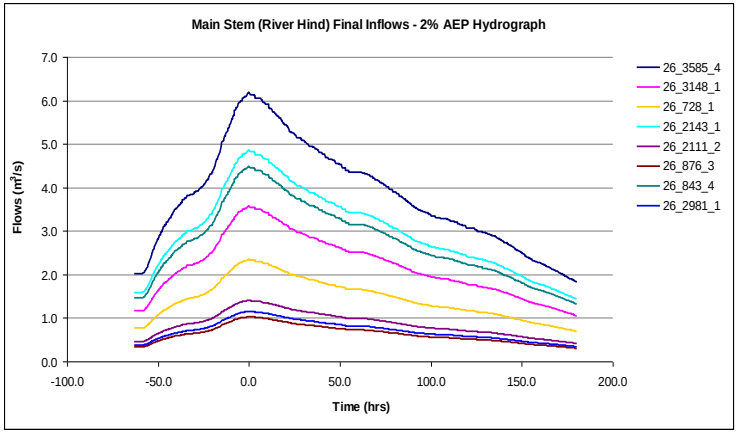
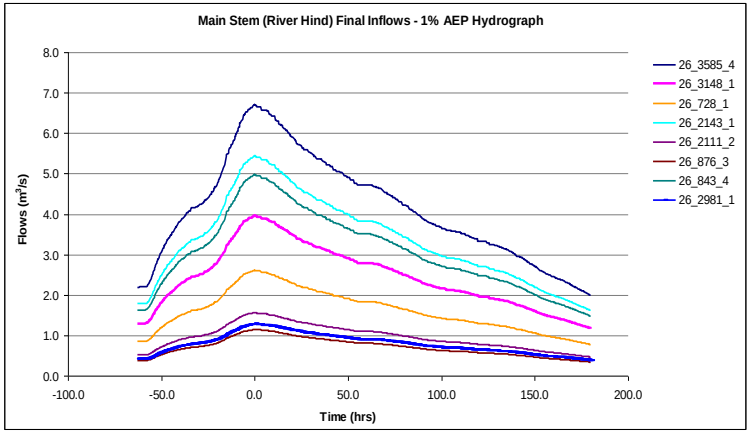
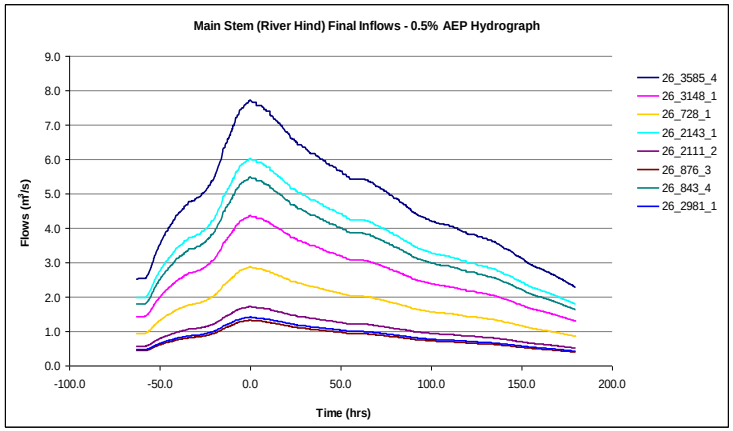


Figure B4.2 N04 Final Design Hydrographs (Main Stem) for 50% AEP, 20% AEP, 10%AEP and 5% AEP







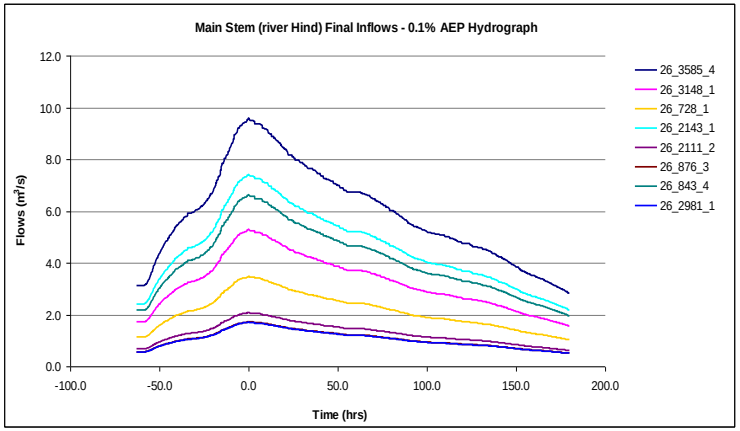
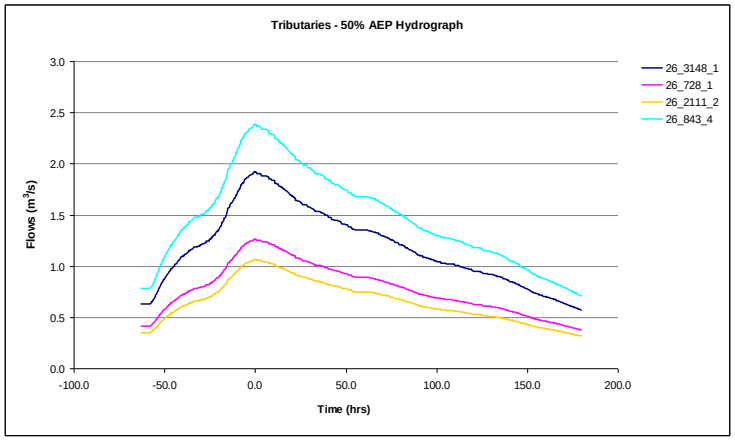
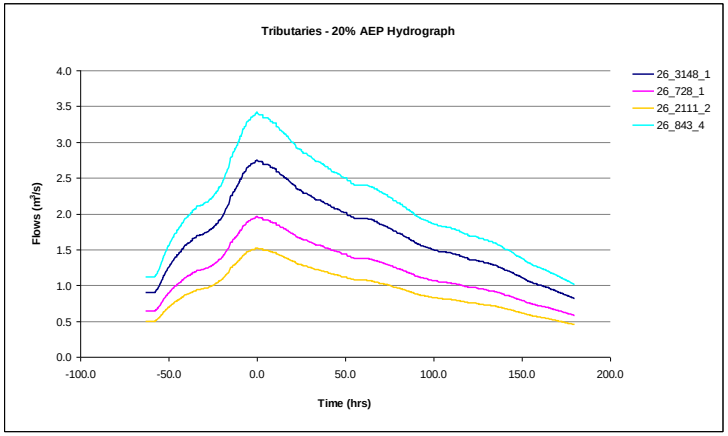
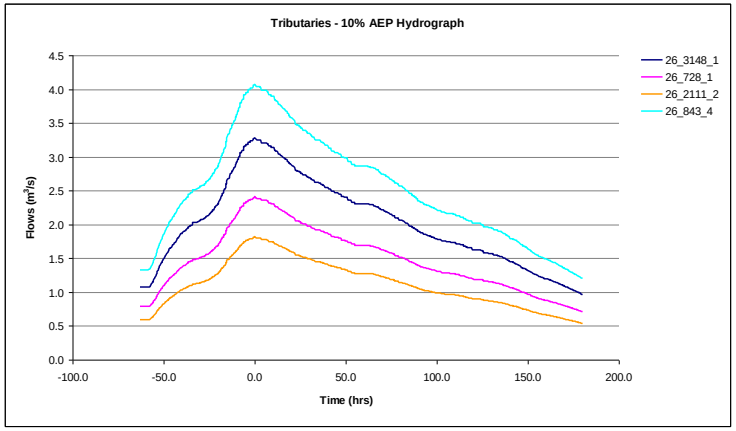


Figure B4.3 N04 Final Design Hydrographs (Main Stem) for 2% AEP, 1% AEP, 0.5%AEP and 0.1% AEP







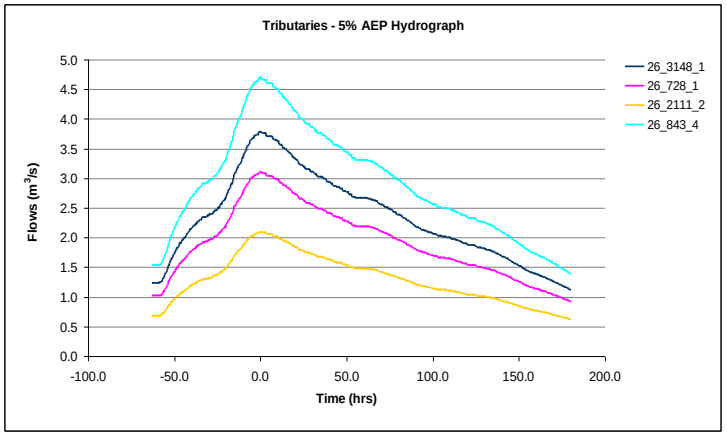


Figure B4.4 N04 Final Design Hydrographs (Tributaries) for 50% AEP, 20% AEP, 10%AEP and 5% AEP

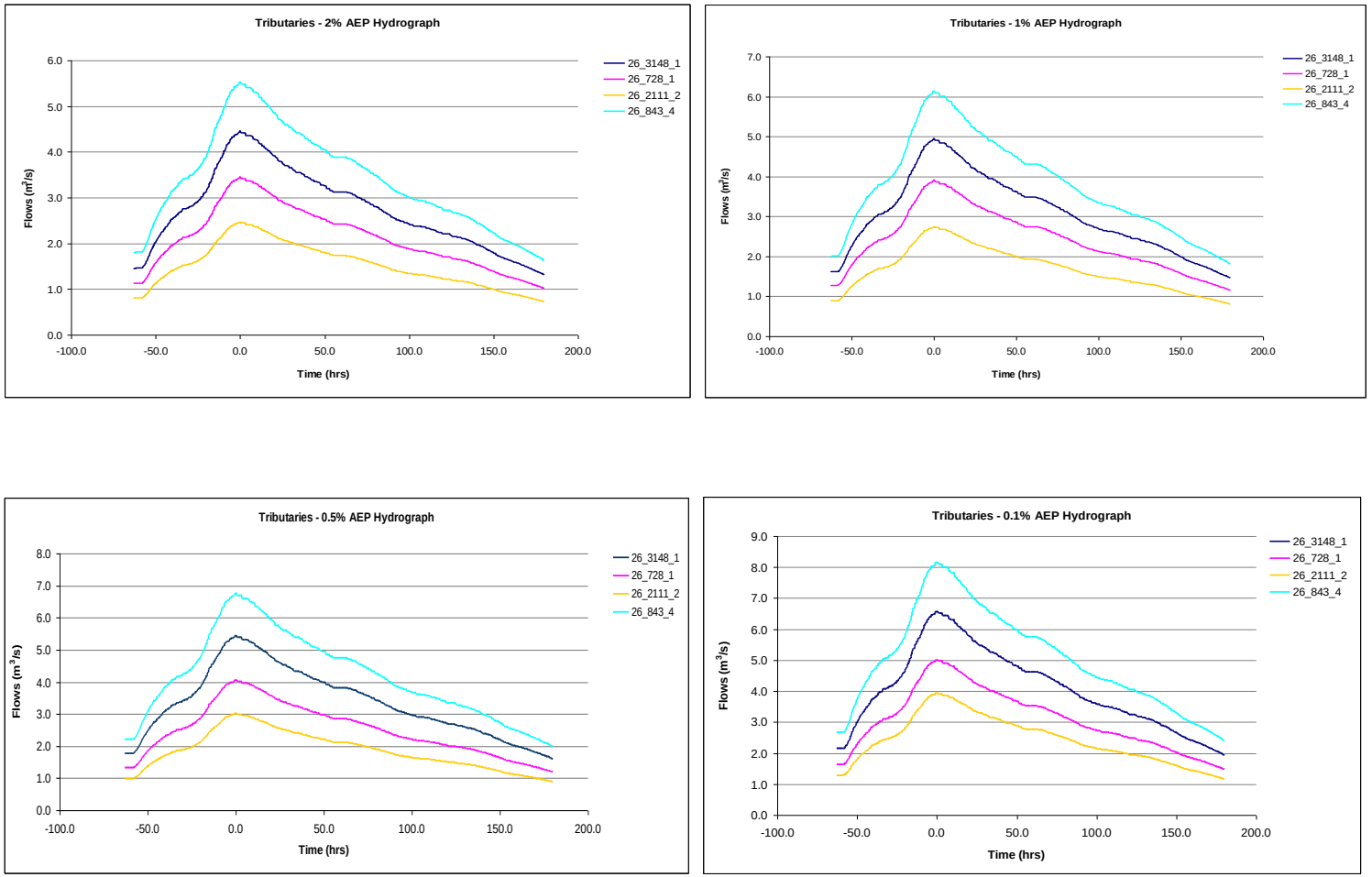


Figure B4.5 N04 Final Design Hydrographs (Tributaries) for 2% AEP, 1% AEP, 0.5%AEP and 0.1% AEP

B5 Model N05

Model N05 covers the upper River Brosna through Mullingar (AFA) and includes Lough Ennell to the south of Mullingar and a section of the River Brosna downstream of Lough Ennell. The model extent is shown in Figure B5.1 below. The tributary joining the Brosna from the north east upstream of Mullingar is the River Sheever. To the south of Mullingar Lacy's Canal runs broadly parallel to the Brosna and may convey a part of any flood runoff. These watercourses are shown in detail in the hydraulic modelling report.

N05 covers Reach 1 and the upstream part of Reach 2 (the reaches are described in Appendix A, Chapter A4). QMED adjustment factors, growth factors and hydrograph shapes are all specified in Appendix A4. The model calibration and design inflow hydrographs are summarised below.

B5.1 Calibration

Model N05 was calibrated using historic gauged data upstream and downstream of Lough Ennell. No historic observational information of sufficient detail was available for calibration or verification of the model (i.e. no flood observations other than gauged levels and flows). Refer to the Calibration Strategy in Appendix F for more detail on the calibration strategy.

Table B5.1 summarises the flow and level gauging stations that have been used for the calibration/verification process. Gauging stations that are considered unreliable for flood flow estimation and/or couldn't be used for water level comparison have been omitted. Station 25213 is a low-flow gauge, and produces suspiciously low flows during flood events. In any case, as the River Sheever is ungauged, station 25213 (upstream of the confluence with the Sheever) could not be used for calibration.

Station	Data Length	Type	Comment
25050 Mullingar Pump House	1978 to Date	Level and Flow	No rating review. OPW rating employed
25032 Mullingar	1975 to 1985	Level Only	No rating
25085 Clonsingle	1954 to Date	Level Only	Lake outflow control, sluice, no rating
25124 Ballynagore	1986 to Date	Level and Flow	No rating review, but rating verified up to QMED
25013 Newell's Bridge	1974 to Date	Level and Flow	Jacobs rating review completed up to 3xQMED, but scatter in the check gaugings

Table B5.1 Gauging Stations Used for Calibration/Verification

A finding of the cross-lake calibration was that the critical events for the upstream Brosna and the downstream Brosna (as well as for the lake itself) were very different. For the design event runs it was therefore decided to split the model extent into two separate models, with the split at the downstream end of Lough Ennell (HEP node 25_3511_1).

Hydraulic modelling aspects and the results of the calibration/verification process are discussed in more detail in the hydraulic modelling report. The flows used to enable the calibration are provided in sub-sections (i), (ii) and (iii) below.

(i) Cross-Lake Calibration

Calibration of the model across Lough Ennell was carried out by inputting observed flows at Mullingar Pump House (25050, HEP node 25_3912_1) for the November 2009 flood event, and estimating scaled flows into the lake from the many other watercourses into the lake. Water levels were compared at Newell's Bridge (25013), the first flow gauge downstream of the lake.

The inflows into the lake (amalgamated for all watercourses other than the Brosna) and other inflows between the upstream (25050) and downstream (25013) gauging station were estimated using a volume balance in the lake. The volume from the other tributaries was estimated by subtracting the Brosna inflow volume at station 25050 from the outflow volume at Newell's Bridge. Hydrographs based on the event hydrograph at station 25050 were then developed for the inflows by scaling the peaks of the hydrographs until the required volume was established. Inflow hydrographs for individual watercourses were scaled down from the total hydrograph using catchment areas. The inflow hydrographs are shown on Figure B5.2 below. The peak inflow at gauging station 25050 is shown in Table B5.2.

Historical Flood Event	Peak Flow (m^3/s)
November 2009 (calibration)	7.63

Table B5.2 Cross-Lake Model Calibration

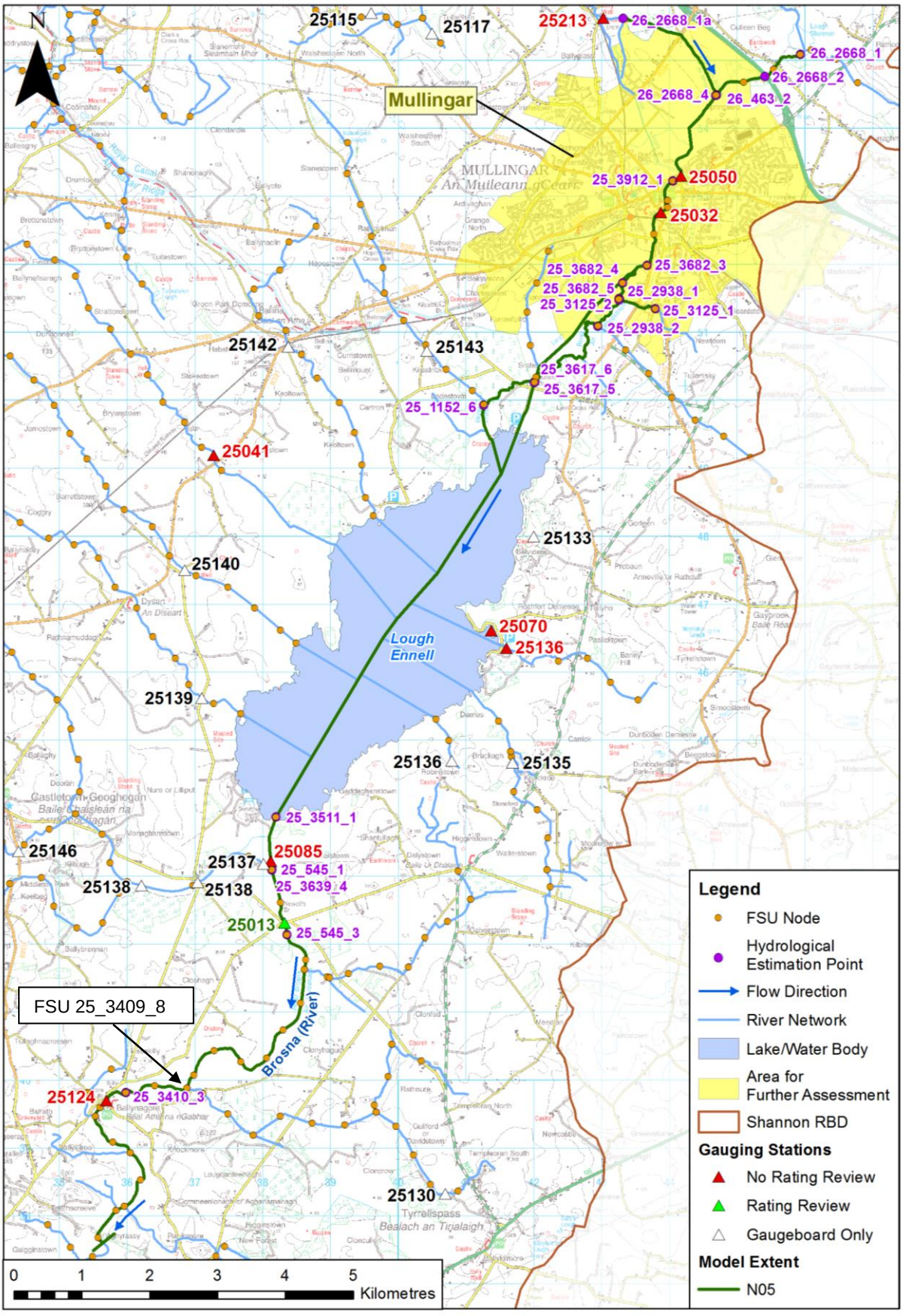


Figure B5.1 N05 Model Extent

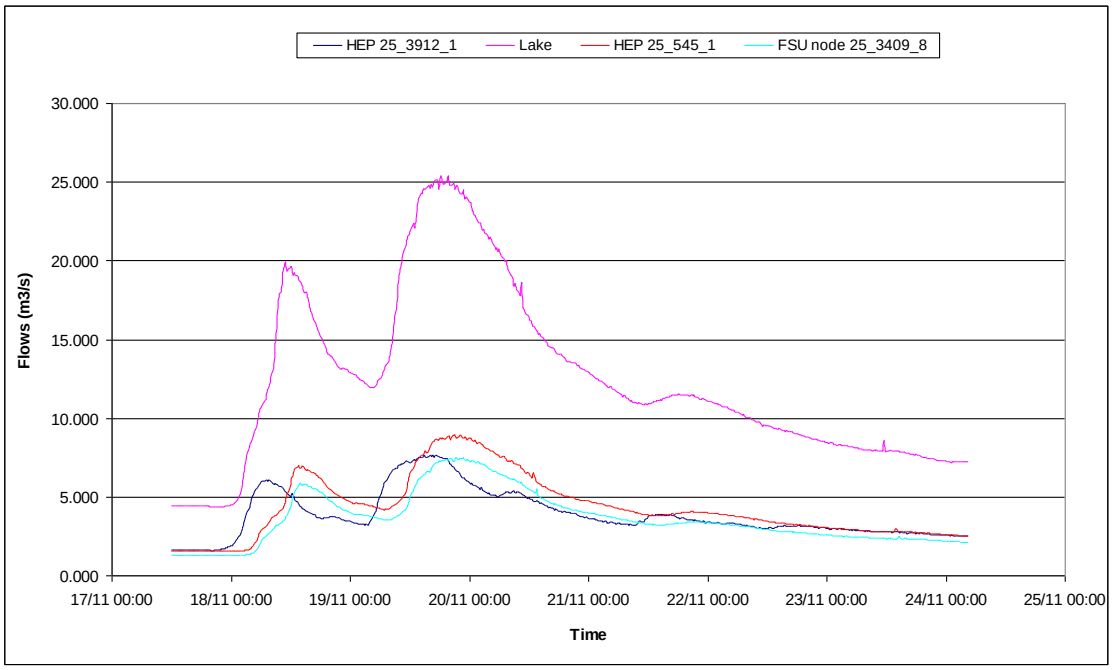


Figure B5.2 Cross-Lake Calibration Inflow Hydrographs for the November 2009 Event

(ii) Upstream of Lough Ennell

Calibration/verification was undertaken from Mullingar Pump House (25050) to Mullingar (25032). Table B.5.3 summarises the events used, with the peak inflows at station 25050. The inflow hydrographs are shown on Figures B.5.3 and B.5.4.

Historical Flood Event	Peak Flow (m^3/s)
January 1984 (calibration)	3.3
January 1983 (verification)	5.9

Table B5.3 Upstream Model Calibration

The events selected upstream of Lough Ennell are relatively old, but as the level gauge in this section (25032) was abandoned in 1985 more recent events were not available.

Model verification upstream of Lough Ennell showed that the 0.1% (1 in 1000) AEP flood outline using the synthetic estimate of QMED would not yield any significant flooding for that event in Mullingar. Using the rating established by OPW (based on low and mid-range check gaugings up to approximately 0.5xQMED only) and a QMED estimate based on that rating of 4 times the synthetic estimate of QMED, showed a more realistic amount of flooding although no evidence is available to confirm the flood levels for any annual exceedance probability.

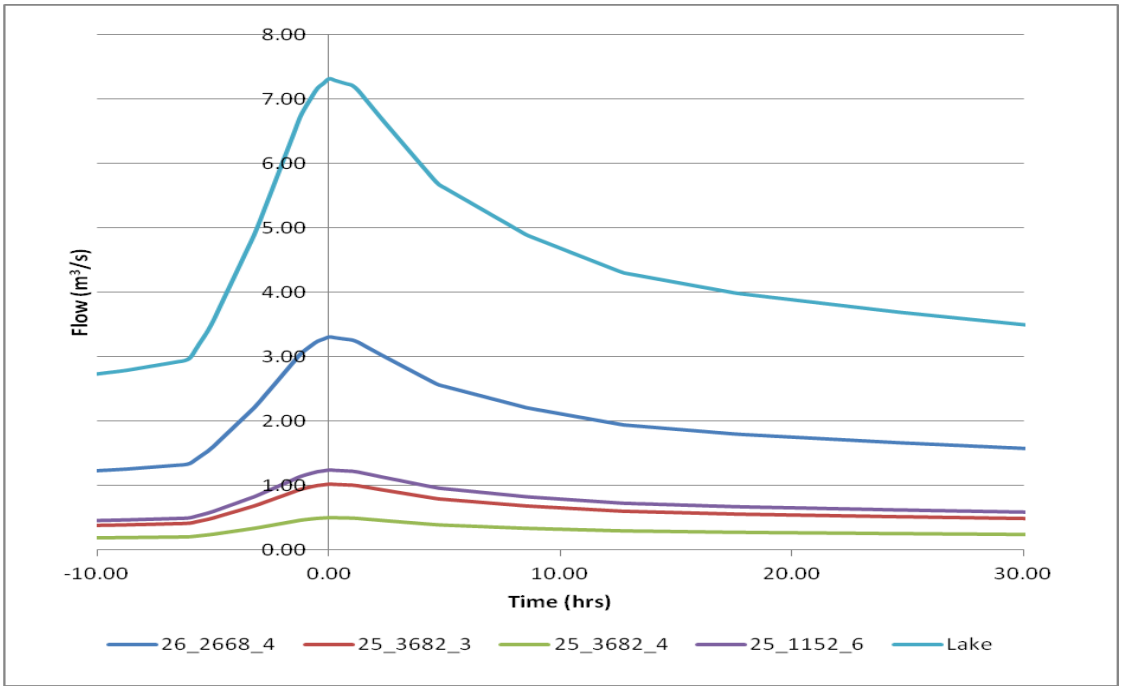


Figure B5.3 Upstream of Lough Ennell Calibration Inflow Hydrographs for 16/01/1984 Event

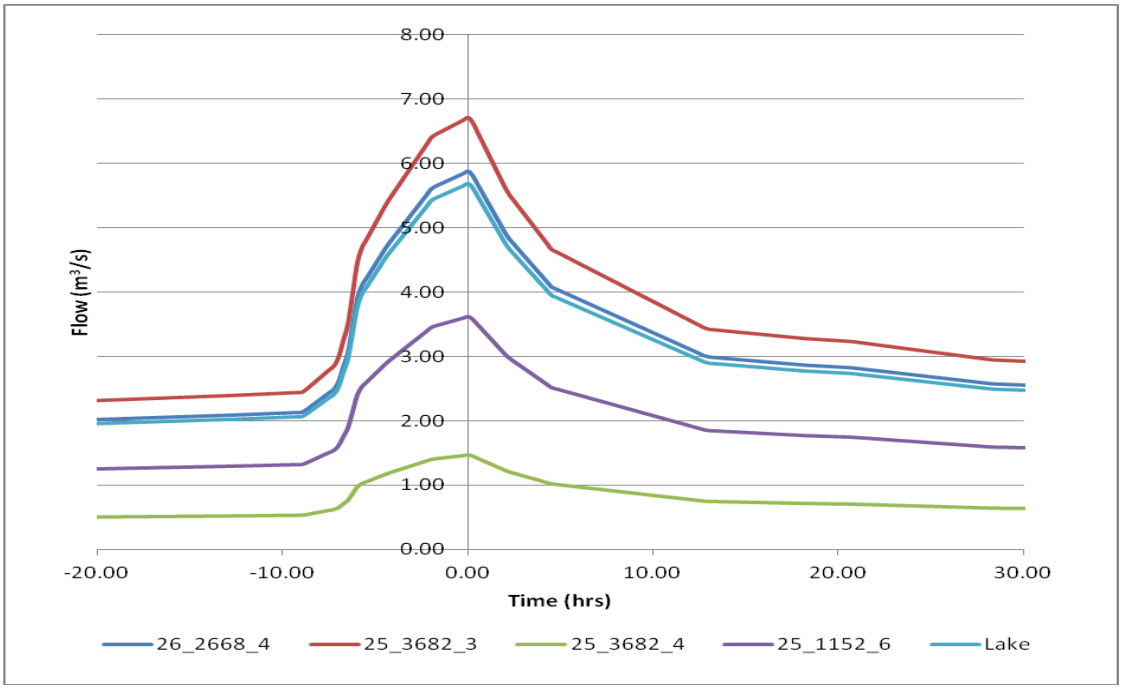


Figure B5.4 Upstream of Lough Ennell Verification Inflow Hydrographs for 31/01/1983 Event

(iii) Downstream of Lough Ennell

Calibration of the downstream model section was carried out from its upstream extent at the Lough Ennell outfall to station Ballynagore (25124). Table B5.4 summarises the events with peak inflows at the upstream model boundary for the

downstream model (at the Lough Ennell outfall). Figures B.5.5 and B5.6 show all inflow hydrographs for the two calibration events.

Historical Flood Event	Peak Flow (m^3/s)
November 2009 (calibration)	17.4
August 2008 (verification)	15.8

Table B5.4 Downstream Model Calibration

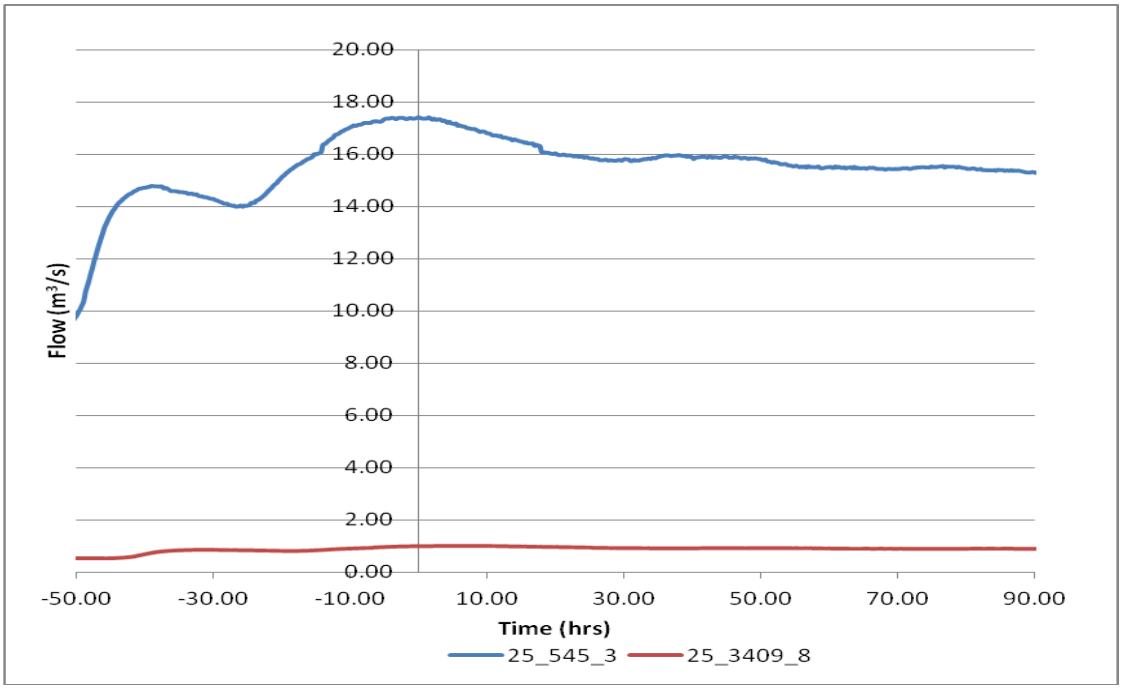


Figure B5.5 Downstream of Lough Ennell Calibration Inflow Hydrographs for 16/11/2009 Event

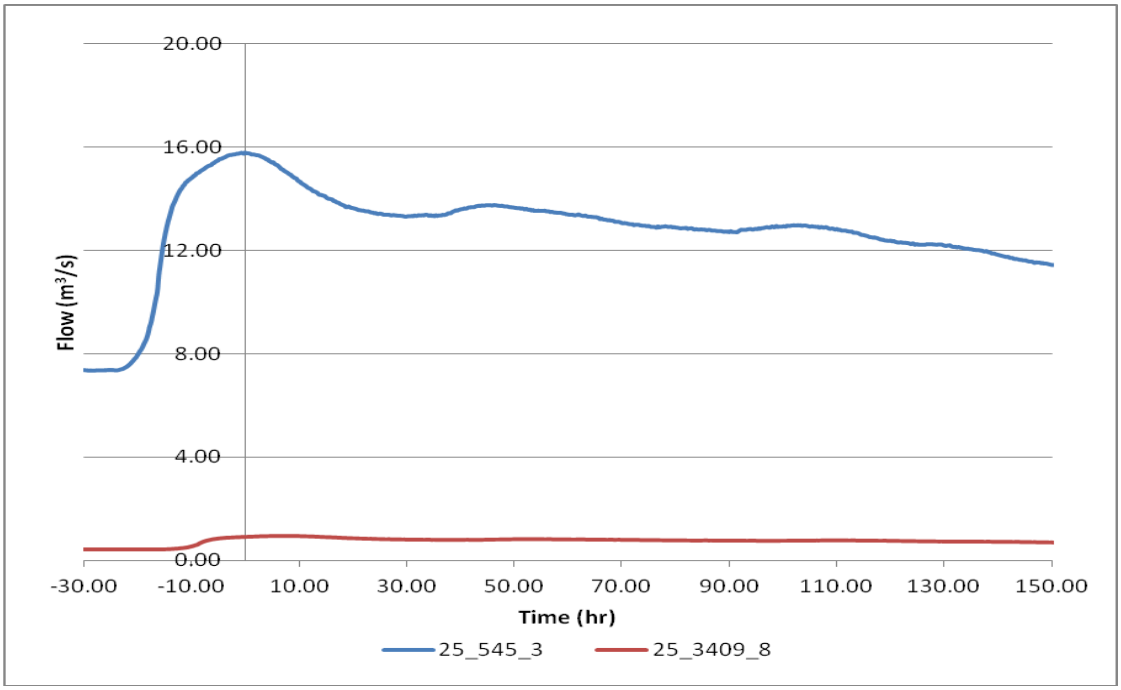


Figure B5.6 Downstream of Lough Ennell Verification Inflow Hydrographs for 15/08/2008 Event

Further calibration/verification run details and results have been provided in the hydraulic modelling report.

B5.2 Target Flows

The target flows are the total flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A4. The target flows at the HEP nodes for model N05 are shown in Table B4.1 below. Model N05 did not require separate tributary runs. It should be noted that only the nodes that were found to be suitable for comparing the modelled total flows with the target flows have been tabulated. Some HEP nodes are excluded from the tables as the modelled total flows in some nodes are affected by localised 2D flow patterns at nearby confluences and can therefore not be meaningfully compared with the target flows.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2668_1	1.1	1.3	1.5	1.6	1.7	1.9	2.0	2.2
26_2668_1a	4.3	5.2	5.9	6.4	6.9	7.4	7.9	8.9
25_3912_1	5.4	6.5	7.4	8.0	8.7	9.3	9.9	11.2
25_3682_3	6.1	7.4	8.4	9.0	9.8	10.5	11.2	12.6
25_3125_1	6.6	8.1	9.1	9.8	10.7	11.4	12.2	13.7
25_2938_1	7.1	8.7	9.7	10.5	11.4	12.2	13.0	14.6
25_2938_2	8.3	10.2	11.3	12.3	13.3	14.3	15.2	17.1
25_1152_6	13.1	16.1	17.9	19.5	21.0	22.6	24.0	27.1
Lough Ennell	28.5	35.0	39.0	42.6	45.8	49.2	52.2	59.1
25_3511_1	37.5	46.0	51.3	56	60.6	65.1	69.0	78.2
25_3639_4	39.8	48.8	54.4	59.4	64.4	69.2	73.3	83.1

Table B4.1 Target Flows at HEP Locations on the Main Stem

B5.3 Preliminary Design Flows

Table B5.5 summarises the preliminary peak inflows at each HEP. The HEPs are shown on Figure B5.1.

HEP reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2668_1	1.1	1.3	1.5	1.6	1.7	1.9	2.0	2.2
26_2668_1a	3.2	3.9	4.4	4.8	5.2	5.5	5.9	6.7
25_3912_1	1.1	1.3	1.5	1.6	1.8	1.9	2.0	2.3
25_3682_3	0.7	0.9	1.0	1.0	1.1	1.2	1.3	1.4
25_3125_1	0.5	0.7	0.7	0.8	0.9	0.9	1.0	1.1
25_2938_1	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9
25_2938_2	1.2	1.5	1.6	1.8	1.9	2.1	2.2	2.5
25_1152_6	4.8	5.9	6.6	7.2	7.7	8.3	8.8	10.0
Lough Ennell	15.4	18.9	21.1	23.1	24.8	26.6	28.2	32.0
25_3511_1	9.0	11.0	12.3	13.4	14.8	15.9	16.8	19.1
25_3639_4	2.3	2.8	3.1	3.4	3.8	4.1	4.3	4.9

Table B5.5 Preliminary Peak Inflows (m^3/s) at HEP Locations

B5.4 Final Design Hydrographs

The process of establishing the final design flows involves extracting from the hydraulic model the total flows at HEPs along the watercourse and comparing these total modelled flows with the total flows anticipated at each HEP from the hydrological analysis detailed in Appendix A4. The required inflow adjustments have to be estimated, and may result in revised modelled flows that still deviate from

the anticipated total flows. Hence a few iterations may be required until the modelled flows are within the accepted margins of the target flows based on the hydrological analysis.

The modelled flood dissipation in Reach 1 was stronger than anticipated, and additional flow had to be added to ensure that the total flows through the town of Mullingar and downstream of the town were sufficiently large. To increase the flow in Mullingar initially flows were added at a model section upstream of the town (approximately 1 km upstream of node 25_3912_1, see node reference US_25_3912_1 in Table B5.5 below). The flow added in this node was largely attenuated immediately downstream of it (in a floodplain upstream of the town), and to obtain sufficient flow at gauging station 25050 additional flow was added to HEP node 25_3912_1 which is at the gauging station, thus avoiding the attenuation in the floodplain upstream of the town and ensuring the appropriate critical flow through the town. To obtain the appropriate flow downstream of the town, additional flow was added at HEP 25_2938_2.

No further changes were made for design hydrographs in Reach 2 (downstream of Lough Ennell) as the total modelled flows at all HEPs were within 5% of the anticipated flows (from the hydrological analysis) using the preliminary design hydrographs.

Table B5.6 summarises the final peak inflows at each HEP location. Figures B5.7 and B5.8 illustrate the final design hydrographs of each return period in the reaches upstream and downstream of the lake.

HEP reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2668_1	1.1	1.3	1.5	1.7	1.7	1.9	2.0	2.2
26_2668_1a	3.2	3.9	4.4	4.8	5.2	5.5	5.9	6.7
US_25_3912_1	N.A.	N.A.	N.A.	N.A.	1.2	1.9	2.3	2.7
25_3912_1	1.1	2.0	2.4	2.8	2.4	2.9	3.3	3.9
25_3682_3	0.7	0.9	1.0	1.0	1.1	1.2	1.3	1.4
25_3125_1	0.5	0.7	0.7	0.8	0.9	0.9	1.0	1.1
25_2938_1	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9
25_2938_2	1.2	1.7	1.9	2.1	2.3	2.6	3.0	3.7
25_1152_6	4.8	5.9	6.6	7.2	7.7	8.3	8.8	10.0
Lough Ennell	15.4	18.9	21.1	23.1	24.8	26.6	28.2	32.0
25_3511_1	9.0	11.0	12.3	13.4	14.8	15.9	16.8	19.1
25_3639_4	2.3	2.8	3.1	3.4	3.8	4.1	4.3	4.9

Table B5.6 Final Peak Inflows (m^3/s) at HEP Locations

B5.5 Warning

Flows and hence flood levels upstream of Lough Ennell should be treated with caution due to the uncertainty in the QMED estimate at station 25050 (Mullingar Pump House), uncertainty in the growth curve and the dearth (and low confidence)

of calibration data. Check gaugings in the high flow range at station 25050 will be needed to improve the estimates in this reach.

Downstream of Lough Ennell (Reach 2) Newell's Bridge appears to be unsuitable for flood estimation purposes due to the large scatter in check gaugings. Calibration of the model in this reach suggests that the flood outlines (which were estimated based on the observed data at Ferbane further downstream on the Brosna) may have yielded reasonable results, but a stable gauging station with sufficient high flow check gaugings will be needed to improve the confidence in the flood estimates in this reach. Although there is no AFA in the N05 part of Reach 2, it is noted that the AFA at Kilbeggan is immediately downstream of the N05 model extent (in N06).

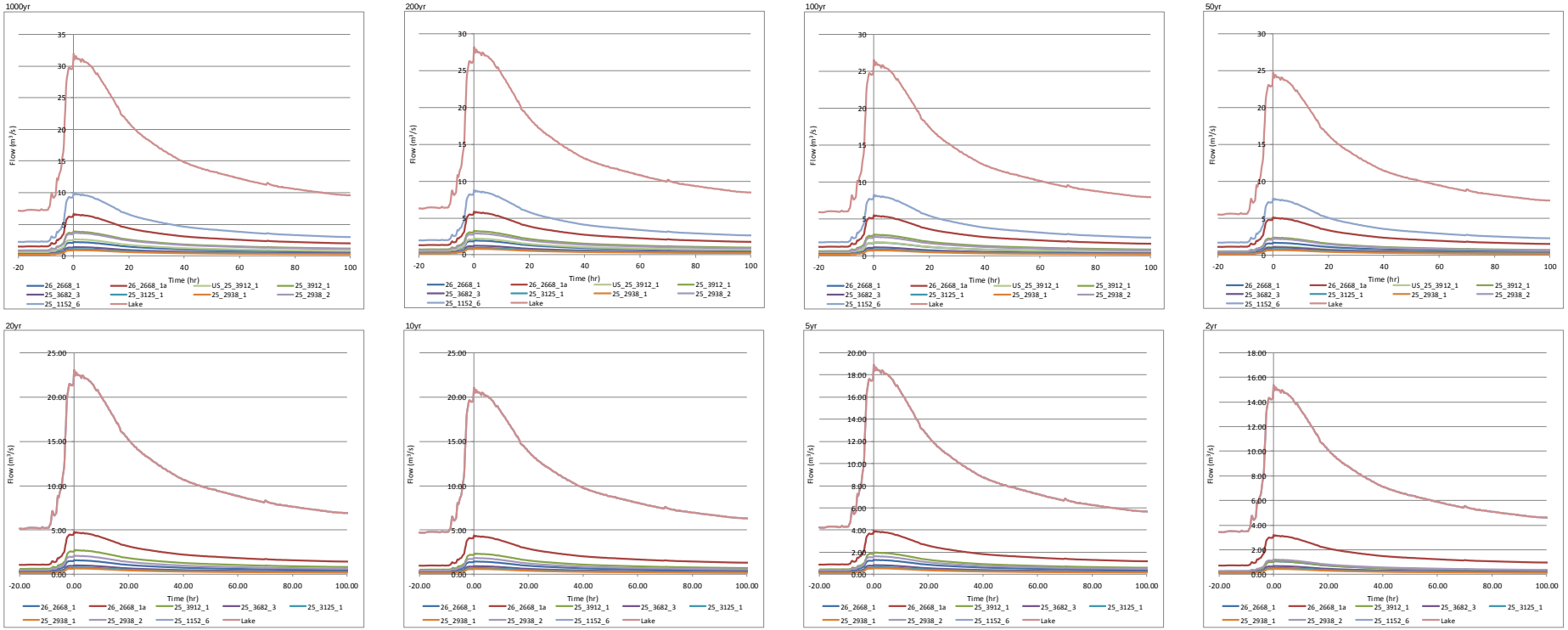


Figure B5.7 Final Design Inflow Hydrographs (Upstream of Lough Ennell)

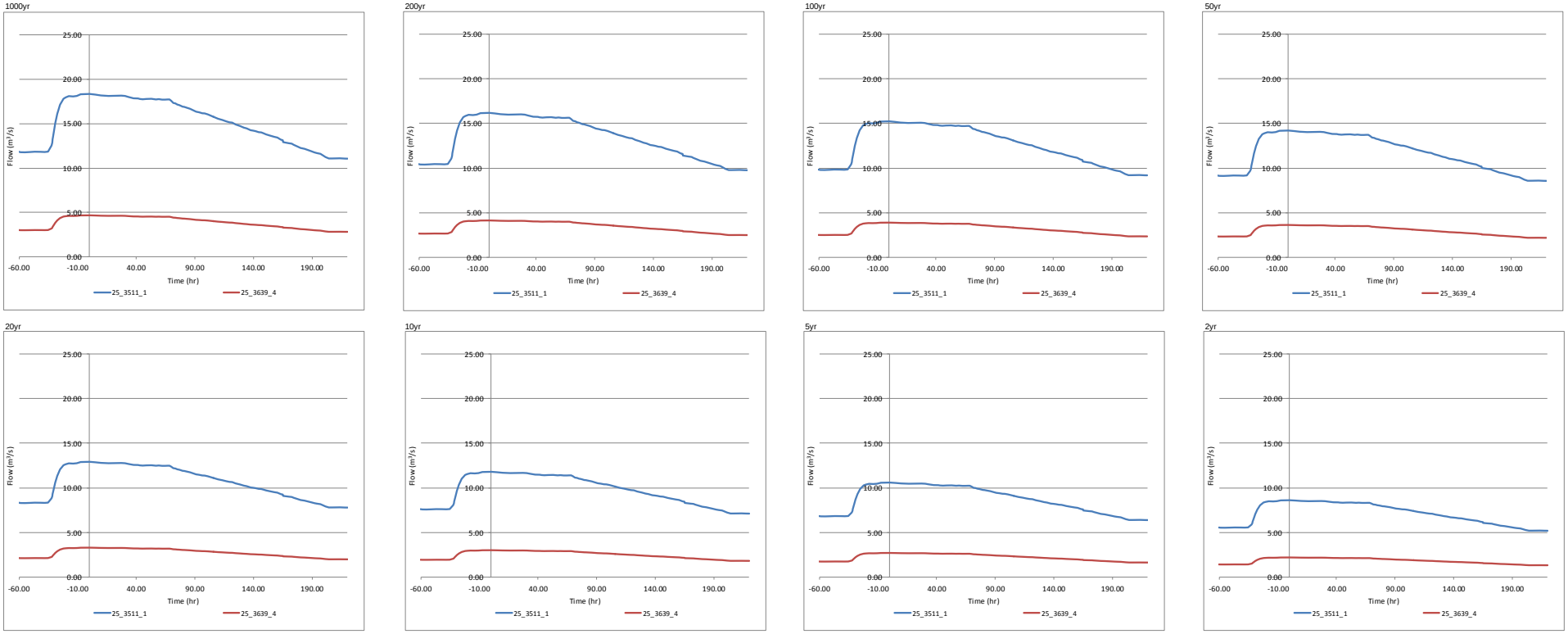


Figure B5.8 Final Design Inflow Hydrographs (Downstream of Lough Ennell)

B6 Model N06

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods and the inflow design hydrographs required to ensure that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B6.1, and shown on Figure B6.1.

Model Attribute	Comment
Rivers included in model	River Brosna[a] River Clodiagh[b] (Tributary of Brosna) River Straduff (Tributary of Brosna) River Killooly (Tributary of Brosna) River Silver (Tributary of Brosna)
Areas for Further Assessment (AFA)	Kilbeggan Clara Pollagh

[a] From HEP node 25_561_2 which is upstream of Kilbeggan to just downstream of Ferbane at HEP node 25_608_1.

[b] From HEP node 25_2952_1a (which is just downstream of the River Clodiagh and the Silver River confluence) to HEP node 25_2952_4 (which is located just upstream of the confluence of the River Clodiagh with the River Brosna).

Table B6.1 Model Extent coverage

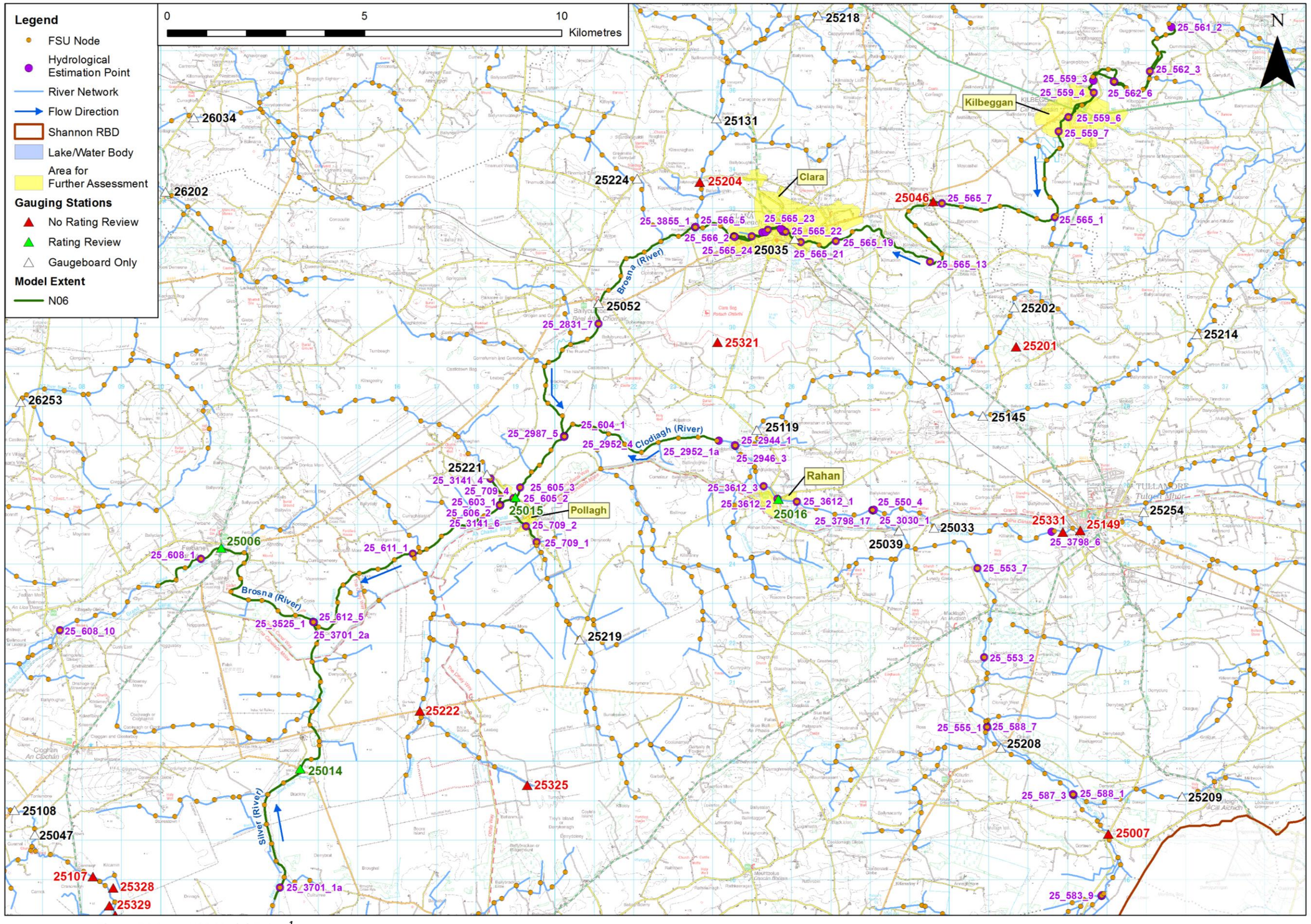


Figure B6.1 N06 Model Extent[1]

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B6.1 Hydrology for Hydraulic Model Calibration

There was insufficient gauged data available to calibrate the N06 model.

A very high level verification of the modelled design levels was suggested to the observed flood levels for the August 2008, February 1995 and November 2009 events. However, it was found that the distances between the reliable flow gauges along the Brosna were large (noting that the stations at Pollagh [25015] and Lismoyny [25046] were found not to be suitable for flow estimation, and Ballynagore [25124] only with caution as described in Section A4.3 in Appendix A, the rating review for 25015 in Appendix C and the calibration sheet in Appendix F).

The proportion of tributaries that have flow gauges (the Clodiagh and Silver) was small compared to the proportion of ungauged (or level-only) tributaries. The gauged tributaries contribute only 38% (439 km^2, measured at the gauges) of the catchment to Station 25006 (1163 km^2), and Station 25124 only 18% (215 km^2). Sweeping assumptions for the contributions from ungauged tributaries would have to be made, which were found to make the attempt to verify the model futile.

Refer to the calibration strategy in Appendix F and the hydraulic modelling report for N06 for details on the model calibration and verification.

B6.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A, Chapter A4. The target flows at the HEP nodes for model N06 are shown in Tables B6.2, B6.3 and B6.4.

To be able to model the critical events on the tributaries independently from the critical events on the main stem, two separate runs were undertaken for each AEP, one run to match the target flows in the main stem, and a separate independent run to obtain the target flows on the tributaries. For modelling purposes the tributary run is defined as the run modelling the critical events on the River Clodiagh, the River Silver and the River Killooly. The River Straduff was included separately in the main stem run as the flow from this watercourse is minimal (contributing less than 5% of the main stem flow).

In the *main stem run* the contributions from the modelled tributaries are determined by the target flows upstream and downstream of the tributaries, using the hydrograph shape relevant for the main stem. In the *tributary run* the hydrographs in the tributaries are as estimated to be critical for those tributaries (from the analysis in the Chapter A4 in Appendix A), and the flow in the main stem (i.e. the downstream boundary for the tributaries) is taken to be a constant flow equal to the 2-year return period (50% AEP) peak flow.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_561_2	11.99	14.75	16.43	17.99	19.79	21.23	22.54	25.54
25_562_3	12.35	15.19	16.92	18.52	20.38	21.86	23.22	26.30
25_562_6	12.35	15.19	16.92	18.52	20.38	21.86	23.22	26.30
25_559_3	12.35	15.19	16.92	18.52	20.38	21.86	23.22	26.30
25_559_4	12.35	15.19	16.92	18.52	20.38	21.86	23.22	26.30
25_559_6	12.35	15.19	16.92	18.52	20.38	21.86	23.22	26.30
25_559_7	12.35	15.19	16.92	18.52	20.38	21.86	23.22	26.30
25_565_1	13.14	16.16	18.00	19.71	21.68	23.25	24.70	27.98
25_565_7	14.51	17.84	19.87	21.76	23.94	25.68	27.27	30.90
25_565_13	14.51	17.84	19.87	21.76	23.94	25.68	27.27	30.90
25_565_19	14.79	18.19	20.27	22.19	24.41	26.18	27.81	31.51
25_565_21	14.79	18.19	20.27	22.19	24.41	26.18	27.81	31.51
25_565_22	15.00	18.45	20.55	22.50	24.75	26.55	28.20	31.95
25_565_23	15.00	18.45	20.55	22.50	24.76	26.56	28.21	31.96
25_565_24	15.00	18.45	20.55	22.50	24.76	26.56	28.21	31.96
25_566_2	15.00	18.45	20.55	22.50	24.76	26.56	28.21	31.96
25_566_5	15.62	19.21	21.40	23.43	25.78	27.65	29.37	33.27
25_3855_1	24.64	30.31	33.76	36.96	40.66	43.61	46.33	52.49
25_2831_7	27.96	34.39	38.30	41.93	46.13	49.48	52.56	59.55
25_2987_5	27.96	34.39	38.30	41.93	46.13	49.48	52.56	59.55
25_604_1	54.19	66.65	74.24	81.28	89.41	95.91	101.87	115.42
25_605_2	55.39	68.13	75.89	83.09	91.40	98.04	104.14	117.98
25_605_3	56.68	69.72	77.66	85.03	93.53	100.33	106.57	120.74
25_606_2	59.02	72.59	80.86	88.53	97.38	104.47	110.96	125.71
25_603_1	59.94	73.73	82.12	89.91	98.90	106.10	112.69	127.68
25_611_1	62.25	76.57	85.28	93.38	102.72	110.19	117.03	132.60
25_612_5	62.48	76.85	85.59	93.71	103.09	110.58	117.45	133.07
25_3525_1	78.42	96.45	107.43	117.63	129.39	138.80	147.42	167.03
25_608_1	79.03	97.20	108.27	118.54	130.40	139.88	148.57	168.33

Table B6.2 Target Flows (m^3/s) at HEP Locations on the N06 Model Extent (Run 1 - Main Stem)

In Figure B6.2 where the FSU regression equation suggested that the target flow in a HEP was lower than that in the HEP upstream of it without obvious physical justification, the target flow in the HEP was increased to the upstream value.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3141_4	2.32	3.01	3.45	3.86	4.39	4.78	5.16	6.05
25_3141_6	2.85	3.70	4.25	4.75	5.40	5.87	6.35	7.45

Table B6.3 Target Flows (m^3/s) at HEP Locations on the N06 Model Extent (Run 1 – River Straduff)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_2952_4 (River Clodiagh)	28.81	35.44	39.76	43.50	48.11	51.57	54.74	62.23
25_709_1 (River Killooly)	6.14	7.98	9.14	10.24	11.62	12.65	13.67	16.04
25_709_4 (River Killooly)	6.76	8.78	10.06	11.27	12.79	13.92	15.04	17.65
25_3701_1a (River Silver)	19.38	23.66	26.26	28.63	31.54	33.65	35.70	40.32
25_3701_2a (River Silver)	22.95	28.01	31.09	33.89	37.34	39.83	42.26	47.74

Table B6.4 Target Flows (m^3/s) at HEP Locations on the N06 Model Extent (Run 2 - Tributaries)

B6.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B6.2, B6.3 and B6.4, an initial set of inflow hydrographs was produced and run through the model.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the QMED adjustment factor, growth curves and hydrograph shapes specified in Appendix A, Chapter A4. The HEPs are shown on Figure B6.1.

Tables B6.5, B6.6 and B6.7 present the peak values of the preliminary inflows applied to the hydraulic model at the HEPs for the main stem and tributary runs.

Preliminary design inflow hydrographs are shown in Figures B6.2, B6.3, B6.4, B6.5 and B6.6 for the 1% AEP design runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_561_2	12.35	15.19	16.92	18.52	20.38	21.86	23.22	26.30
25_559_7	0.79	0.97	1.08	1.18	1.30	1.40	1.48	1.68
25_565_1	1.37	1.68	1.88	2.05	2.26	2.42	2.57	2.92
25_565_7	0.29	0.35	0.39	0.43	0.47	0.50	0.54	0.61
25_565_19	0.21	0.25	0.28	0.31	0.34	0.36	0.39	0.44
25_565_22	0.62	0.77	0.85	0.93	1.03	1.10	1.17	1.33
25_566_5	9.02	11.09	12.36	13.53	14.88	15.96	16.96	19.21
25_3855_1	3.31	4.08	4.54	4.97	5.47	5.87	6.23	7.06
25_2987_5	26.23	32.26	35.94	39.35	43.28	46.43	49.31	55.87
25_604_1	2.50	3.07	3.42	3.75	4.12	4.42	4.69	5.32
25_605_3	2.34	2.87	3.20	3.51	3.86	4.14	4.39	4.98
25_603_1	1.53	1.88	2.09	2.29	2.52	2.70	2.87	3.25
25_612_5	16.55	20.36	22.68	24.83	27.31	29.30	31.12	35.26

Table B6.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N06 Model Extent (Run 1 - Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3141_4	2.85	3.70	4.25	4.75	5.40	5.87	6.35	7.45

Table B6.6 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N06 Model Extent (Run 1 – River Straduff)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_2952_1a (River Clodiagh)	28.81	35.44	39.76	43.50	48.11	51.57	54.74	62.23
25_709_1 (River Killooly)	6.76	8.78	10.06	11.27	12.79	13.92	15.04	17.65
25_3701_1a (River Silver)	22.95	28.01	31.09	33.89	37.34	39.83	42.26	47.74

Table B6.7 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N06 Model Extent (Run 2 - Tributaries)

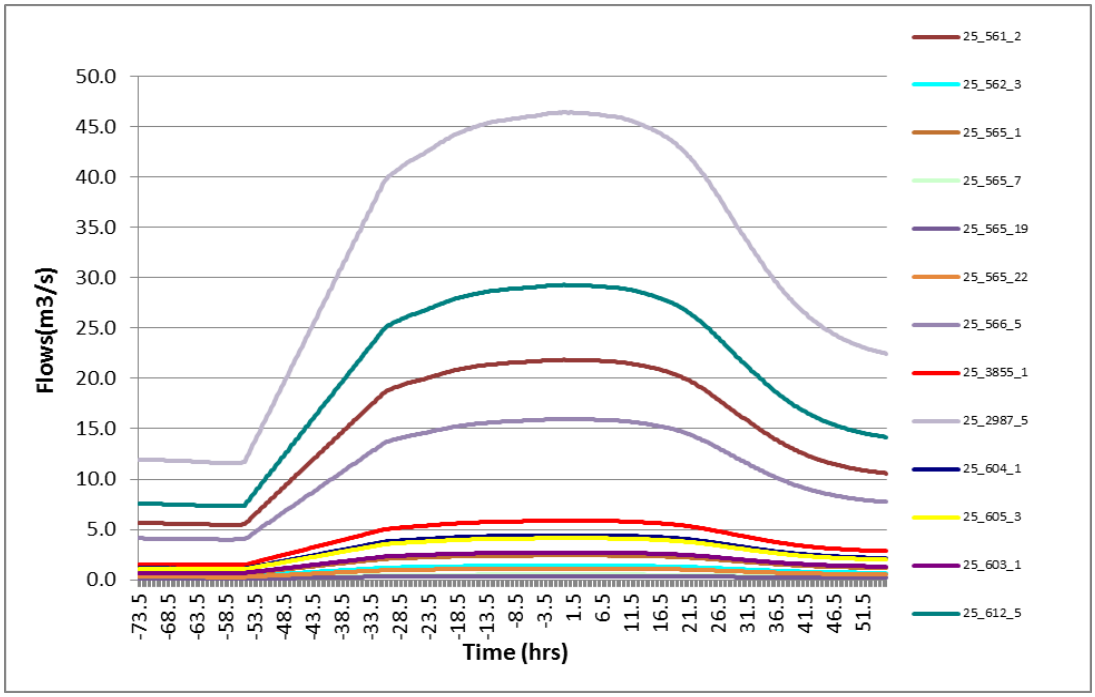

Figure B6.2 N06 Preliminary Design Inflow Hydrographs for 1% AEP (Run 1 – Main Stem)

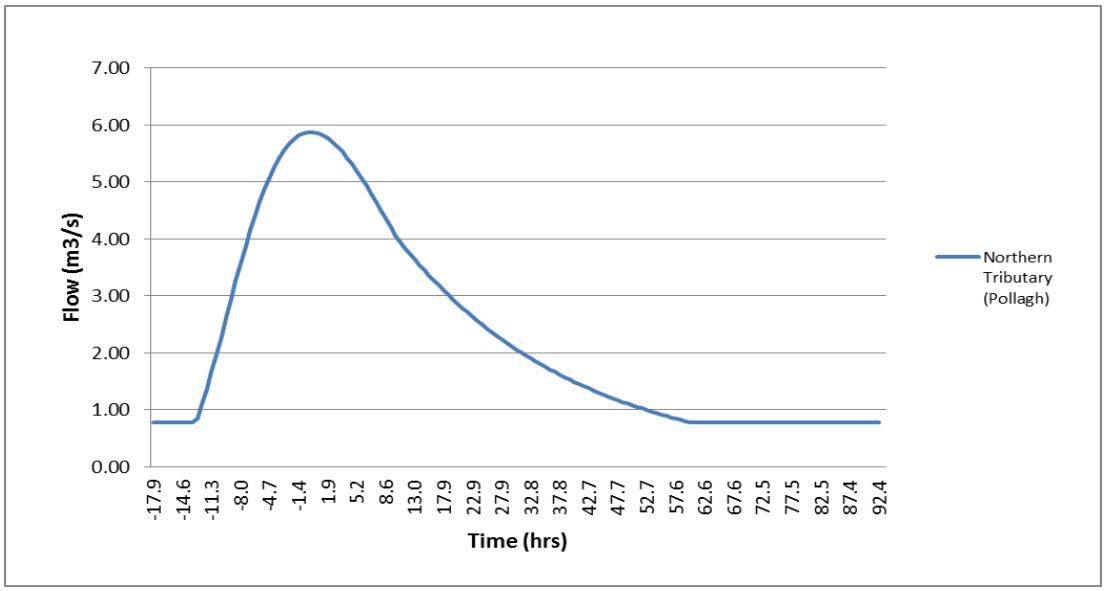

Figure B6.3 N06 Preliminary Design Inflow Hydrographs for 1% AEP (Run 1 – River Straduff)

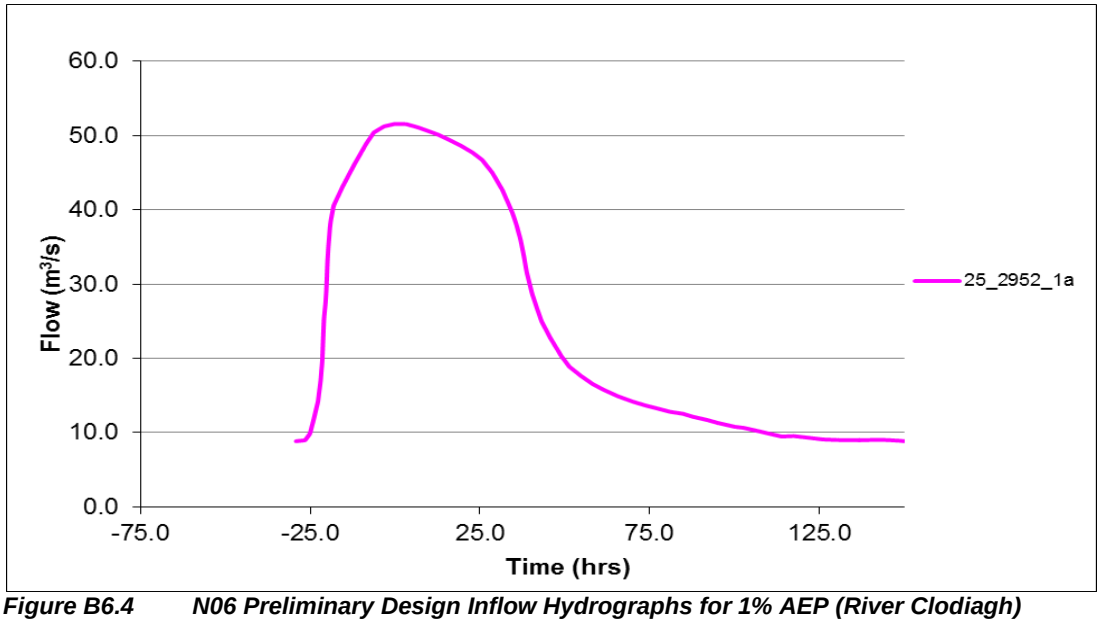

Figure B6.4 N06 Preliminary Design Inflow Hydrographs for 1% AEP (River Clodiagh)

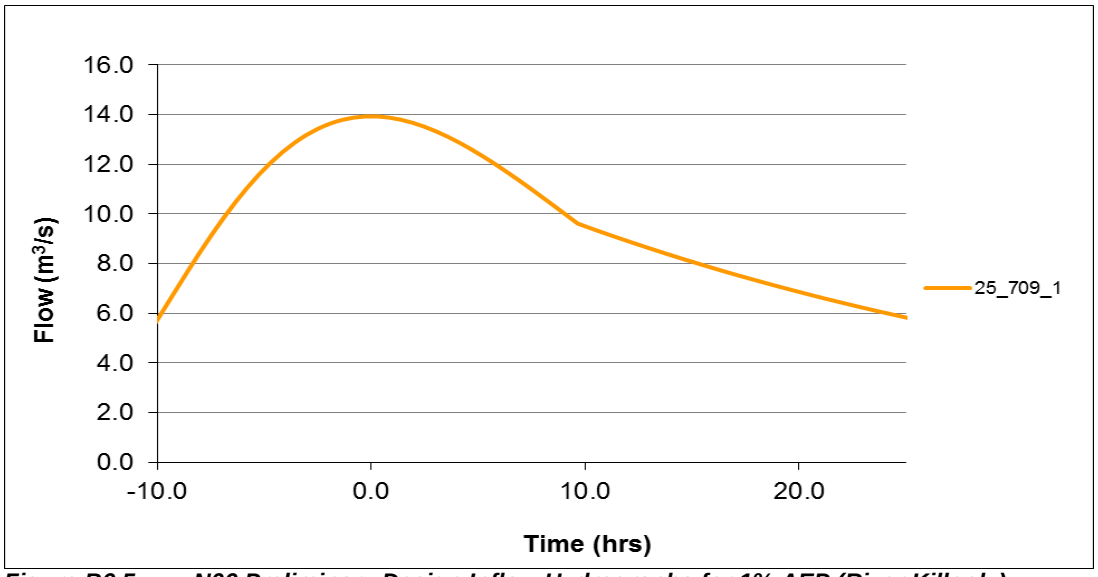

Figure B6.5 N06 Preliminary Design Inflow Hydrographs for 1% AEP (River Killooly)

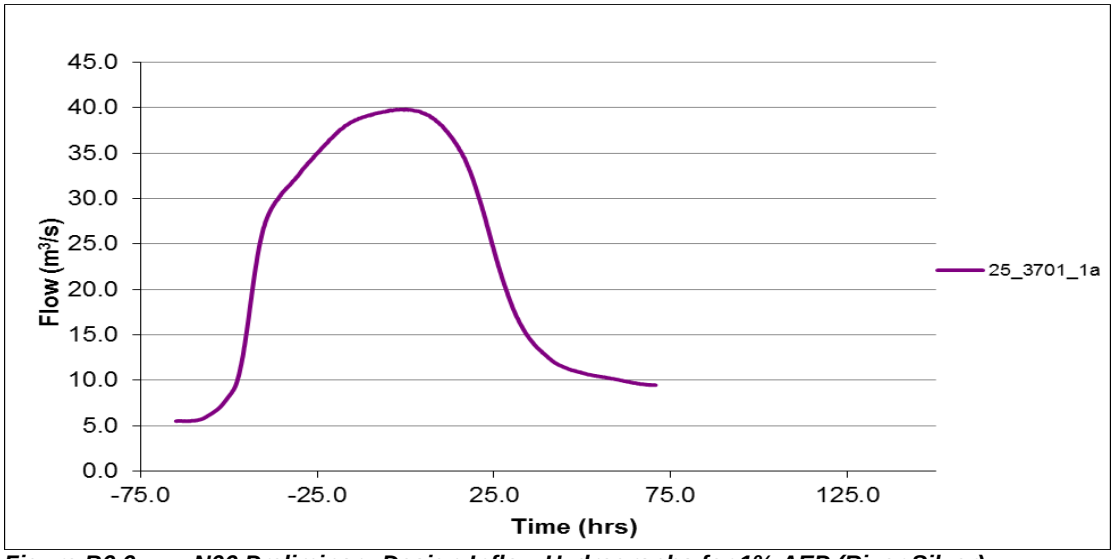

Figure B6.6 N06 Preliminary Design Inflow Hydrographs for 1% AEP (River Silver)

B6.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B6.5, B6.6 and B6.7 for calibrating the model to the HEP target flows presented in Tables B6.2, B6.3 and B6.4.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N06.

B7 Model N07

Model extent N07 comprises of the River Clodiagh (a tributary of the River Brosna), the River Tullamore and the River Gorragh which are both tributaries of the Clodiagh. There are two AFAs located within this model extent, Rahan and Clonaslee . Both the River Clodiagh and River Gorragh flow through the Clonaslee AFA.

The estimation of QMED adjustment factors, growth curve and hydrograph shapes are all documented in Appendix A, Chapter 4. The model calibration and design inflow hydrographs are summarised below.

B7.1 Calibration

Limited historic data for verification and calibration is available for this model, as summarised in the calibration sheet for this model in Appendix F. Gauging stations 25016 (Rahan), 25149 (Tullamore) and 25301 (Bracknagh Bridge) were identified for potential use. Table B7.1 summarises the flow and level gauging stations considered for the calibration/verification process.

Calibration from Stations 25301 and 25149 was attempted in accordance with the calibration sheet for N07 (see Appendix F), with the intention of comparing modelled water levels and flows with the gauged water levels and flows at the downstream station 25016. A very poor match was obtained (with modelled peak flows and levels much lower than gauged, and hydrograph shapes completely different) and it was concluded that the upstream and downstream stations (in particular stations 25301 and 25016) were too far apart to reproduce the observed flows and levels at station 25016, with the need to make sweeping assumptions about the large amount of ungauged flows entering the domain between the upstream and downstream stations. This calibration attempt had to be abandoned.

Station	Data Length	Type	Comment
25016 Rahan	1963 to Date	Level and Flow	CFRAM rating review site
25149 Tullamore	2001 to Date	Level and Flow	HGF/QMED~1.1; no FSU classification; no rating review.
25301 Bracknagh Bridge	2002 to Date	Level and Flow	No high flow check gaugings; no FSU classification; no rating review.

Table B7.1 Gauging Stations used for Calibration/Verification

In addition, calibration of the N07 model near Rahan was carried out in accordance with the calibration sheet for this model (see Appendix F) by applying observed flows recorded at Rahan (25016) for the August 2008 flood event upstream of Killina. As aerial photography was available for this event, water levels could be estimated from the photographs and these levels checked at Killina. The flow hydrograph used for this calibration event is shown in Figure B7.1.

The results of the calibration process are discussed in the hydraulic modelling report for N07.

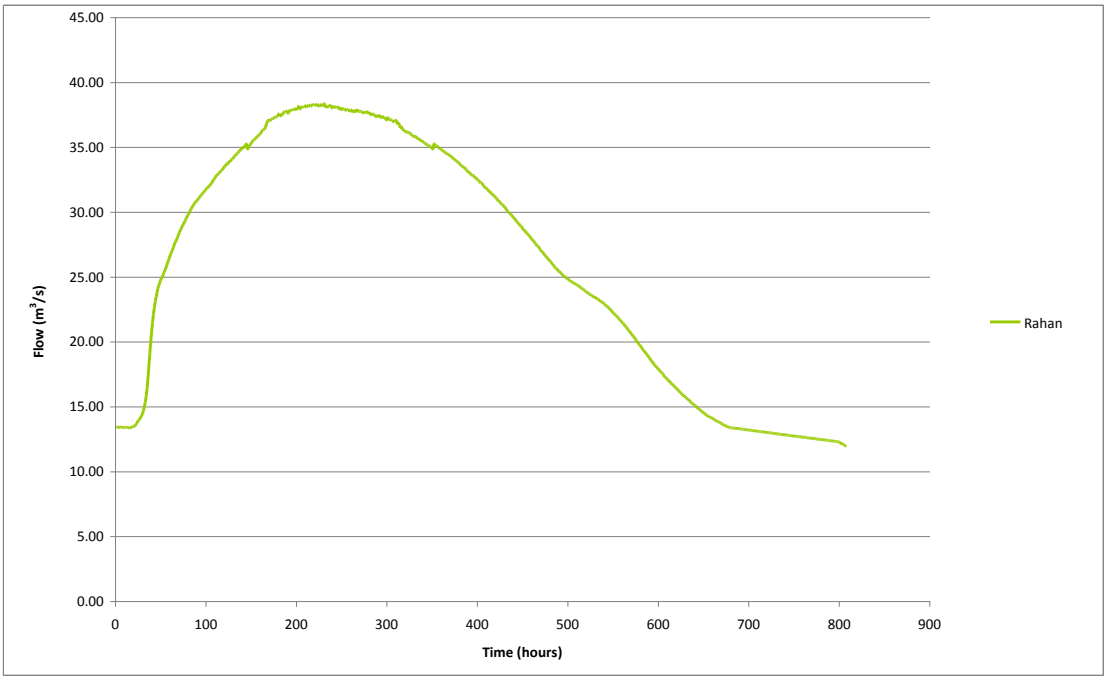

Figure B7.1 Inflow hydrograph for the August 2008 Event

B7.2 Target Flows

The target flows are the total flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A, Chapter 4. The target flows at the HEP nodes for model N07 are shown in Tables B7.2 and B7.3 below. It should be noted that only the nodes that were found to be suitable for comparing the modelled total flows with the target flows have been tabulated. Some HEP nodes are excluded from the tables as the modelled total flows in some nodes are affected by localised 2D flow patterns at nearby confluences and can therefore not be meaningfully compared with the target flows.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
25_570_12	9.85	12.12	13.59	14.87	16.45	17.63	18.72	21.28
25_570_14	10.00	12.30	13.80	15.10	16.70	17.90	19.00	21.60
25_583_1	15.77	19.63	22.02	24.10	26.65	28.57	30.32	34.47
25_583_6	15.96	19.77	22.18	24.27	26.84	28.77	30.53	34.71
25_583_9	20.05	24.66	27.67	30.28	33.48	35.89	38.10	43.31
25_588_1	20.50	25.87	29.02	31.76	35.12	37.64	39.96	45.42
25_550_4	20.71	25.47	28.58	31.27	34.59	37.07	39.35	44.73
25_3030_1	23.59	29.02	32.55	35.62	39.40	42.23	44.82	50.95
25_3612_3	23.38	29.25	32.82	35.91	39.71	42.57	45.18	51.36
25_2946_3	24.00	29.52	33.12	36.24	40.08	42.96	45.60	51.84
25_2944_1	28.05	34.50	38.71	42.36	46.84	50.21	53.30	60.59

Table B7.2 Target Flows at HEP Locations on the N07 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
25_582_5	11.04	13.58	15.24	16.67	18.44	19.76	20.98	23.85
25_582_6	11.98	13.74	16.53	18.09	20.01	21.44	22.76	25.88
25_582_9	11.98	14.74	16.53	18.09	20.01	21.44	22.76	25.88
25_3798_6	9.63	10.84	13.29	12.54	16.08	17.24	18.30	20.80
25_3798_17	9.63	11.84	13.29	14.54	16.08	17.24	18.30	20.80

Table B7.3 Target Flows at HEP Locations on the N07 Model Extent (Tributaries)

B7.3 Preliminary Design Flows

To obtain the target flows shown in Tables B7.2 and B7.3, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, two separate runs were undertaken for each AEP. One run was to obtain the target flows in the main stem and one run was to obtain the target flows on the tributaries.

The inflow hydrographs shown in Figures B7.3 to B7.11 were derived using the procedure outlined in Chapter 2 and the adjustment factor, growth curves and hydrograph shape specified in Appendix A4. Tables B7.4 and B7.5 below summarise the preliminary peak inflows at each HEP. The HEPs used are shown on Figure B7.2.

HEP reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_570_12	10.00	12.30	13.80	15.11	16.71	17.91	19.01	21.61
25_582_5	5.76	7.09	7.95	8.70	9.62	10.32	10.95	12.45
25_583_1	0.19	0.24	0.27	0.29	0.32	0.34	0.37	0.42
25_583_6	0.11	0.14	0.15	0.17	0.19	0.20	0.21	0.24
25_583_9	4.43	5.45	6.11	6.69	7.40	7.93	8.41	9.57
25_588_1	0.53	0.65	0.72	0.79	0.88	0.94	1.00	1.13
25_3612_3	0.40	0.50	0.56	0.61	0.67	0.72	0.77	0.87
25_3798_6	2.57	3.16	3.54	3.88	4.29	4.59	4.88	5.54
25_2946_3	4.06	4.99	5.60	6.13	6.78	7.26	7.71	8.76

Table B7.4 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N07 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
25_570_12	3.79	4.67	5.23	5.73	6.33	6.79	7.21	8.19
25_582_5	11.04	13.57	15.23	16.66	18.43	19.75	20.97	23.84
25_582_6	0.94	1.15	1.30	1.42	1.57	1.68	1.78	2.03
25_3798_6	9.63	11.84	13.29	14.54	16.08	17.23	18.29	20.79

Table B7.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N07 Model Extent (Tributaries)

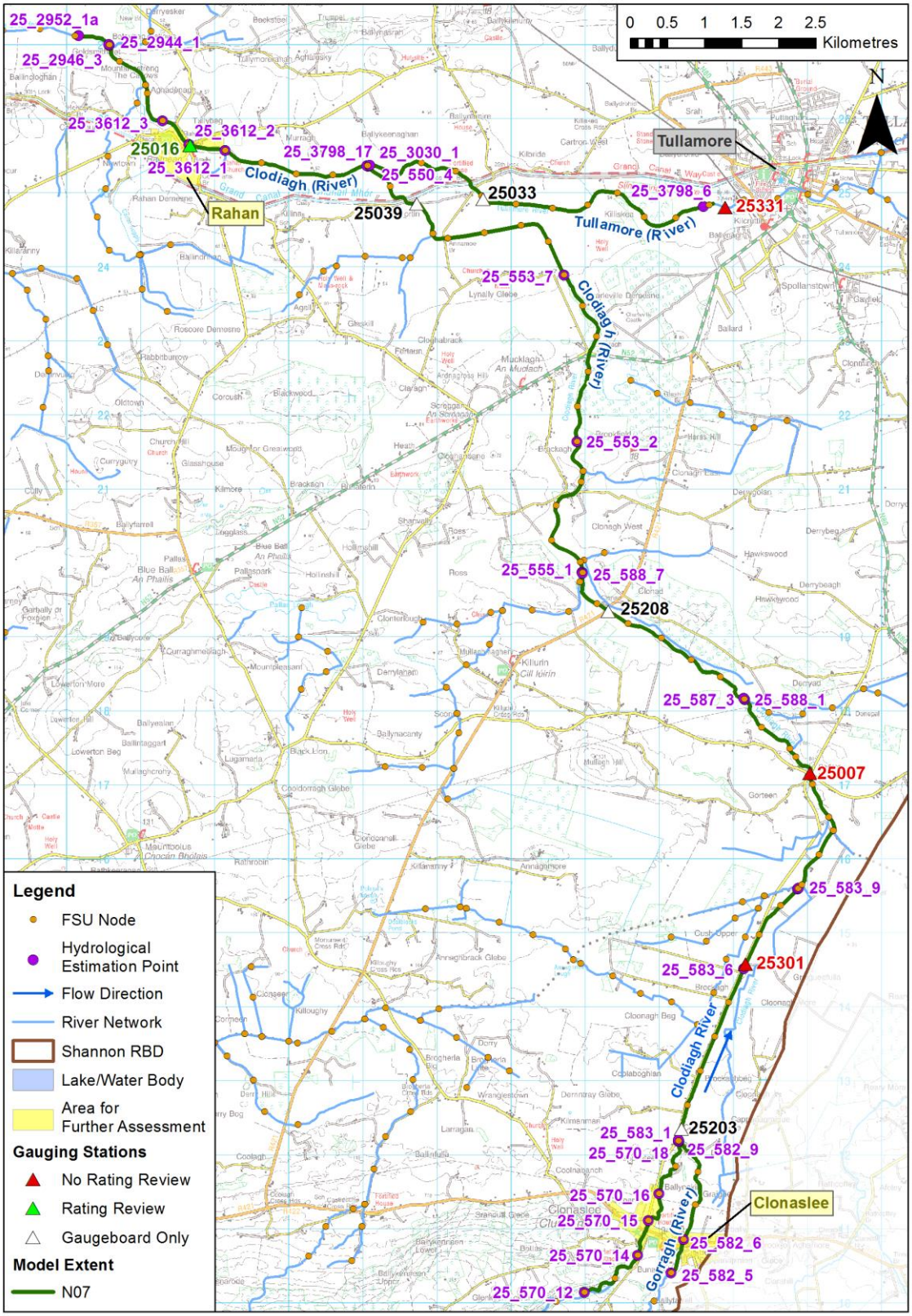

***Figure B7.2 Model Extent*[1]**

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B7.4 Final Design Hydrographs

The process of establishing the final design flows involved extracting from the hydraulic model the total flows at HEPs along the watercourse and comparing these target flows tabulated in Tables B7.2 and 7.3. If modelled flows at a node were more than approximately 5% different than the target flows, then the model inflows were adjusted by the right amount for the modelled flows to accord with the anticipated flows from the hydrological analysis. The required adjustment had to be estimated and resulted for some design events in revised model inflows that still deviated from the target flows. The model was then re-run with the adjusted flows and a further comparison was made. A few iterations were required until the modelled flows were within approximately 5% of the target flows.

Tables B7.6 and B7.7 summarise the final peak inflows. Figures B7.3 to B7.11 illustrate the final design hydrographs using the design event hydrographs specified in Appendix A, Chapter 4. Only the 10%, 1% and 0.1% flows are shown so far. The other AEPs will be included in the final version of this report.

HEP reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_570_12			13.80			17.91		21.61
25_570_18			0.00			2.80		4.20
25_582_5			7.95			10.32		12.45
25_583_1			0.27			0.34		0.42
25_583_6			0.15			0.20		0.24
25_583_9			6.11			7.93		9.57
25_588_1			0.72			0.94		1.13
25_550_4			3.30			5.53		12.00
25_3612_3			0.56			0.72		0.87
25_3798_6			3.54			4.59		5.54
25_2946_3			5.60			7.26		8.76

Table B7.6 Final Design Hydrograph Total Peak Inflows (m^3/s) at HEP Locations on N07 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50 %	0.10%
25_570_12			5.23			6.79		8.19
25_582_5			15.23			19.75		23.84
25_582_6			1.30			1.68		2.03
25_3798_6			13.42			17.40		22.82

Table B7.7 Final Design Hydrograph Total Peak Inflows (m^3/s) at HEP Locations on N07 Model Extent (Tributaries)

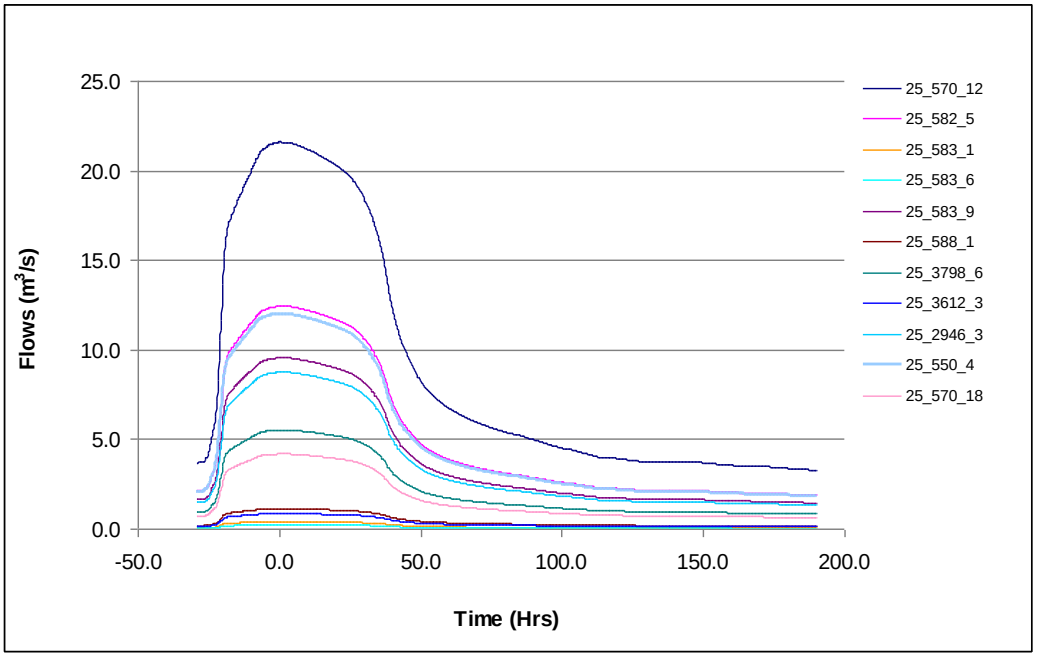

Figure B7.3 N07 Final Design Inflow Hydrographs (Main Stem) for 0.1% AEP

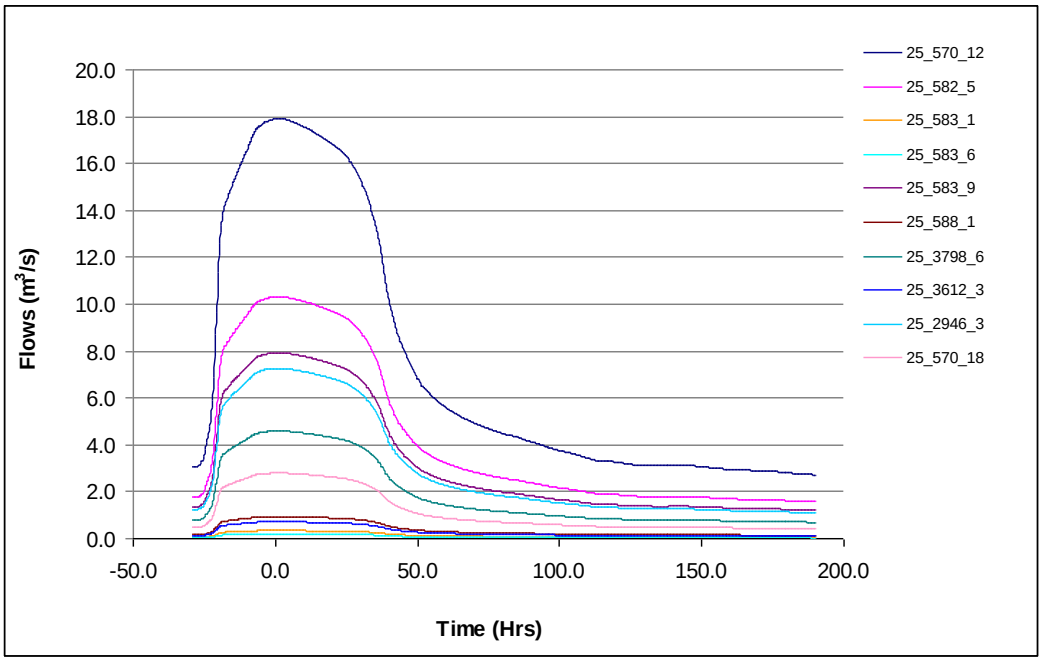

Figure B7.4 N07 Final Design Inflow Hydrographs (Main Stem) for 1% AEP

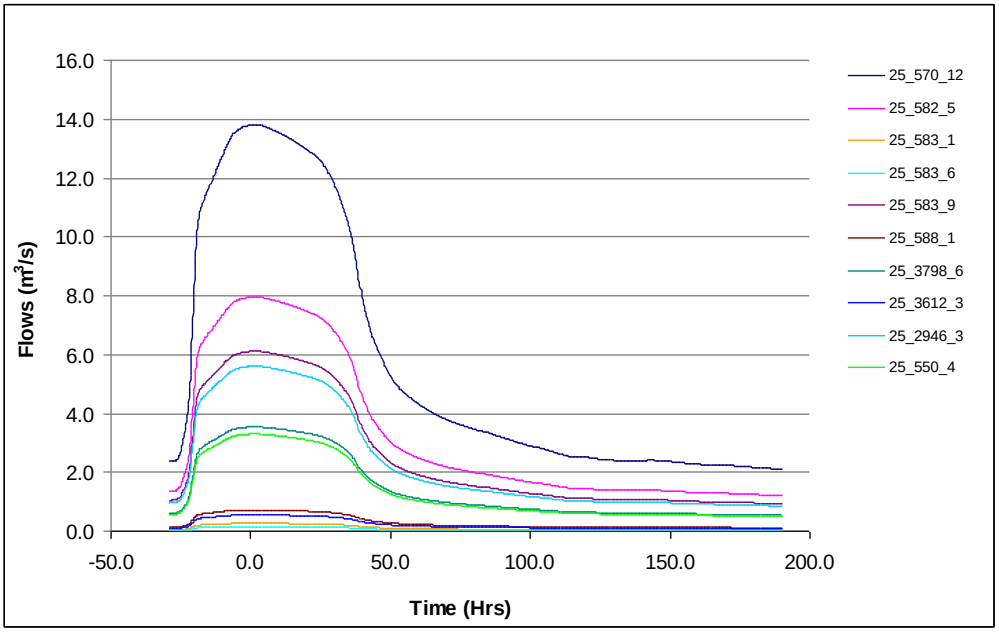

Figure B7.5 N07 Final Design Inflow Hydrographs (Main Stem) for 10% AEP

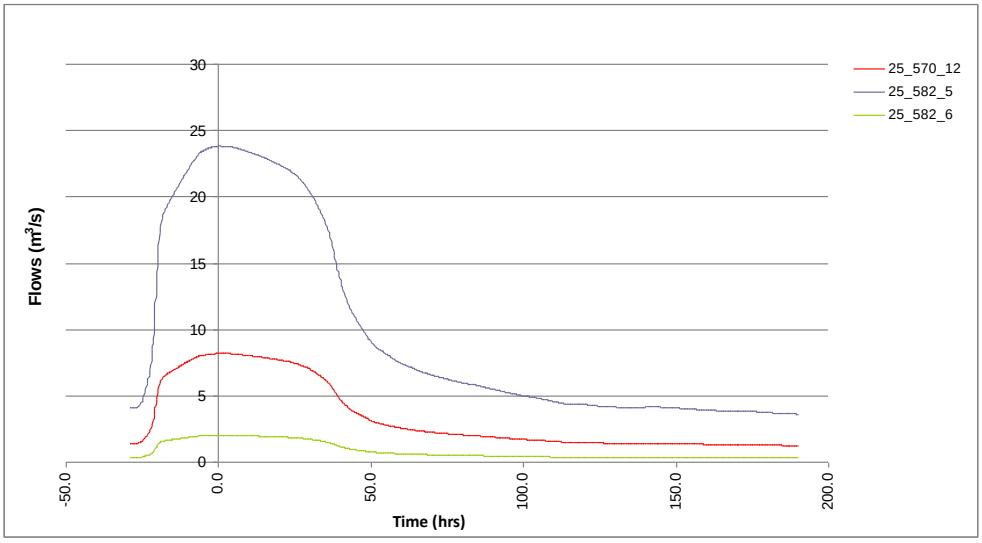

Figure B7.6 N07 Final Design Inflow Hydrographs (Tributaries – Clodiagh & Gorragh) for 0.1% AEP

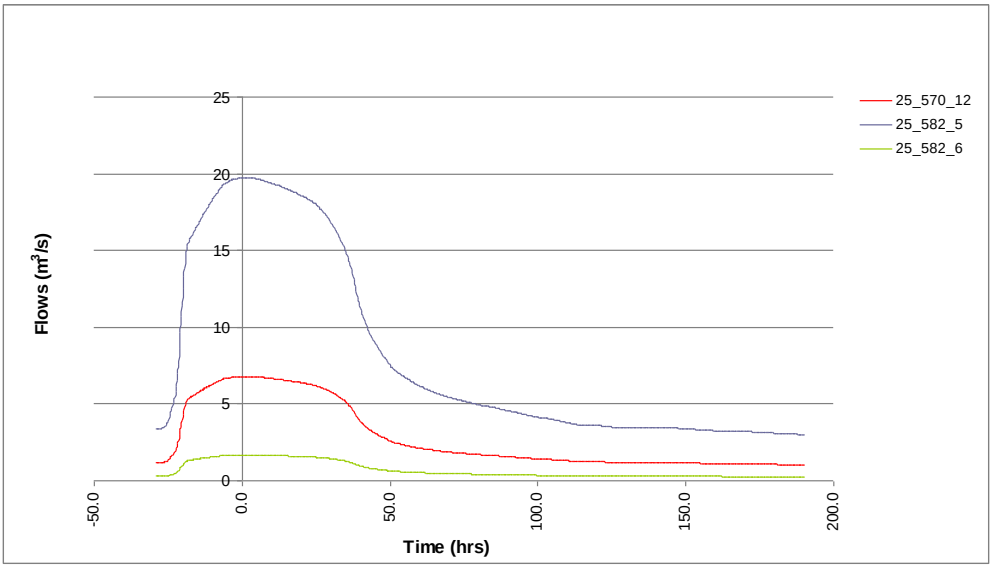

Figure B7.7 N07 Final Design Inflow Hydrographs (Tributaries – Clodiagh & Gorragh) for 1% AEP

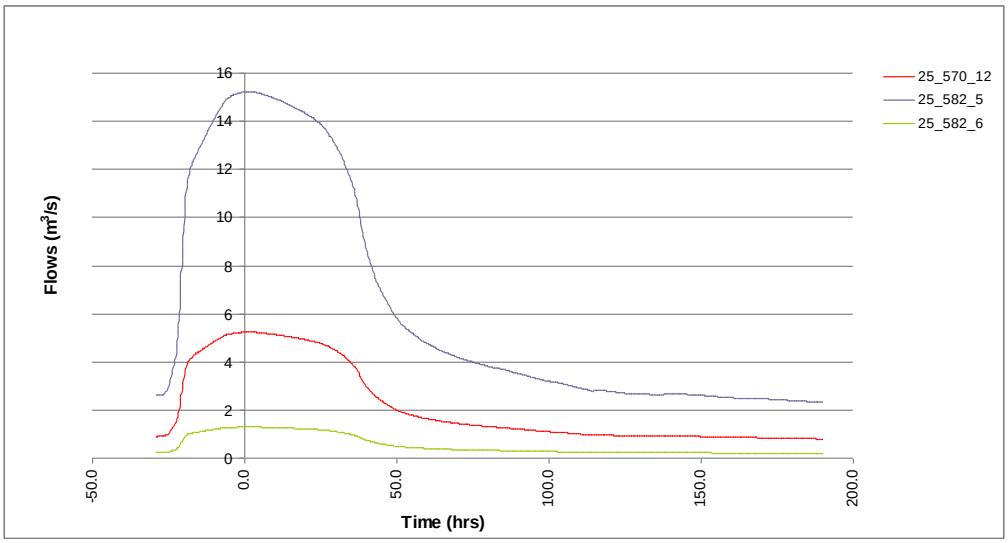

Figure B7.8 N07 Final Design Inflow Hydrographs (Tributaries – Clodiagh & Gorragh) for 10% AEP

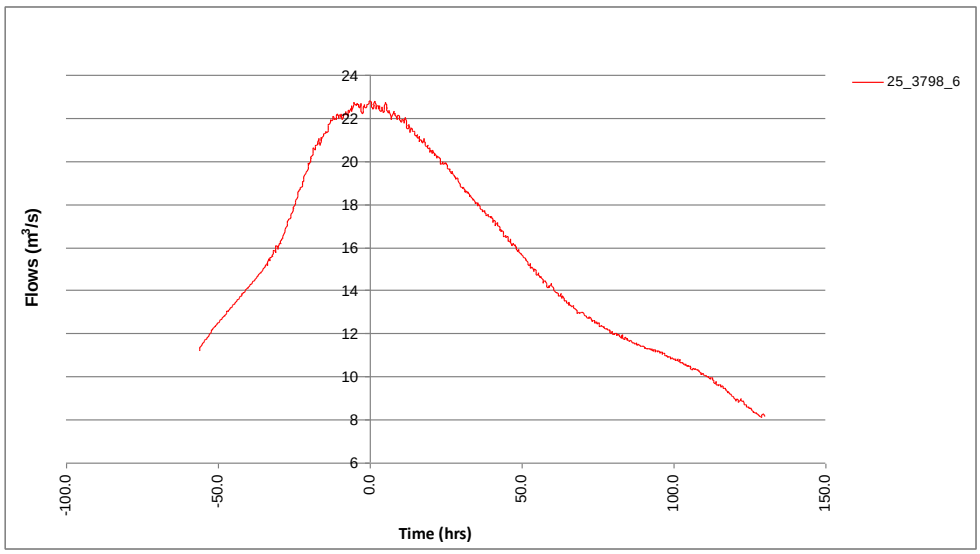

Figure B7.9 N07 Final Design Inflow Hydrographs (Tributaries – Tullamore) for 0.1% AEP

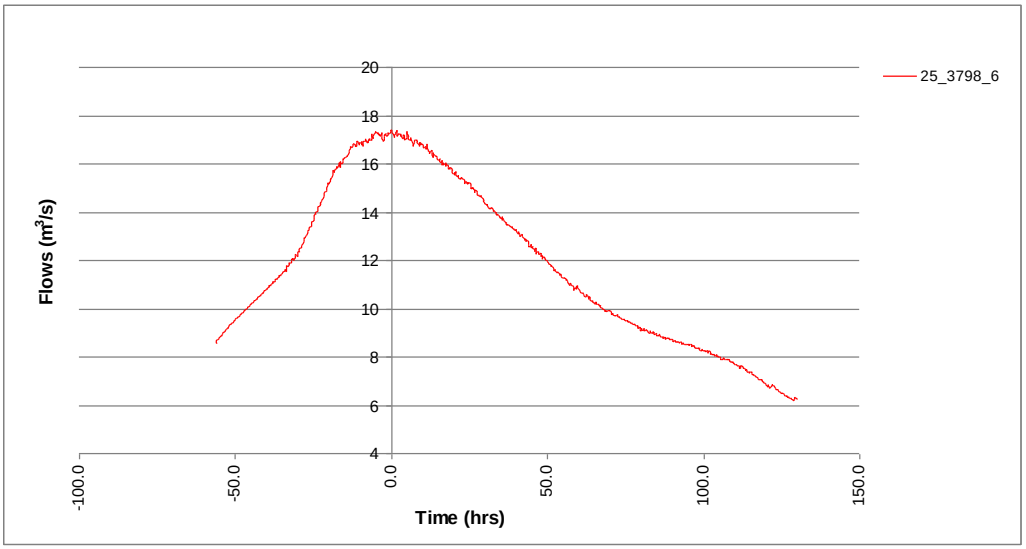

Figure B7.10 N07 Final Design Inflow Hydrographs (Tributaries – Tullamore) for 1% AEP

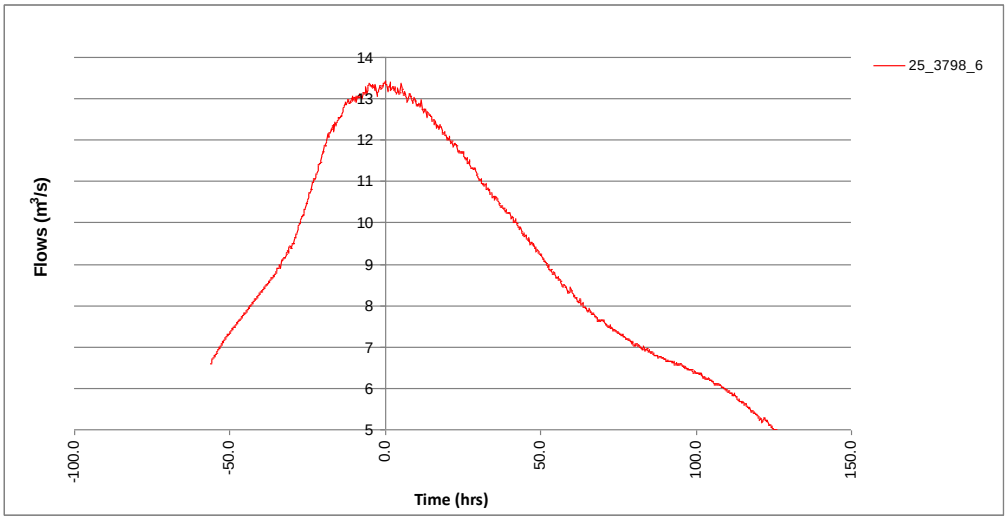

Figure B7.11 N07 Final Design Inflow Hydrographs (Tributaries – Tullamore) for 10% AEP

B8 Model N08

Model extent N08 comprises of the River Suck and its tributary the River Francis. There are two AFAs located within this model extent, Castlerea and Athleague. The model extent of N08 is shown in Figures B8.1-a and -b on the next page.

The estimation of QMED adjustment factors, growth curve and hydrograph shapes are all documented in Appendix A, Chapter A5. The model calibration and design inflow hydrographs are summarised below.

B8.1 Calibration

Limited historic data for verification and calibration is available for this model. Gauging stations 26002 (Rookwood) and 26005 (Derrycahill) were identified for use in the calibration for this model, see Appendix F. Table B8.1 summarises the flow and level gauging stations considered for the calibration/verification process.

Calibration and verification was completed for the following two sections: section 1 from upstream of Athleague (HEP node 26_1452_1) to gauging station 26002; section 2 from gauging station 26002 to 26005 on the River Suck. No observed data was available for calibration in the Castlerea AFA.

Station	Data Length	Type	Comment
26002 Rookwood	1952 - 2010	Level and Flow	CFRAM rating review site
26005 Derrycahill	1954 - 2010	Level and Flow	CFRAM rating review site

Table B8.1 Gauging Stations used for Calibration/Verification

Calibration of the model near Athleague (section 1) was carried out in accordance with the calibration sheet for this model (see Appendix F) by applying observed flows recorded at Rookwood (26002) for the 21/11/2009 flood event at node 26_1452_1 upstream of Athleague. The modelled water levels were checked against the gauged levels at station 26002, as well as observed water levels and photographs at Athleague. The inflow hydrograph used for this calibration event is shown in Figure B8.2.

Calibration/verification between Stations 26002 and 26005 (section 2) was attempted for four events in accordance with the calibration sheet, by comparing modelled water levels with the gauged water levels at the downstream Station 26005. The four events selected are shown below:

1. November 2009
2. October 2002
3. February 2002
4. January 2005.

Lateral inflows between the upstream and downstream stations have been estimated by scaling the 2-year design inflows at each HEP (see Section B8.3 below) proportionally using a factor obtained from the ratio of the flow peak and the

QMED at the upstream gauging station (26002). In other words all inflows have been scaled proportionally with the design inflows.

The inflow hydrographs are shown in Figure B8.3 to B8.6.

The use of aerial photos of the January 2005 event for broad brush verification was considered but the photos were found unsuitable for identifying the flood extents.

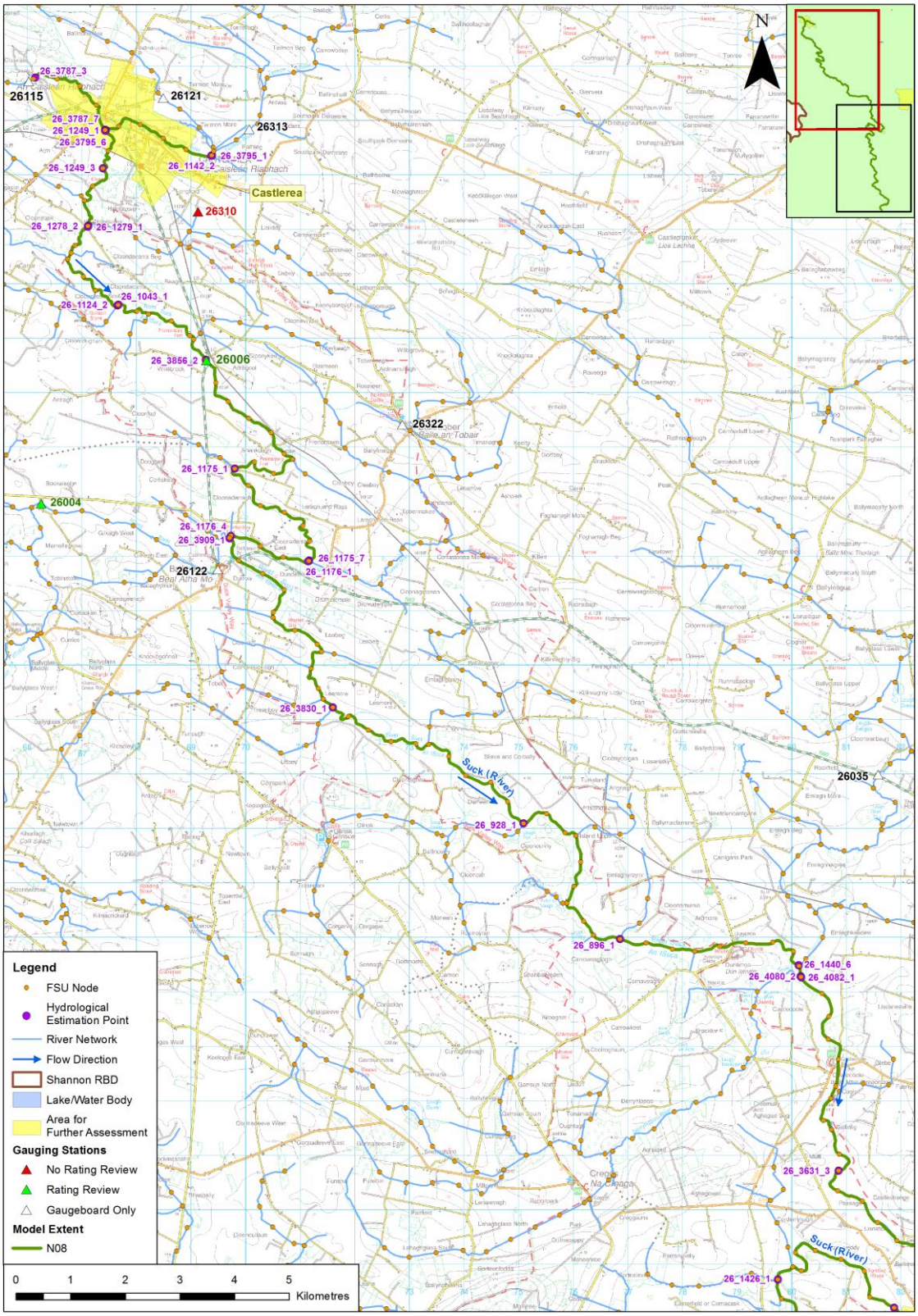

Figure B8.1-a Model Extent[1] (North)

[1] Copyright Office of Public Works. All rights reserved. Includes Ordnance Survey Ireland data Reproduced under OSi License number EN0021011. Unauthorized reproduction infringes Ordnance Survey Ireland and Government of Ireland copyright, © Ordnance Survey Ireland, 2013.

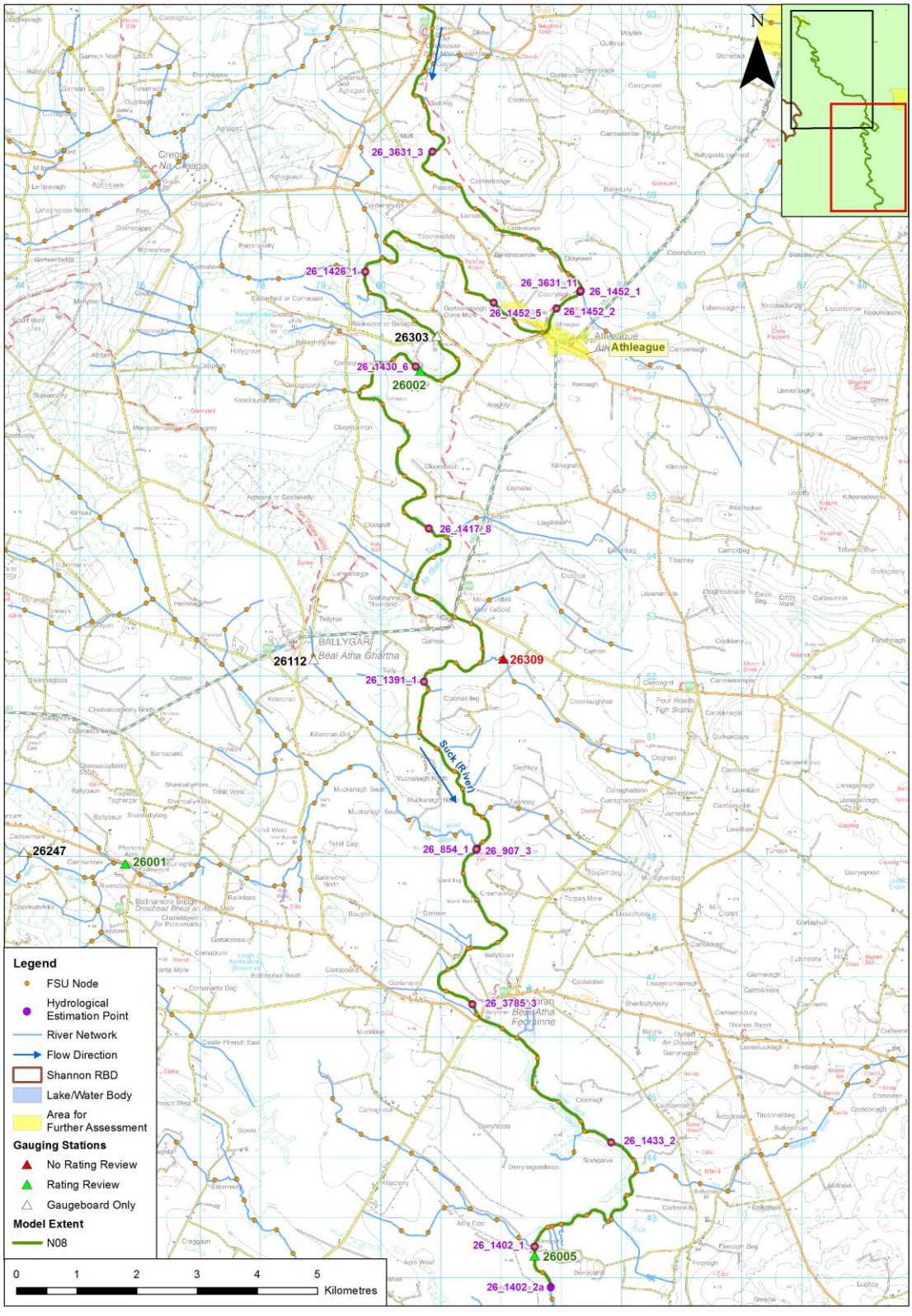

Figure B8.1-b Model Extent (South)

The results of the calibration process are discussed in the hydraulic modelling report for N08.

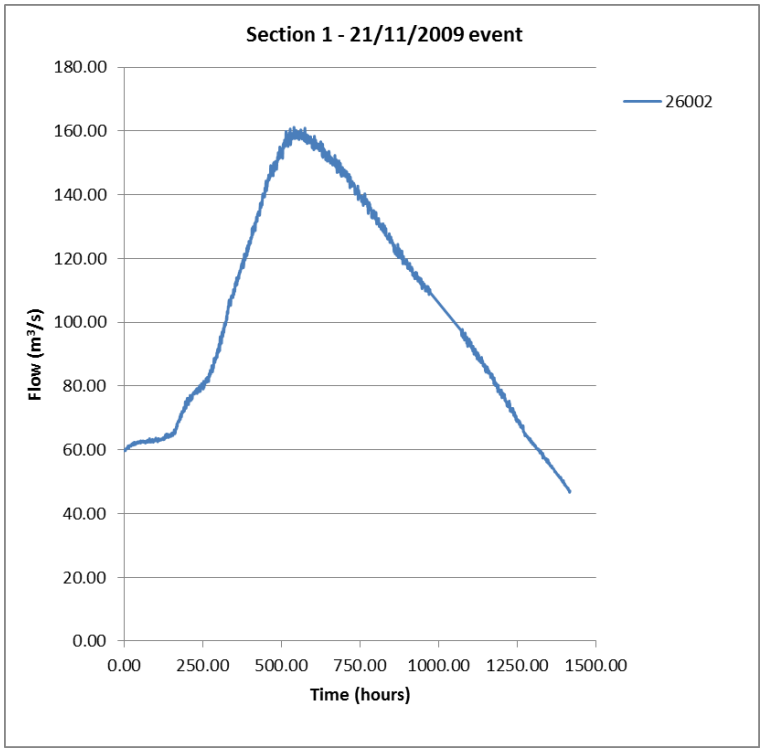

Figure B8.2 Section 1 Inflow hydrograph for the Nov 2009 Event

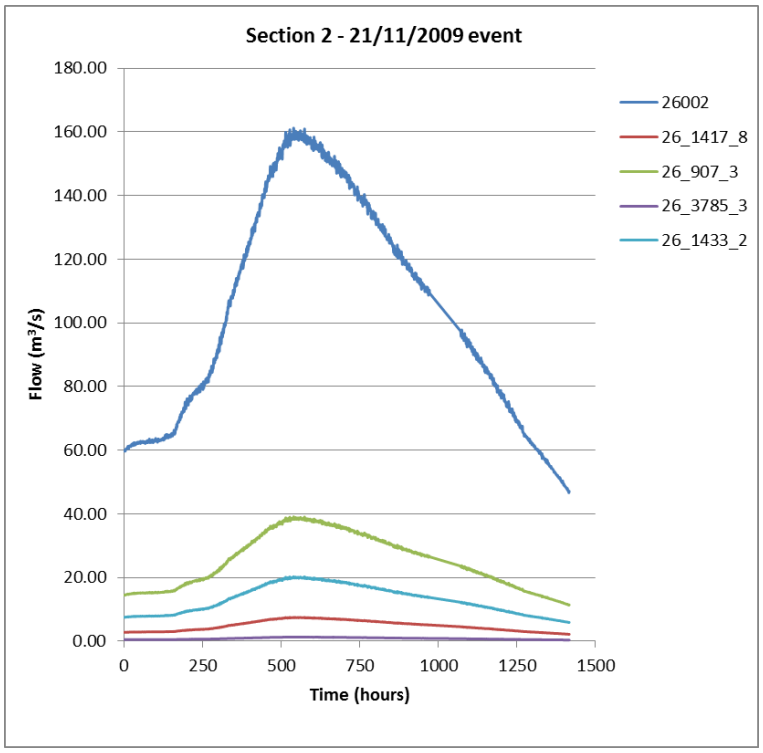

Figure B8.3 Section 2 Inflow hydrographs for the Nov 2009 Event

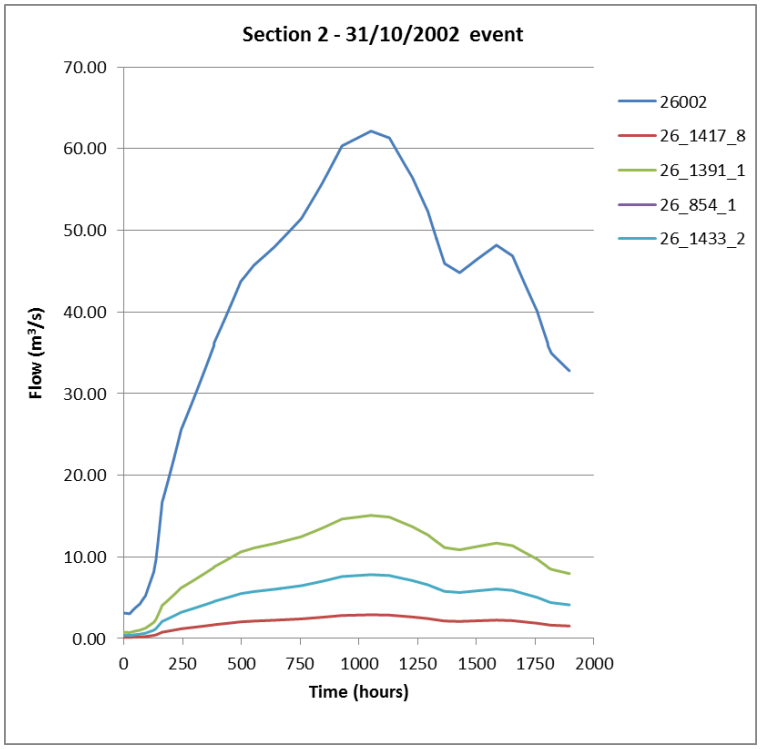

Figure B8.4 Section 2 Inflow hydrograph for the Oct 2002 Event

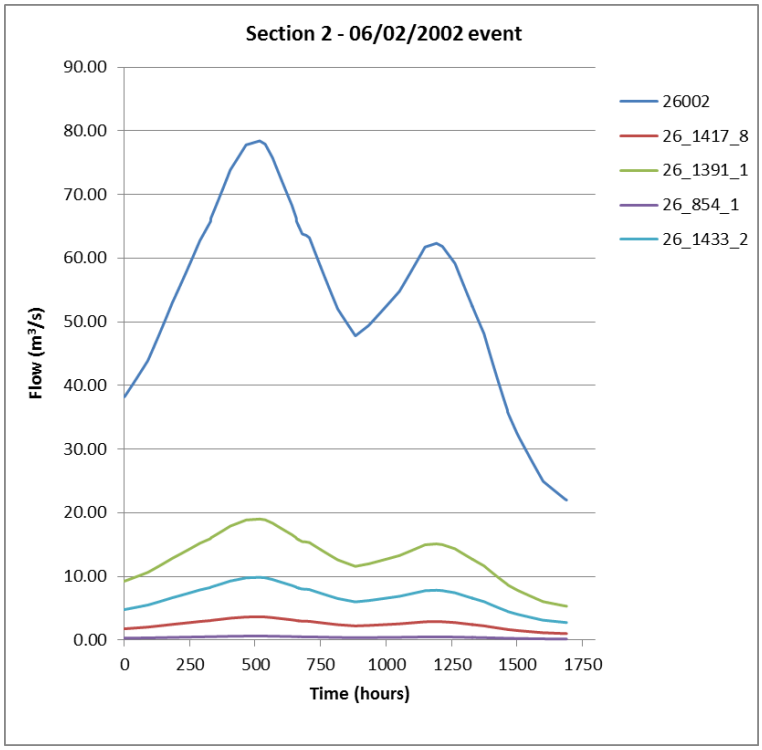

Figure B8.5 Section 2 Inflow hydrograph for the Feb 2002 Event

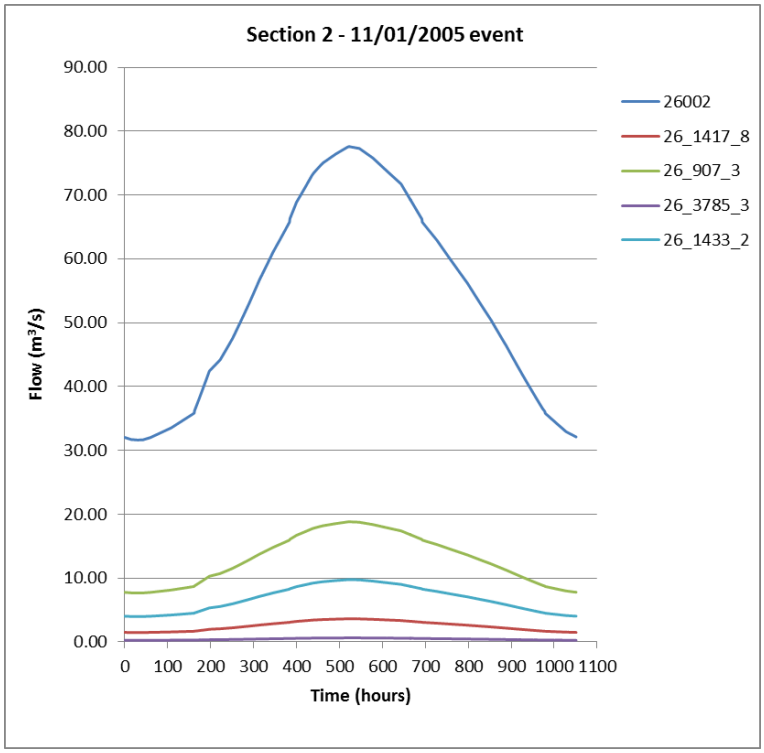

Figure B8.6 Section 2 Inflow hydrograph for the Jan 2005 Event

B8.2 Target Flows

The target flows are the total peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A, Chapter A5. The target flows at all HEP nodes for model N08 are shown in Tables B8.2 and B8.3 below. The main stem run includes the River Francis and the River Suck from the confluence with the River Francis, while the tributary run covers the upper reach of the River Suck upstream of the confluence with the River Francis.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_3795_6	16.03	23.17	27.33	31.33	36.50	40.38	44.24	53.19
26_1249_1	17.53	25.33	29.89	34.26	39.92	44.16	48.38	58.16
26_1249_3	19.49	28.17	33.23	38.09	44.38	49.10	53.79	64.67
26_1278_2	22.80	32.95	38.88	44.57	51.93	57.44	62.94	75.67
26_1279_1	24.12	34.86	41.12	47.14	54.92	60.76	66.57	80.03
26_1124_2	24.12	34.86	41.12	47.14	54.92	60.76	66.57	80.03
26_1043_1	26.06	37.66	44.44	50.94	59.35	65.65	71.93	86.48
26_3856_2	26.76	38.68	45.64	52.31	60.95	67.42	73.87	88.81
26_1175_1	28.28	40.88	48.23	55.28	64.41	71.25	78.07	93.86
26_1175_7	28.28	40.88	48.23	55.28	64.41	71.25	78.07	93.86
26_1176_1	33.33	48.18	56.84	65.15	75.91	83.97	92.01	110.62
26_1176_4	33.33	48.18	56.84	65.15	75.91	83.97	92.01	110.62
26_3909_1	47.39	61.27	70.25	78.87	90.02	98.38	106.71	125.99
26_3830_1	47.63	61.58	70.61	79.27	90.48	98.88	107.25	126.63
26_928_1	49.98	64.62	74.10	83.18	94.95	103.76	112.54	132.89
26_896_1	49.98	64.62	74.10	83.18	94.95	103.76	112.54	132.89
26_1440_6	49.98	64.62	74.10	83.18	94.95	103.76	112.54	132.89
26_4080_2	53.11	68.66	78.73	88.38	100.88	110.24	119.57	141.19
26_4082_1	58.41	75.51	86.58	97.20	110.95	121.25	131.51	155.28
26_3631_3	59.27	76.63	87.87	98.64	112.59	123.04	133.45	157.58
26_3631_11	59.27	76.63	87.87	98.64	112.59	123.04	133.45	157.58
26_1452_1	59.27	76.63	87.87	98.64	112.59	123.04	133.45	157.58
26_1452_2	59.89	77.43	88.78	99.67	113.76	124.33	134.85	159.22
26_1452_5	59.89	77.43	88.78	99.67	113.76	124.33	134.85	159.22
26_1426_1	60.15	77.77	89.17	100.11	114.26	124.87	135.44	159.92
26_1430_6	60.96	78.82	90.37	101.45	115.80	126.55	137.26	162.07
26_1417_8	62.05	80.23	91.99	103.27	117.87	128.81	139.71	164.97
26_1391_1	64.90	83.91	96.21	108.01	123.28	134.73	146.13	172.54
26_907_3	64.90	75.52	96.21	108.01	123.28	134.73	146.13	172.54
26_854_1	79.69	103.03	101.66	110.86	124.04	135.05	147.14	180.19
26_3785_3	79.69	92.73	101.66	110.86	124.04	135.05	147.14	180.19
26_1433_2	80.19	93.32	102.30	111.56	124.82	135.90	148.07	181.33
26_1402_1	87.86	102.25	112.09	122.23	136.76	148.90	162.23	198.67

Table B8.2 Target Flows at HEP Locations on the N08 Model Extent (Main Stem)

HEP	Annual Exceedance Probability

Reference	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_3787_3	6.31	9.11	10.75	12.33	14.36	15.89	17.41	20.93

Table B8.3 Target Flows at HEP Locations on the N08 Model Extent (Tributary)

B8.3 Preliminary Design Flows

To obtain the target flows shown in Tables B8.2 and B8.3, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributary independently from the critical events on the main stem, two separate runs were undertaken for each AEP. One run was to obtain the target flows in the main stem and one run was to obtain the target flows on the tributaries.

The inflow hydrographs shown in Figures B8.7 to B8.15 were derived using the procedure outlined in Chapter 2 and the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A5. Tables B8.4 and B8.5 below summarise the preliminary peak inflows at each HEP. The HEPs used are shown on Figure B8.1-a and B8.1-b.

Preliminary design inflow hydrographs of main stem run and tributary run are shown in Figures B8.7 to B8.15 for the 10%, 1% and 0.1% AEP flows.

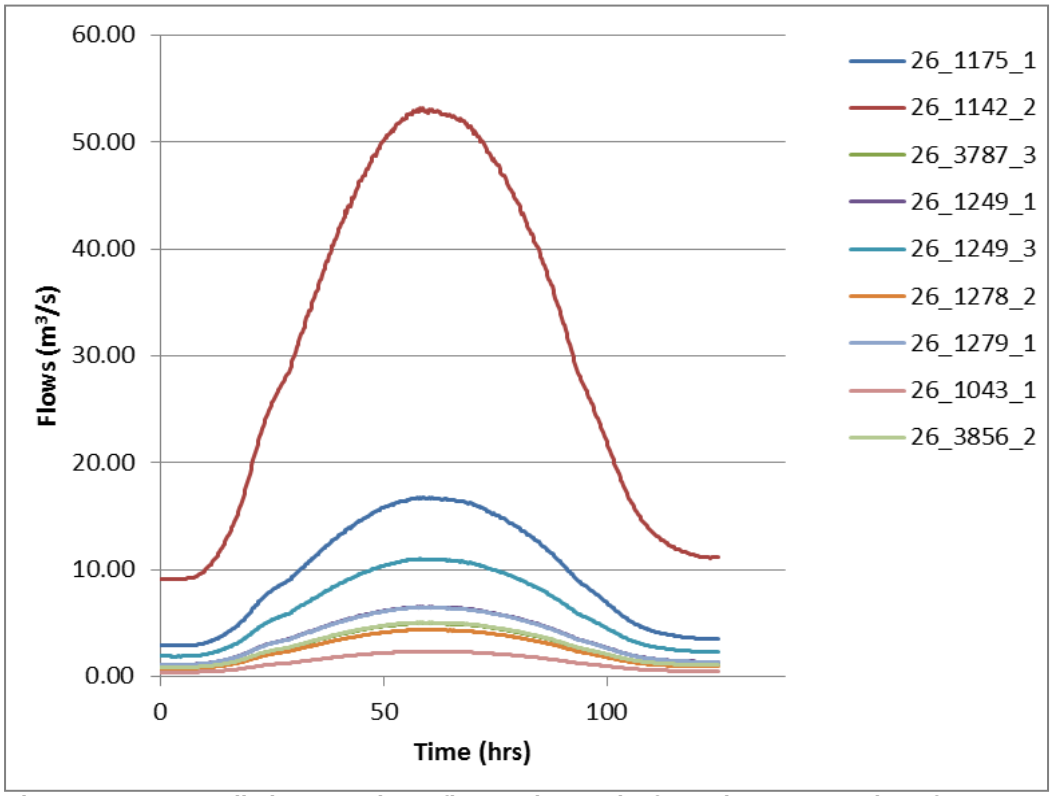

Figure B8.7 Preliminary Design Inflow Hydrographs for Main Stem Reach 1 of 0.1% AEP

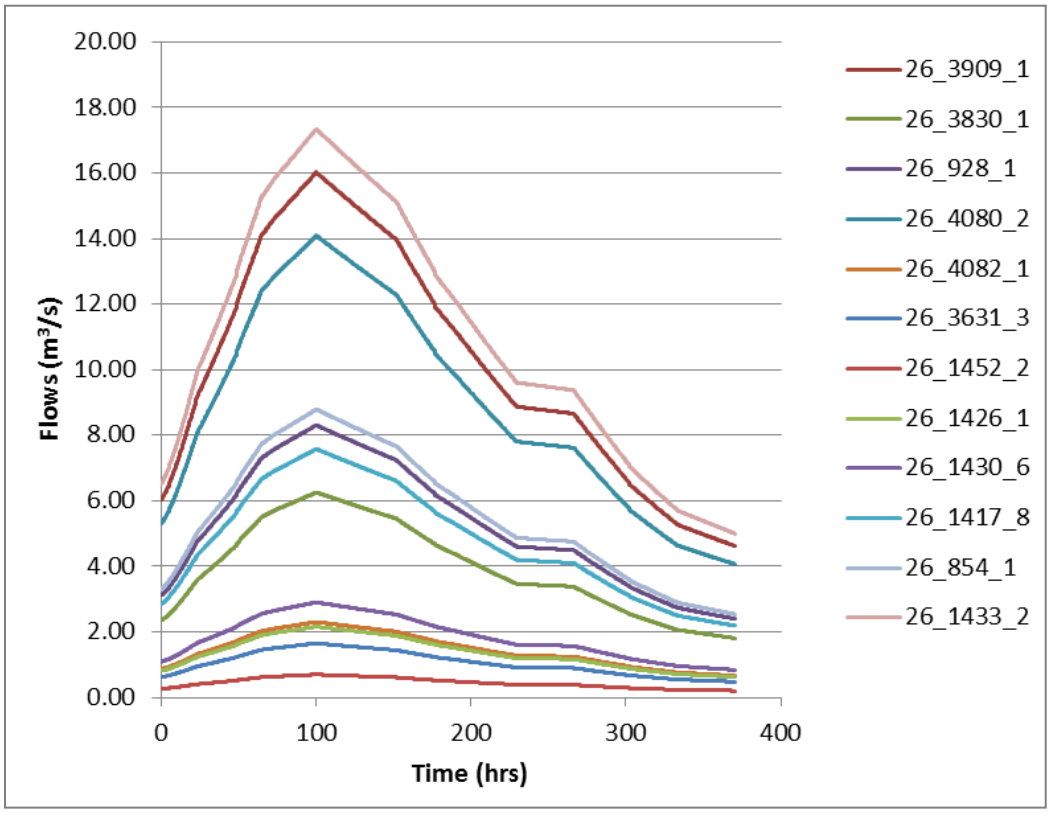

Figure B8.8 Preliminary Design Inflow Hydrographs for Main Stem Reach 2-3 of 0.1% AEP

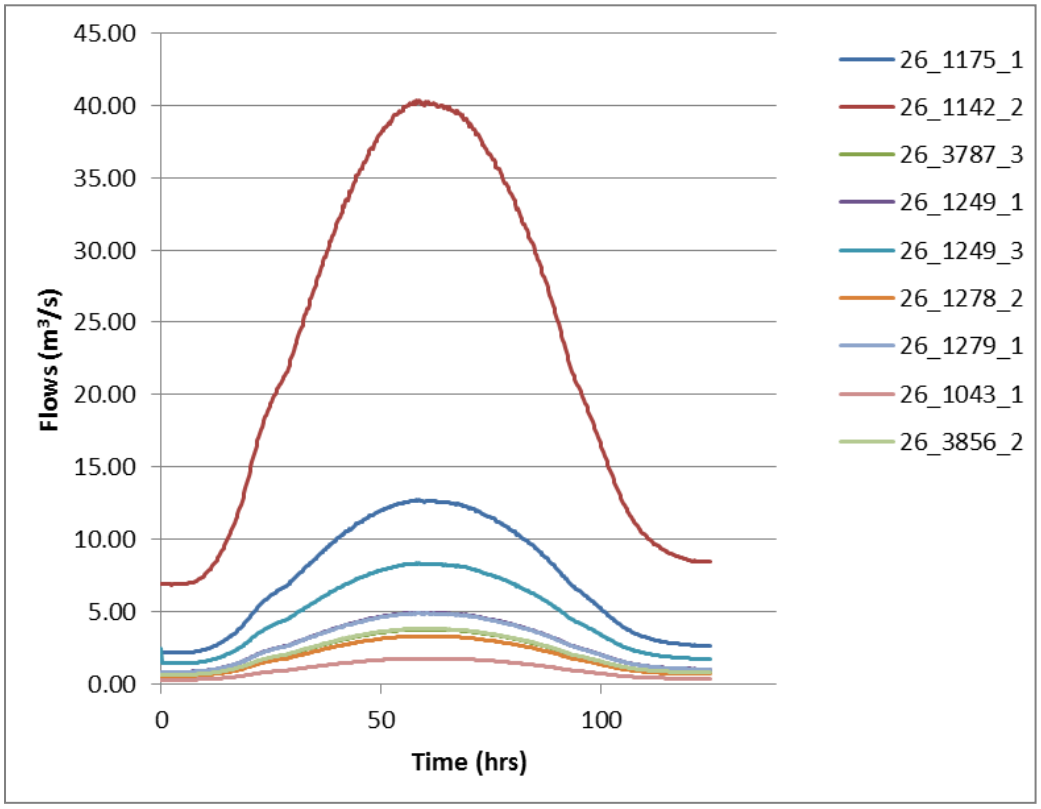

Figure B8.9 Preliminary Design Inflow Hydrographs for Main Stem Reach 1 of 1% AEP

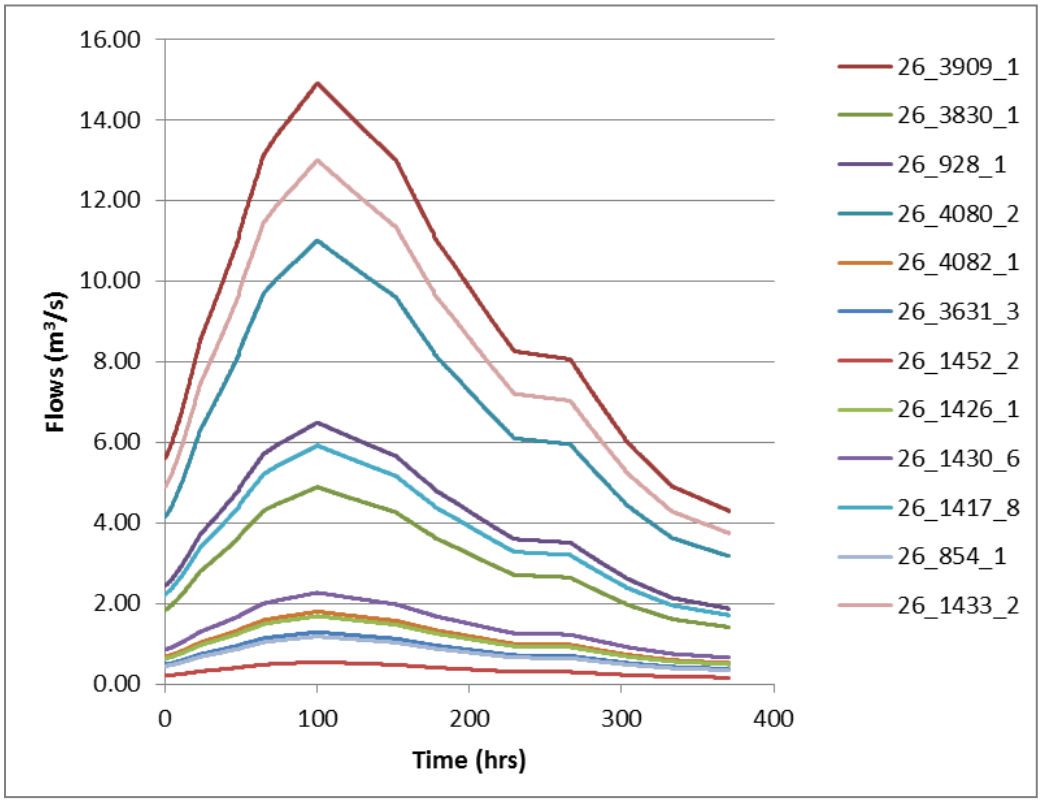

Figure B8.10 Preliminary Design Inflow Hydrographs for Main Stem Reach 2-3 of 1% AEP

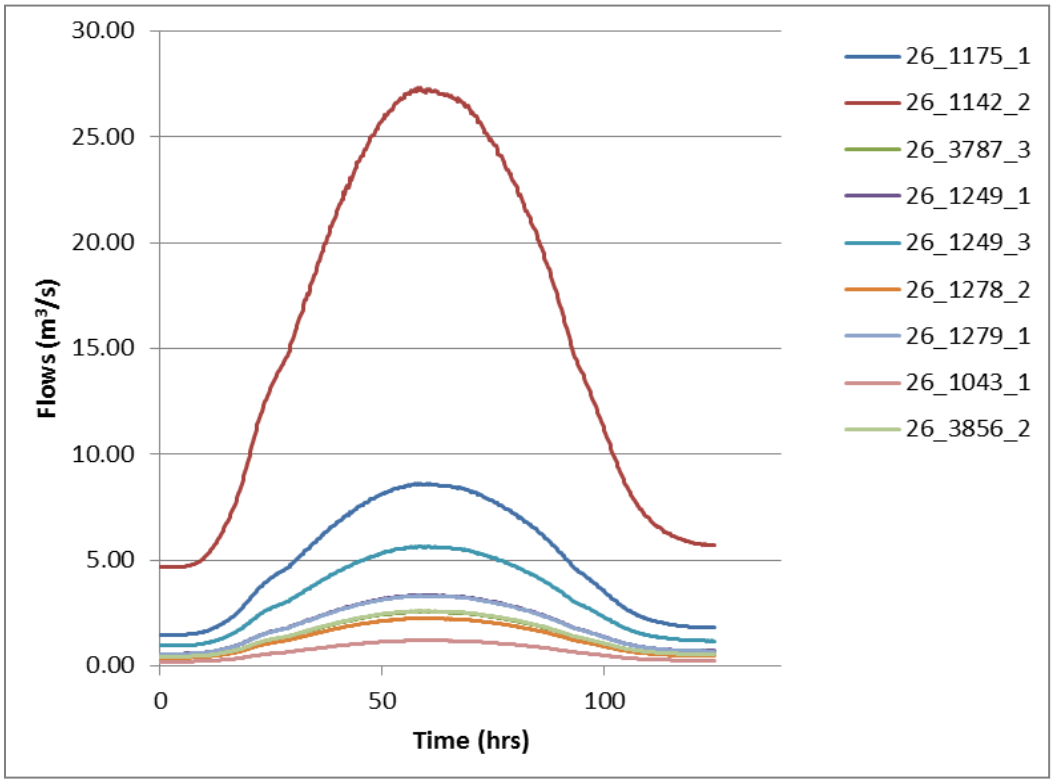

Figure B8.11 Preliminary Design Inflow Hydrographs for Main Stem Reach 1 of 10% AEP

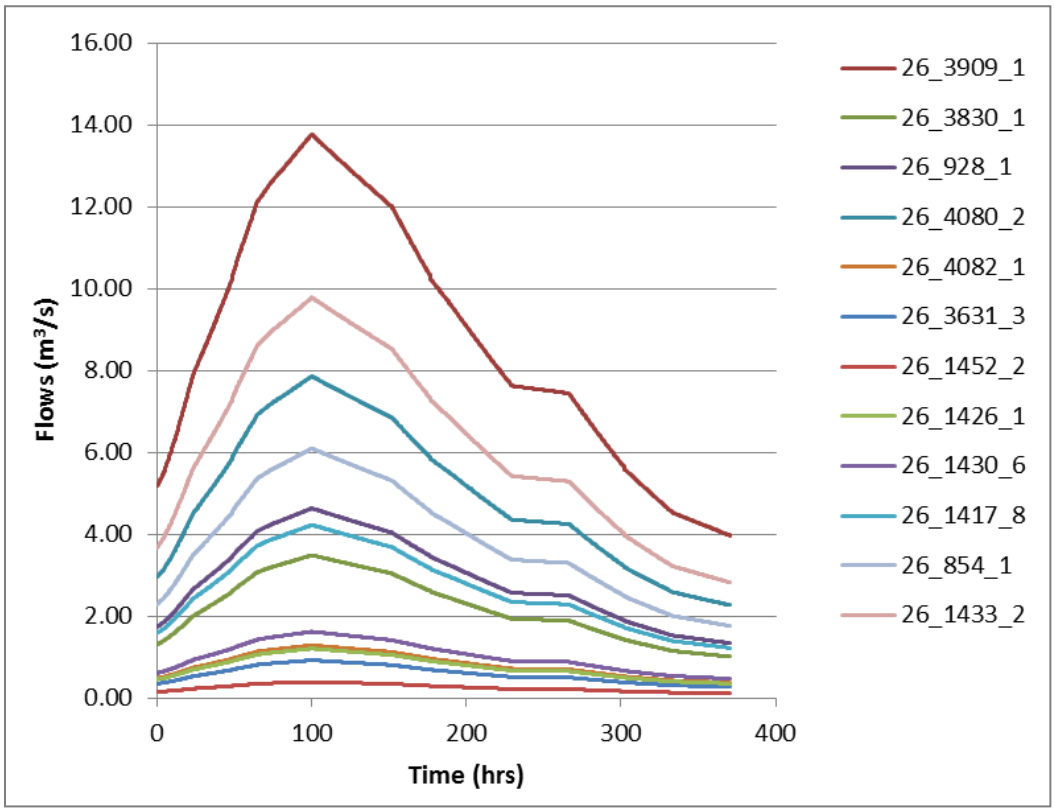

Figure B8.12 Preliminary Design Inflow Hydrographs for Main Stem Reach 2-3 of 10% AEP

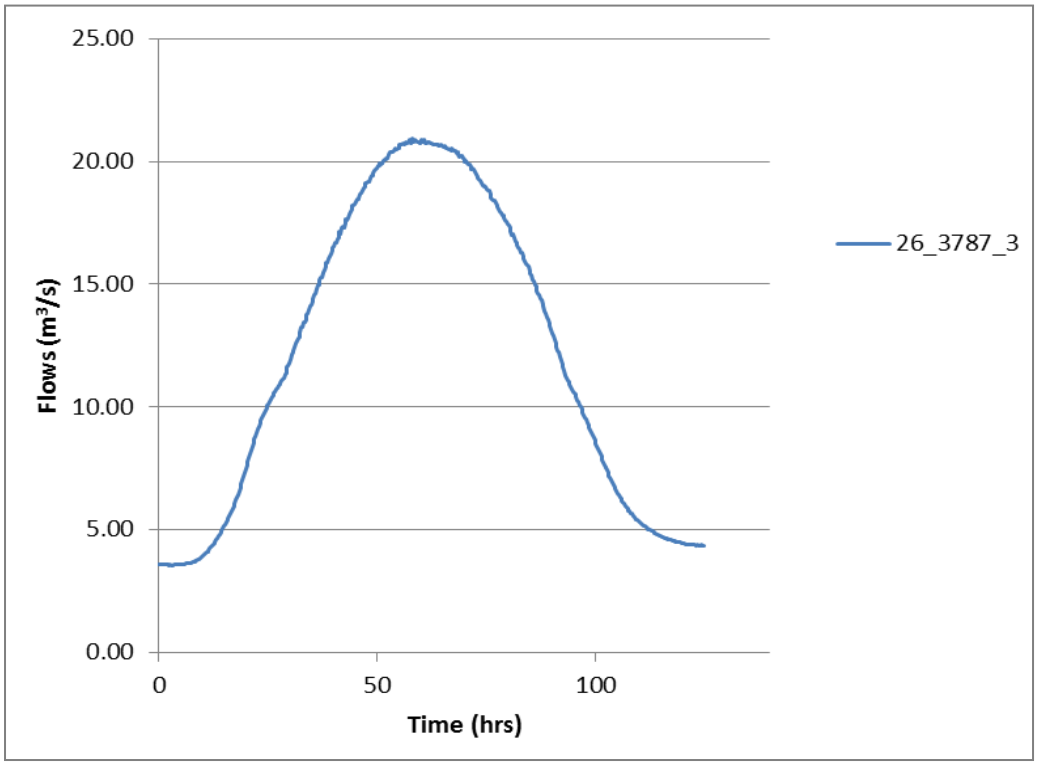

Figure B8.13 Preliminary Design Inflow Hydrographs for Tributary (Top of Suck) of 0.1% AEP

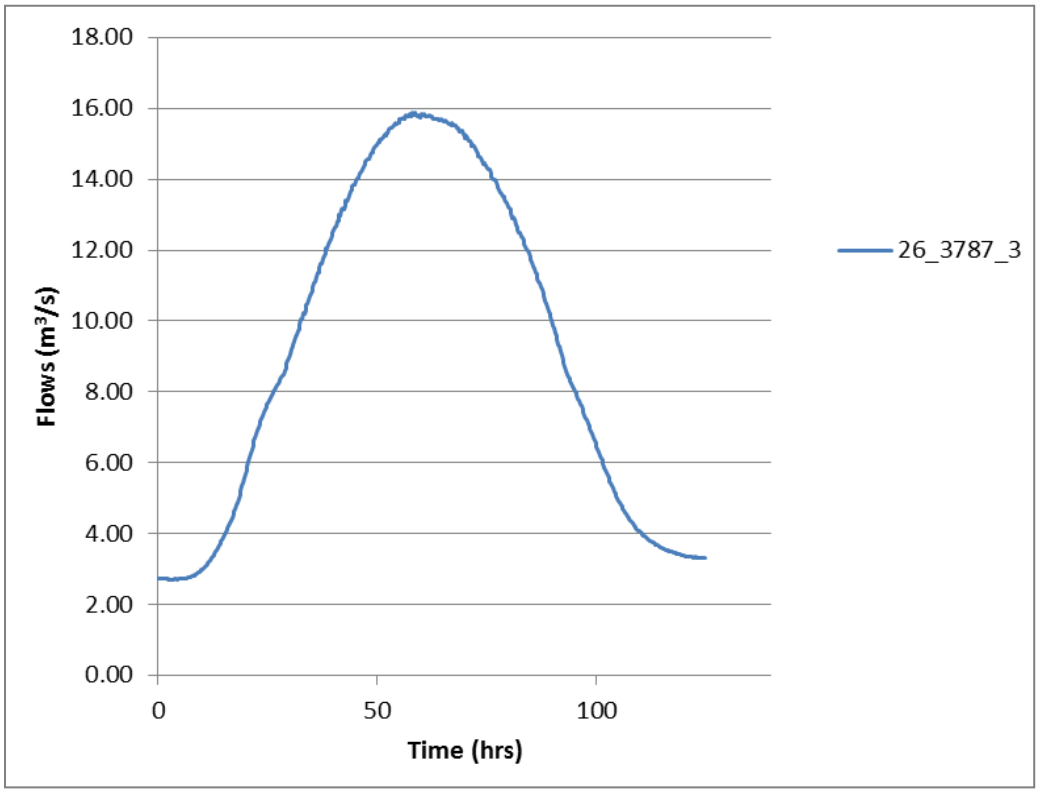

Figure B8.14 Preliminary Design Inflow Hydrographs for Tributary (Top of Suck) of 1% AEP

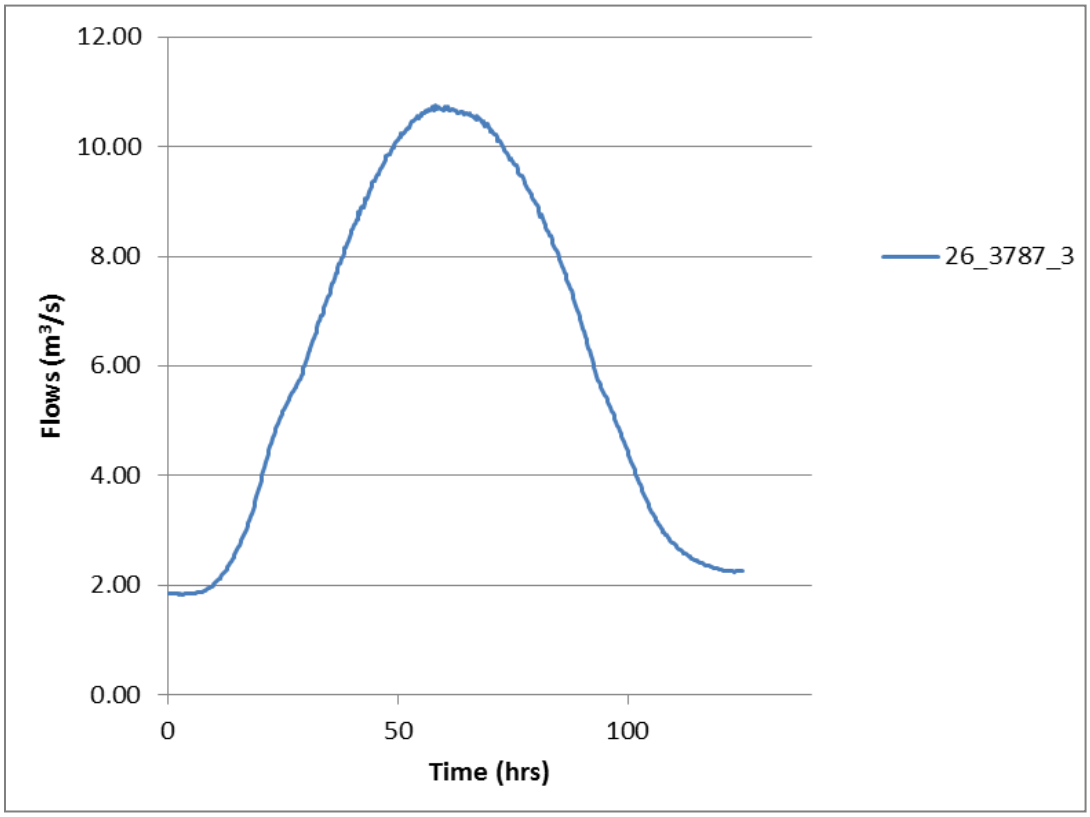

Figure B8.15 Preliminary Design Inflow Hydrographs for Tributary (Top of Suck) of 10% AEP

HEP reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_1142_2	16.03	23.17	27.33	31.33	36.50	40.38	44.24	53.19
26_3787_3	1.50	2.17	2.55	2.93	3.41	3.77	4.14	4.97
26_1249_1	1.96	2.83	3.34	3.83	4.47	4.94	5.41	6.51
26_1249_3	3.31	4.79	5.65	6.48	7.54	8.35	9.14	10.99
26_1278_2	1.32	1.90	2.24	2.57	3.00	3.31	3.63	4.37
26_1279_1	1.94	2.81	3.31	3.80	4.42	4.89	5.36	6.45
26_1043_1	0.70	1.02	1.20	1.37	1.60	1.77	1.94	2.33
26_3856_2	1.52	2.20	2.59	2.97	3.46	3.83	4.20	5.05
26_1175_1	5.05	7.30	8.61	9.87	11.50	12.72	13.94	16.76
26_3909_1	14.30	13.41	13.77	14.12	14.57	14.90	15.24	16.02
26_3830_1	2.35	3.04	3.49	3.91	4.47	4.88	5.29	6.25
26_928_1	3.12	4.04	4.63	5.20	5.93	6.48	7.03	8.30
26_4080_2	5.30	6.85	7.86	8.82	10.07	11.00	11.93	14.09
26_4082_1	0.86	1.12	1.28	1.44	1.64	1.79	1.95	2.30
26_3631_3	0.62	0.80	0.92	1.03	1.18	1.28	1.39	1.65
26_1452_2	0.26	0.34	0.39	0.43	0.50	0.54	0.59	0.69
26_1426_1	0.81	1.05	1.20	1.35	1.54	1.68	1.82	2.15
26_1430_6	1.09	1.41	1.62	1.81	2.07	2.26	2.45	2.90
26_1417_8	2.85	3.68	4.22	4.74	5.41	5.92	6.42	7.58
26_854_1	15.29	28.10	6.09	3.55	1.54	1.18	1.94	8.79
26_1433_2	7.67	8.93	9.78	10.67	11.94	13.00	14.16	17.34

Table B8.4 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N08 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
26_3787_3	6.31	9.11	10.75	12.33	14.36	15.89	17.41	20.93

Table B8.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N08 Model Extent (Tributary)

B9 Model N09

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods and the inflow design hydrographs required to ensure that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B9.1, and shown on Figure B9.1.

Model Attribute	Comment
Rivers included in model	River Suck River Bunowen-Ahascragh River Mackney River Deerpark River Ballyhugh River Cleaghbeg
Areas for Further Assessment (AFA)	Ballinasloe, Ahascragh

Table B9.1 Model Extent coverage

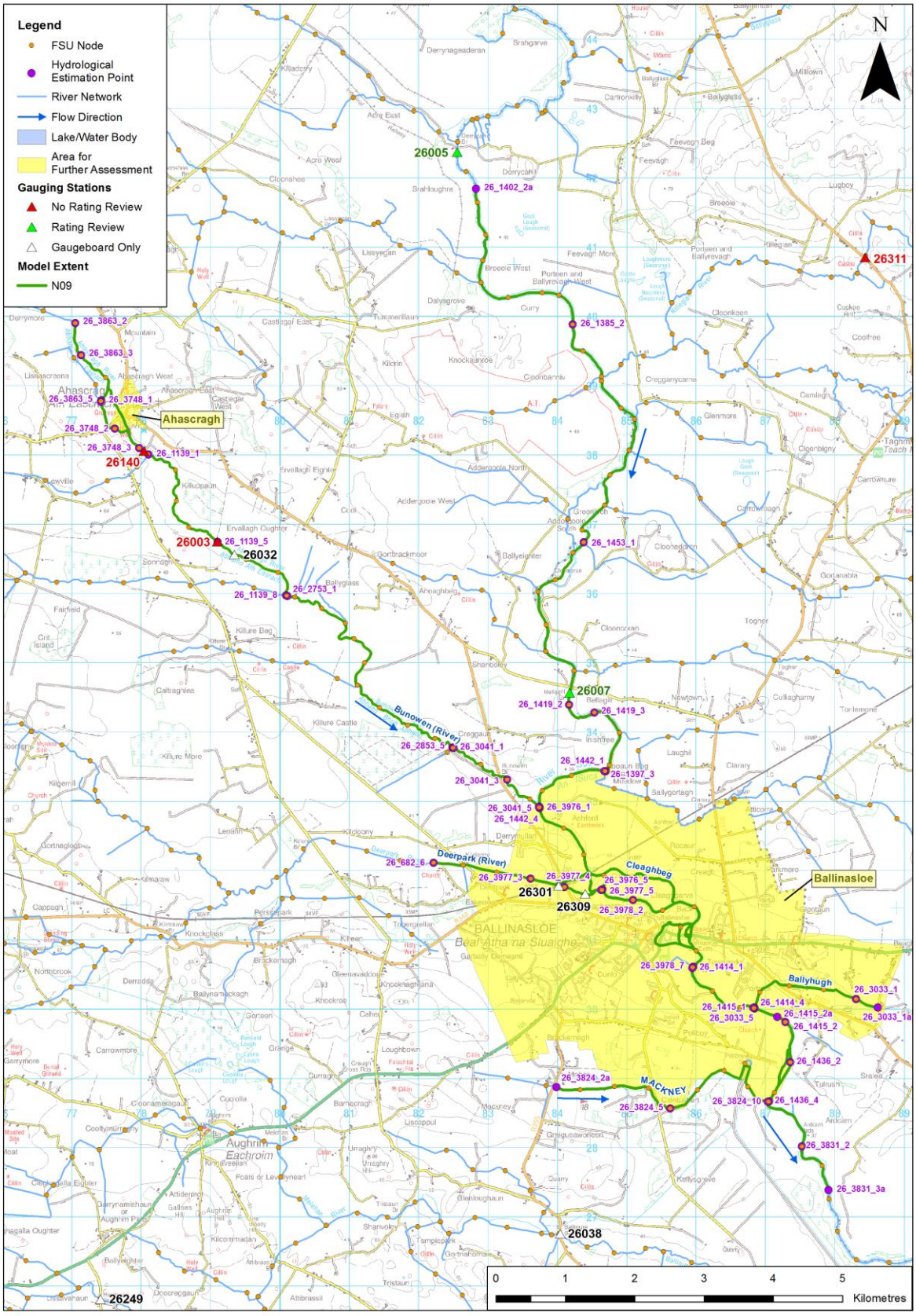

Figure B9.1 N09 Model Extent

B4.1 Hydrology for Hydraulic Model Calibration

There was sufficient hydrometric data at the gauging stations of 26005, (Derrycahill) and 26007 (Bellagill) available for calibration and verification against a number of flood events (Table B9.2).

A broad verification (sense check) of the modelled design extents was undertaken via comparison to the observed flood levels\extents of the 10 November 2009 flood for which an approximate rarity of 1 in 50 years (2% AEP) has been assigned (RCC, August 2010).

	Calibration or Verification	Date of Event	Peak Flow (m^3/s)
Out of bank	Calibration	21/11/2009	179.49
	Verification	26/12/1999	108.66
In bank	Calibration	16/06/1993	88.26
	Verification	25/11/1982	94.13

Table B9.2 Events used in the Calibration and Verification of the hydraulic model upstream of Ballinasloe based on Hydrometric data from 26005 and 26007.

More details on the selection of the calibration/verification events is provided in the calibration strategy sheets in Appendix F.

The hydraulic model calibration process is detailed in the hydraulic modelling report for N09. The calibration did not affect the design hydrology.

B4.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology detailed in Chapter A1 in Appendix A. The target flows at the HEP nodes for model N09 are shown in Tables B9.3 and B9.4.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_1385_2	86.4	101	110	120	135	146	160	195
26_1453_1	89.1	108	122	137	161	183	209	288
26_1419_2	89.1	108	122	137	161	183	209	288
26_1419_3	89.1	108	122	137	161	183	209	288
26_1397_3	89.1	108	122	137	161	183	209	288
26_1442_1	89.7	108	122	138	163	185	211	290
26_1442_4	89.8	108	123	138	163	185	211	291
26_3976_1	107	129	146	164	193	220	251	345
26_3976_5	107	129	146	165	194	220	251	345
26_3978_2	113	136	154	174	204	232	264	364
26_3978_7	113	136	154	174	204	232	264	364
26_1414_1	113	136	154	174	204	232	264	364
26_1414_4	113	136	154	174	204	232	264	364

26_1415_1	113	136	154	174	204	232	264	364
26_1415_2	113	136	154	174	204	232	264	364
26_1436_2	113	136	154	174	204	232	264	364
26_1436_4	113	137	155	175	206	234	266	367
26_3831_2	114	138	156	176	207	235	268	370

Table B9.3 Target Flows (m^3/s) at HEP Locations on the N09 Model Extent (Main Stem).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3033_1	0.26	0.35	0.40	0.46	0.54	0.59	0.65	0.77
26_3033_5	0.47	0.63	0.74	0.84	0.98	1.1	1.2	1.4
26_3824_5	0.67	0.91	1.1	1.2	1.4	1.6	1.7	2.0
26_3824_10	1.2	1.6	1.8	2.1	2.4	2.7	2.9	3.5
26_3863_3	13.5	16.3	18.1	19.9	22.2	23.9	25.6	29.5
26_3863_5	13.5	16.3	18.1	19.9	22.1	23.9	25.6	29.5
26_3748_1	13.9	16.7	18.6	20.4	22.7	24.5	26.2	30.3
26_3748_2	14.8	17.9	19.9	21.8	24.3	26.2	28.0	32.4
26_3748_3	14.9	17.9	20.0	21.9	24.4	26.3	28.2	32.5
26_1139_1	15.3	18.4	20.5	22.4	25.0	26.9	28.9	33.3
26_1139_5	15.4	18.6	20.7	22.7	25.3	27.2	29.1	33.6
26_1139_8	15.7	18.9	21.0	23.1	25.7	27.7	29.7	34.2
26_2753_1	17.5	21.0	23.4	25.7	28.6	30.8	33.0	38.1
26_2853_5	17.5	21.1	23.5	25.7	28.7	30.9	33.1	38.2
26_3041_1	17.7	21.4	23.8	26.1	29.1	31.3	33.6	38.7
26_3041_3	18.0	21.7	24.1	26.4	29.5	31.7	34.0	39.3
26_3041_5	18.1	21.9	24.3	26.7	29.7	32.0	34.3	39.6
26_3977_3	10.8	13.6	15.4	17.2	19.5	21.2	22.9	26.9
26_3977_4	10.9	13.7	15.5	17.3	19.6	21.3	23.1	27.1
26_3977_5	10.9	13.7	15.5	17.3	19.6	21.3	23.1	27.1

Table B9.4 Target Flows (m^3/s) at HEP Locations on the N09 Model Extent (Tributaries)

B4.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B9.3 and B9.4, an initial set of inflow hydrographs was produced and run through the model.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the Qmed adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A1.

The HEPs are shown on Figure B9.2. Tables B2.5 and B2.6 present the peak values of the preliminary lateral inflows inserted into the model in the reach immediately upstream of the HEP in the hydraulic model for the main stem and tributary runs.

Preliminary design inflow hydrographs are shown in Figures B9.2, B9.3, B9.4 and B9.5 for the 1% AEP design runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_1402_2a	86.4	101	110	120	135	146	160	195
26_1385_2	2.6	7.0	11.4	17.0	26.9	36.9	49.6	92.7
26_1453_1	17.6	21.3	24.1	27.2	32.0	36.3	41.4	57.0
26_3976_1	5.9	7.2	8.10	9.14	10.8	12.2	13.9	19.2

Table B9.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N09 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3033_1a	0.26	0.35	0.40	0.46	0.54	0.59	0.65	0.77
26_3033_1	0.21	0.28	0.33	0.38	0.44	0.49	0.53	0.64
26_1415_2	0.33	0.33	0.35	0.39	0.47	0.56	0.69	1.17
26_3824_2a	0.67	0.91	1.1	1.2	1.4	1.6	1.7	2.0
26_3824_5	0.48	0.65	0.76	0.87	1.01	1.11	1.21	1.45
26_3863_2	13.51	16.3	18.1	19.9	22.2	23.9	25.6	29.5
26_3863_3	0.36	0.43	0.48	0.52	0.58	0.63	0.67	0.78
26_3748_1	0.96	1.2	1.3	1.4	1.6	1.7	1.8	2.1
26_3748_2	0.43	0.52	0.58	0.64	0.71	0.76	0.82	0.94
26_1139_1	0.15	0.18	0.20	0.22	0.25	0.27	0.29	0.33
26_1139_5	0.28	0.34	0.38	0.41	0.46	0.50	0.53	0.61
26_1139_8	1.78	2.1	2.4	2.6	2.9	3.1	3.4	3.9
26_2753_1	0.27	0.33	0.37	0.40	0.45	0.48	0.52	0.60
26_3041_1	0.24	0.29	0.32	0.35	0.39	0.42	0.45	0.52
26_3041_3	0.17	0.20	0.22	0.24	0.27	0.29	0.31	0.36
26_682_6	10.80	13.6	15.4	17.2	19.5	21.2	22.9	26.9
26_3977_3	0.08	0.10	0.11	0.12	0.14	0.15	0.17	0.19

Table B9.6 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N09 Model Extent (Tributaries)

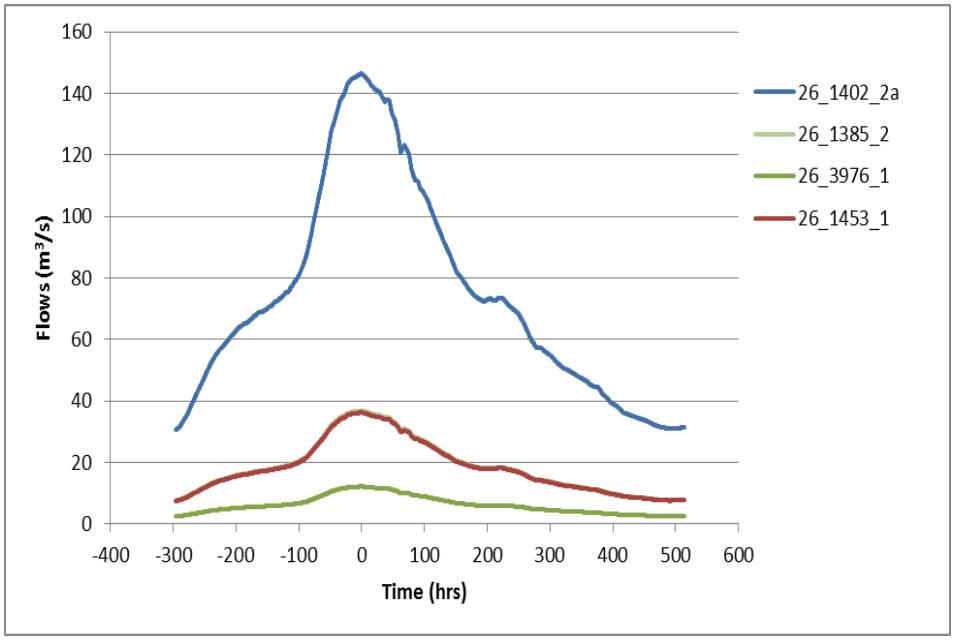

Figure B9.2 N09 Preliminary Design Inflow Hydrographs for 1% AEP (Main Stem)

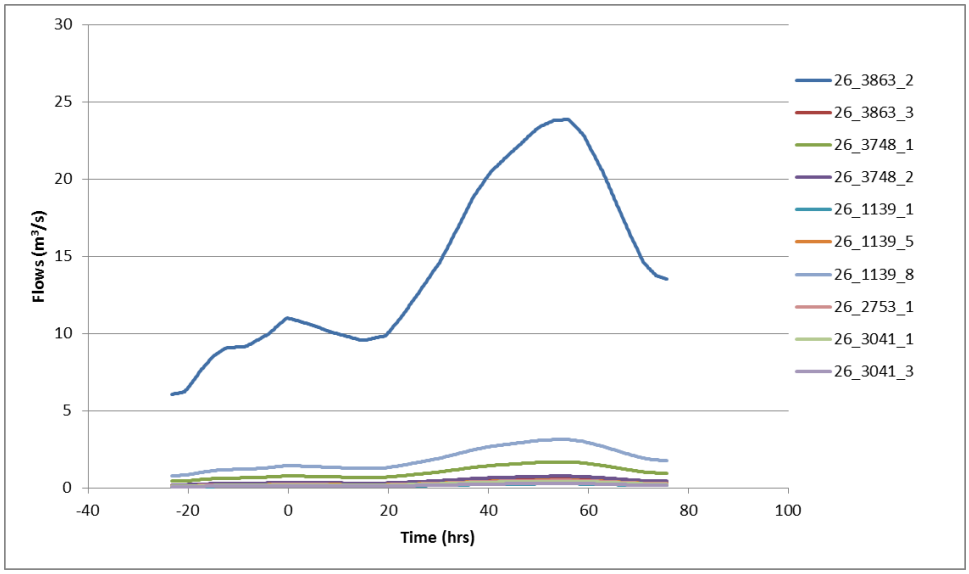

Figure B9.3 N09 Preliminary Design Inflow Hydrographs for 1% AEP (Tributary Bunowen-Ahascragh)

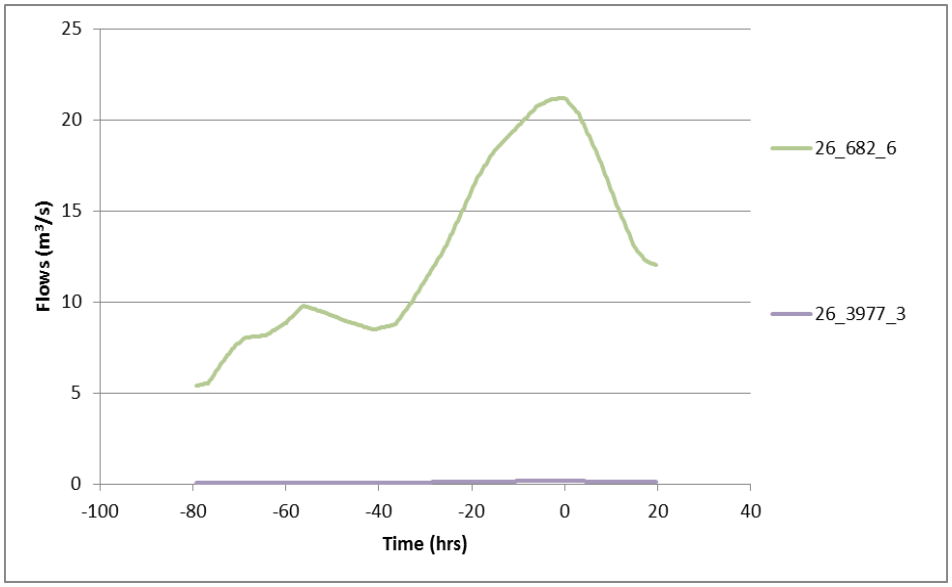

Figure B9.4 N09 Preliminary Design Inflow Hydrographs for 1% AEP (Tributary Deerpark)

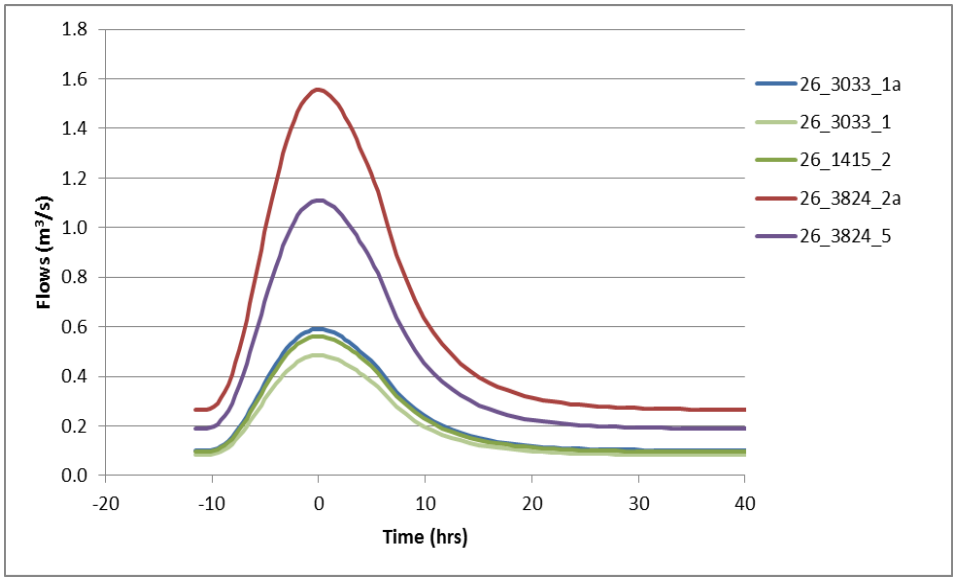

Figure B9.5 & Mackney) N09 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries Ballyhugh

B4.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B9.4 and B9.5 for calibrating the model to the HEP target flows presented in Tables B9.2 and B9.3.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model 09.

B10 Model N10

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods and the inflow design hydrographs required to ensure that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B10.1, and shown on Figures B10.1a to d.

Model Attribute	Comment
Watercourses / Water bodies included in model	River Shannon Culiaghy tributary River Hind (downstream extent only) River Inny (or Owenacharra) (d/s extent only) Garrycastle tributary River Cross and Cuilglass tributary Fardrum tributary River Suck (downstream extent only) River Brosna (downstream extent only) River Little Brosna (downstream extent only) Lough Ree
Areas for Further Assessment (AFA)	Athlone, Shannon Harbour, Cloondara
Individual Risk Receptors (IRR)	Lanesboro (Power Station), Shannonbridge (Power Station)
Hydrological subcatchments (see Main Report and Appendix A)	Upper Shannon (upstream of Lough Ree) (Chapter A1), Inny (Chapter A2), Hind (Chapter A3), Brosna (Chapter A4), Suck (Chapter A5) Lower and Middle Shannon (from Lough Ree to the outflow into the Shannon Estuary) (Chapter A6), Little Brosna (Chapter A7)

Table B10.1 Model Extent coverage

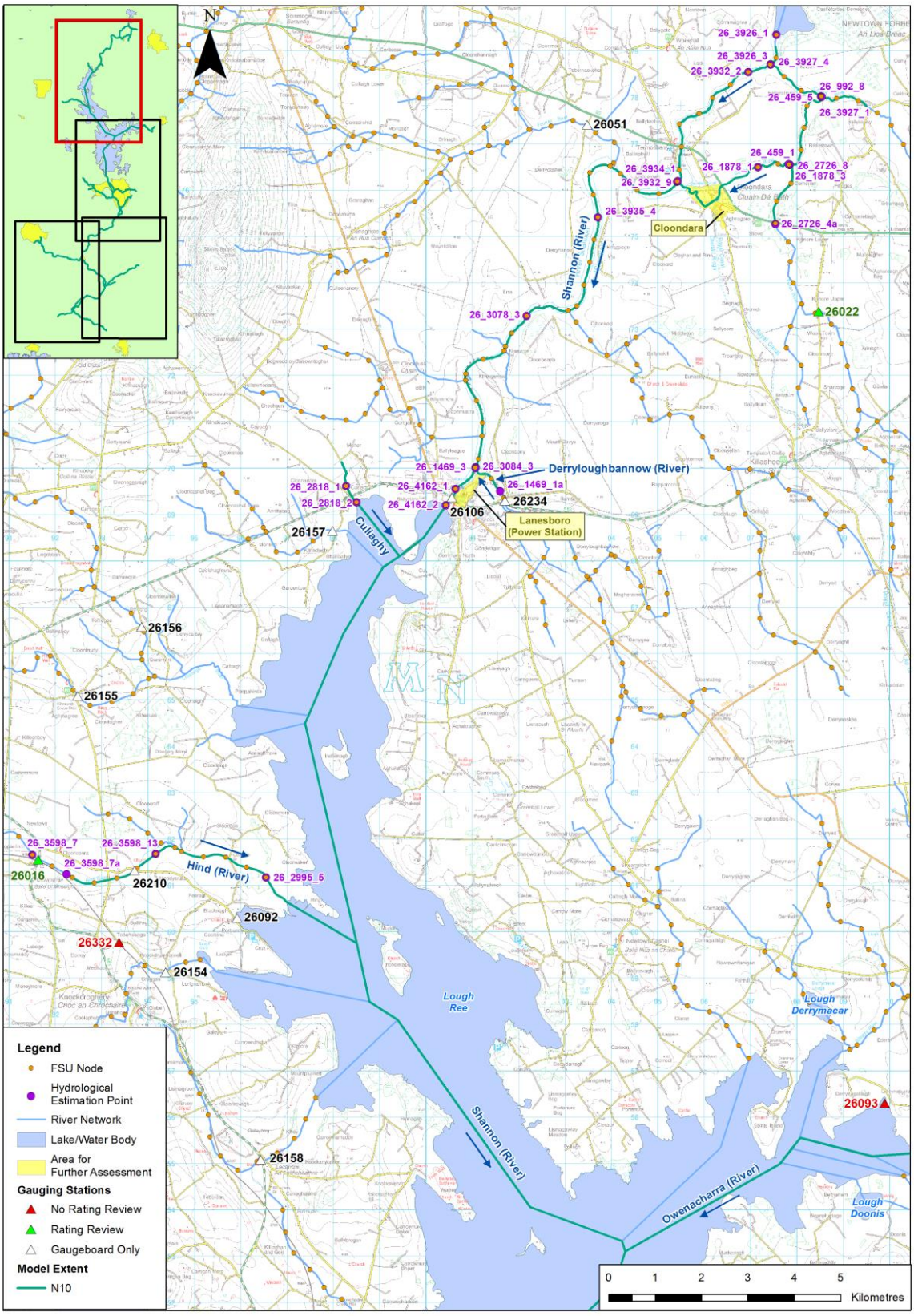

Figure B10.1a N10 Model Extent [1]

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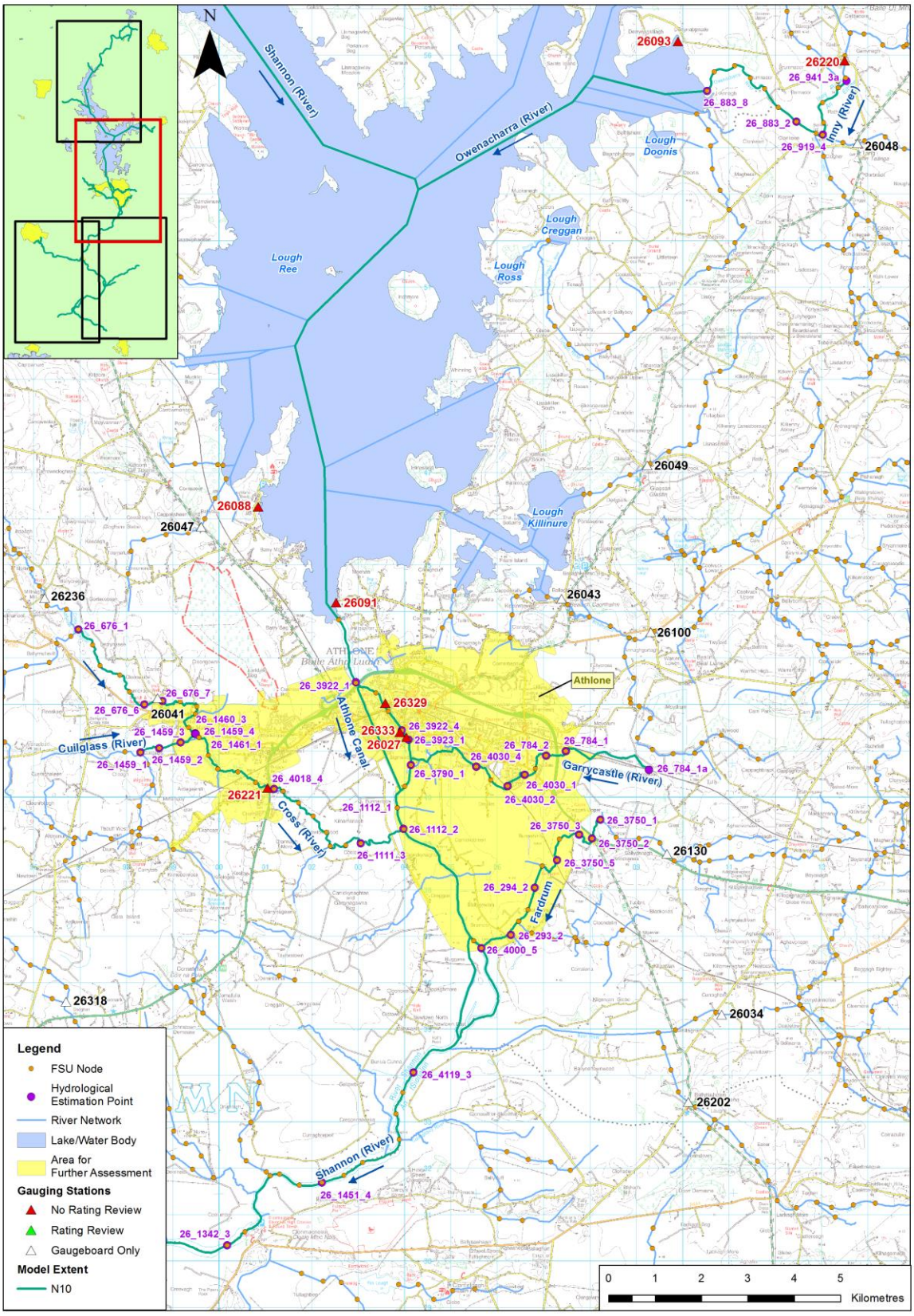

Figure B10.1b N10 Model Extent

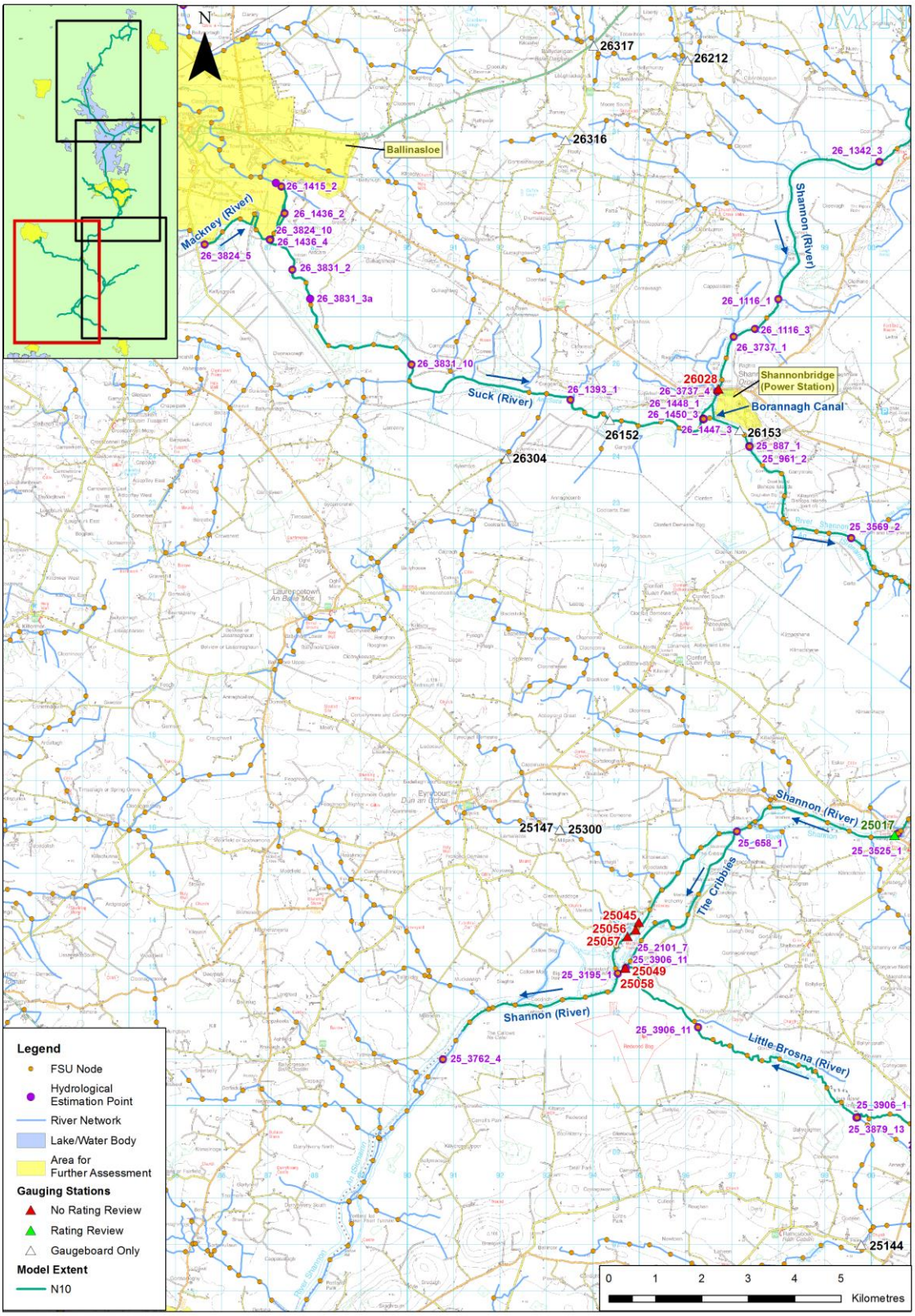

Figure B10.1c N10 Model Extent

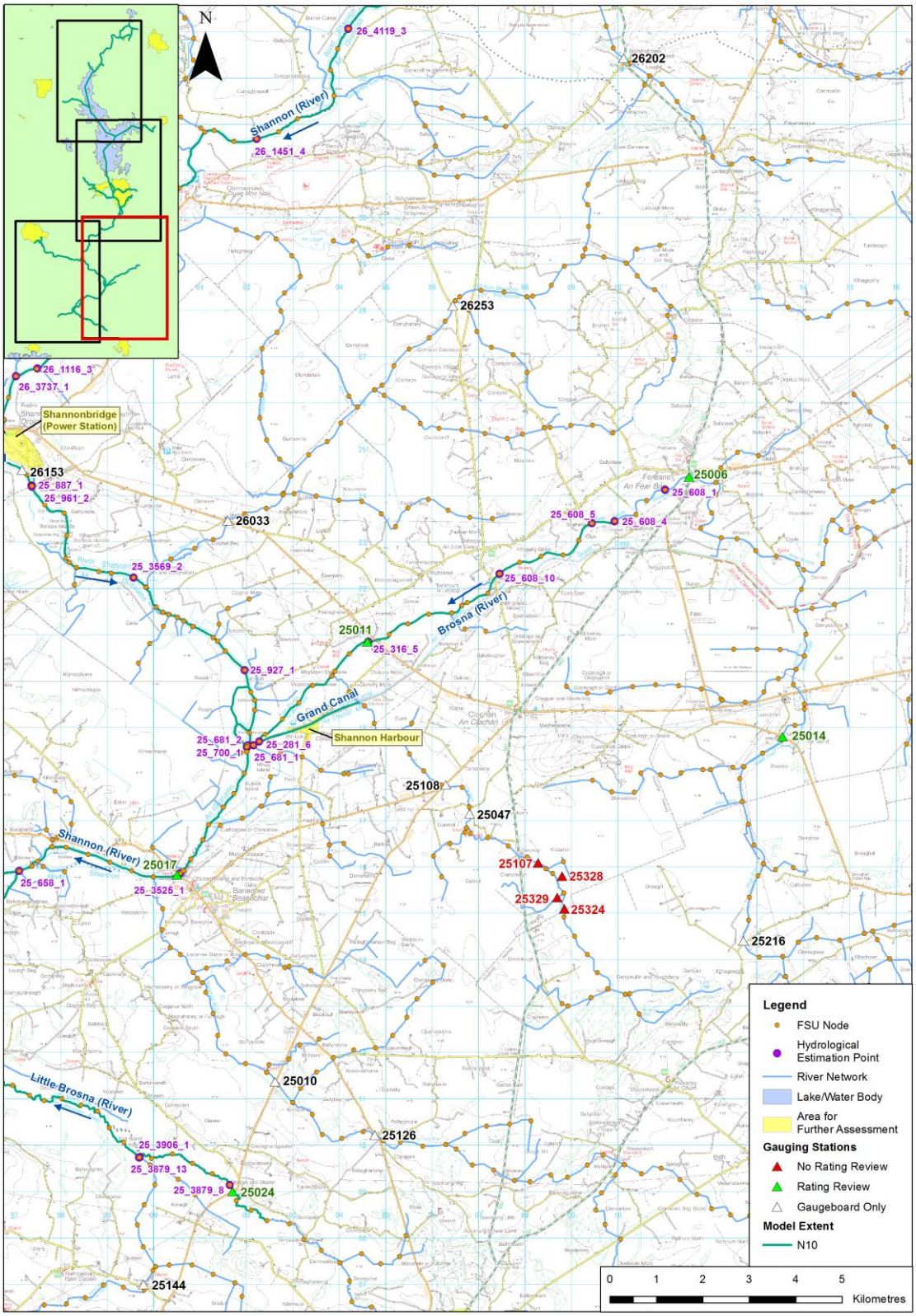

Figure B10.1d N10 Model Extent

B10.1 Hydrology for Hydraulic Model Calibration

Model N10 was calibrated using historic flood information for the November/December 2009 flood. Gauged flow and level data was used to undertake this calibration.

The section of N10 between Lough Ree and Portumna was calibrated by applying flow hydrographs to the model at gauged tributaries into the Shannon (Brosna, Suck, Little Brosna). As Portumna was a small distance downstream of the N10 extent the model was extended to include the Portumna level gauge. The November 2009 calibration run included allowances for ungauged catchments (using a pivotal catchment hydrograph shape as a typical shape, scaled up or down proportional to catchment area).

The model was initially truncated immediately downstream of Lough Ree, upstream of Athlone Weir. The observed flow at Athlone gauging station was included as the upstream inflow. This allowed for a comparison of modelled and observed flows and water levels downstream of Lough Ree, confirming the accuracy of the schematisation of Athlone Weir and river channel/floodplain roughness. Water levels were compared at Athlone Weir (U/S and D/S), Shannonbridge, Banagher and Meelick Weir.

Once the weir arrangement at the downstream end of Lough Ree was found to be well represented, the lake was reinstated into the model schematisation. An estimate of the total inflow (peak and hydrograph) into the lake from the upstream River Shannon was obtained from the N02 model of the Shannon upstream of Lough Ree from a run that produced a good match with the 2009 flood extent. In addition, an initial estimate of the total inflow hydrograph from lateral tributaries into Lough Ree was obtained using the hydrograph shape at Ballymurray GS (26016) on the River Hind by scaling this hydrograph up proportionally to account for ungauged catchments, combined with the gauged hydrograph from the Inny. Direct rainfall onto the lake during the event was also accounted for.

As part of the calibration process the lateral inflows into Lough Ree were then reduced to replicate the observed water levels in Lough Ree. The result of this calibration was used to determine the lateral design inflows into Lough Ree, see Section B10.3 below.

The design run flood outlines were compared with the November 2009 flood outline to verify the design run model results throughout the N10 domain. The results of this comparison are discussed in the hydraulic modelling report for N10.

B10.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design flood estimation process detailed in Appendix A, Chapters A1- A7 for the various subcatchments that the N10 model partly covers. The target flows at the HEP nodes for model N10 are shown in Tables B10.2 to B10.11.

The peak flow estimation process for the N10 main stem (River Shannon) and tributaries is described in Appendix A, in the chapters indicated in Table B10.1 above.

To get detail on the design peak flows on the Little Brosna (the downstream end of which is part of the N10 model), the reader is referred to Chapter A7. However, to understand the inflow allowed for from the Little Brosna to obtain the critical flood on the River Shannon, Chapter A6 should be consulted.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3934_1*	163	198	222	253	281	307	333	395
26_3935_4	170	205	231	263	292	319	346	411
26_3078_3	172	208	234	267	296	324	351	416
26_3084_3	172	209	235	267	297	324	352	417
26_4162_1	175	211	237	271	300	328	356	423
26_4162_2	175	211	238	271	301	329	357	423

** HEP nodes 26_3932_2, 26_3932_9, 26_1873_1 and 26_1873_3 upstream of HEP node 26_3934_1 do not have target flows due to a hydraulic flow split; the proportion of flow in each channel is determined by the hydraulic model, not by the hydrological analysis.*

Table B10.2 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Main Stem) (Upper Shannon Reach 4).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3922_1	239	275	307	337	377	406	436	504
26_3922_4	240	276	308	338	377	407	436	505
26_3923_1	240	276	308	338	377	407	436	505
26_3790_1	240	276	308	338	377	407	436	505
26_1112_2	240	276	308	338	377	407	436	505
26_4000_5	246	283	316	347	387	418	448	518
26_4119_3	252	290	324	356	397	429	460	531
26_1451_4	254	292	326	358	400	431	462	535
26_1342_3	255	293	327	359	401	432	464	536
26_3737_1	259	298	332	365	407	439	471	544
26_3737_4	259	298	332	365	408	440	471	545
26_1450_3	259	298	333	365	408	440	472	546

Table B10.3 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Main Stem) (Lower/Middle Shannon Reach 1).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_1448_1	354	408	455	500	558	602	645	746
26_961_2	354	408	455	500	558	602	645	746
25_887_1	354	408	455	500	558	602	645	746
25_3569_2	356	409	456	501	560	604	647	748
25_927_1	362	416	464	510	570	614	659	762

Table B10.4 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Main Stem) (Lower/Middle Shannon Reach 2).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_700_1	429	494	551	605	676	729	781	903
25_3525_1	429	494	551	605	676	729	781	903
25_658_1	436	502	560	615	687	741	794	919
25_3195_1	469	540	602	662	739	796	854	987

Table B10.5 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Main Stem) (Lower/Middle Shannon Reach 3).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_2818_2	1.32	1.71	1.97	2.22	2.55	2.79	3.03	3.59
26_1469_3	7.35	9.44	10.8	12.1	13.9	15.2	16.4	19.4
26_784_1	0.30	0.47	0.59	0.70	0.85	0.95	1.06	1.31
26_784_2	0.40	0.63	0.79	0.94	1.14	1.28	1.43	1.77
26_4030_1	0.75	1.20	1.49	1.78	2.15	2.42	2.70	3.33
26_4030_2	1.04	1.66	2.07	2.46	2.97	3.36	3.74	4.62
26_4030_4	1.65	2.64	3.29	3.92	4.73	5.34	5.95	7.35
26_676_6	5.40	6.80	7.73	8.62	9.78	10.6	11.5	13.5
26_676_7	5.40	6.80	7.73	8.62	9.78	10.6	11.5	13.5
26_1460_3	5.57	7.01	7.97	8.89	10.1	11.0	11.9	13.9
26_1461_1	7.17	9.04	10.3	11.5	13.0	14.1	15.3	17.9
26_4018_4	7.55	9.51	10.8	12.1	13.7	14.9	16.1	18.9
26_1111_3	7.87	9.92	11.3	12.6	14.3	15.5	16.8	19.7
26_3750_2	1.44	1.85	2.12	2.38	2.72	2.98	3.23	3.82
26_3750_3	1.49	1.91	2.20	2.47	2.82	3.08	3.35	3.95
26_3750_5	1.67	2.14	2.46	2.77	3.16	3.45	3.75	4.43
26_294_2	2.02	2.60	2.98	3.35	3.83	4.18	4.54	5.36
26_293_2	2.78	3.58	4.10	4.61	5.27	5.76	6.25	7.38
26_1459_2	2.69	3.50	4.04	4.55	5.22	5.72	6.21	7.37
26_1459_3	2.84	3.69	4.26	4.80	5.51	6.03	6.56	7.77
26_1459_4	2.84	3.69	4.26	4.80	5.51	6.03	6.56	7.77

Table B10.6 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Tributaries) (excludes Rivers Suck, Hind, Brosna, Owenacharra / Inny and Little Brosna)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_1415_2	113	136	154	173	204	232	264	364
26_1436_2	113	136	154	174	205	233	265	365
26_1436_4	114	137	155	175	206	234	267	368
26_3824_10*	1.15	1.56	1.83	2.08	2.42	2.67	2.91	3.49
26_3831_2	115	139	157	177	208	236	269	371
26_3831_10	115	139	157	178	209	237	271	373
26_1393_1	124	149	169	190	224	255	290	400
26_1447_3	126	152	172	194	229	260	296	408

** Mackney tributary*

Table B10.7 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Tributary- River Suck) (River Suck Catchment Reach 4)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3598_13	10.1	14.4	17.2	19.8	23.3	25.9	28.5	34.5
26_2995_5	10.5	15.0	17.9	20.7	24.3	27.0	29.7	35.9

Table B10.8 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Tributary- River Hind) (River Hind Catchment Reach 1)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_608_10	77.7	95.5	106	116	128	137	146	165
25_316_5	78.7	96.8	108	118	130	139	148	168
25_281_6	83.6	103	115	125	138	148	157	178
25_681_1	83.7	103	115	126	138	148	157	178
25_681_2	84.0	103	115	126	139	149	158	179

Table B10.9 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Tributary- River Brosna) (River Brosna Catchment Reach 4)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_919_4	78.6	97.2	108	118	131	140	150	171
26_883_2	93.3	115	128	140	155	167	178	204
26_883_8	94.7	117	130	142	158	169	180	207

Table B10.10 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Tributary- River Owenacharra) (River Inny Catchment Reach 2)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3879_13	49.1	61.8	70.1	78.2	88.6	96.4	104	122
25_3906_1	52.5	66.0	74.9	83.5	94.6	103	111	130
25_3906_11	53.0	66.6	75.6	84.3	95.5	104	112	132
25_2101_7	53.0	66.6	75.6	84.3	95.5	104	112	132

Table B10.11 Target Flows (m^3/s) at HEP Locations on the N10 Model Extent (Tributary- Little Brosna River) (Little Brosna Catchment Reach 1)

B10.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B10.2 to B10.11, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, three separate independent runs were undertaken for each AEP, one run to match the target flows in the main stem, a second run to obtain the target flows on the main tributaries and a third run to obtain target flows on the Cuilglass tributary to the River Cross. For modelling purposes the tributaries are defined as the short downstream section of the River Hind down to 26_2995_5, the short downstream section of the Owenacharra down to 26_883_8, the Garrycastle tributary down to 26_4030_4, the Culiaghy tributary down to 26_2818_2, Derrloughbannow River down to 26_1469_3the River Cross down to 26_1111_3, the Cuilglass tributary down to 26_1459_4, the Fardrum tributary down to 26_293_2, the short downstream section of the River Suck down to node 26_1447_3, the short downstream section of the River Brosna down to 25_681_2 and the short downstream section of the Little Brosna down to 25_2101_7.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Section 2.7 of the main hydrology report. The HEPs are shown on Figure B10.1 (a to d). Tables B10.12 to B10.18 present the peak values of the preliminary lateral inflows applied to the model in the reach immediately upstream of the HEP in the hydraulic model for the main stem and tributary runs.

The lateral inflows for design events were estimated using the ratio of the peak of the calibrated lateral inflow hydrograph into Lough Ree during the November/ December 2009 event (see Section B10.1 above) and the peak inflow from the Shannon (0.56). This ratio was multiplied with the design event target flows in the

Shannon immediately upstream of the lake to obtain suitable lateral inflows into Lough Ree for the design event runs.

Preliminary design inflow hydrographs are shown in Figures B10.2 to B10.14 for the 1% AEP design runs. It should be noted that the hydrograph shape used for the downstream Little Brosna covered by the N10 model extent is obtained from gauging station 25024.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3934_1	6.23	7.54	8.47	9.66	10.7	11.7	12.7	15.1
26_3935_4	5.15	6.23	7.01	7.99	8.86	9.69	10.5	12.5
Lough Ree	98.3	119	134	152	169	185	201	238
26_1112_2	14.9	17.2	19.2	21.1	23.5	25.4	27.2	31.5
26_1342_3	4.54	5.23	5.83	6.40	7.15	7.71	8.27	9.56
26_1450_3	96.3	111	124	136	152	164	175	203
25_3569_2	6.35	7.31	8.15	8.96	10.0	10.8	11.6	13.4
25_681_2	67.3	77.5	86.4	95.0	106	114	123	142
25_700_1	7.17	8.25	9.19	10.1	11.3	12.2	13.0	15.1
25_2101_7	32.8	37.7	42.0	46.2	51.6	55.6	59.6	69.0

Table B10.12 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N10 Model Extent (Main Stem) (Upper Shannon Reach 4 and Lower/Middle Shannon Reaches 1, 2 and 3).

The reference 'Lough Ree' in Table B10.12 above represents the inflows that were applied to the model to represent the lateral tributaries to the lake (i.e. all inflows except the Shannon). It was applied to the Lough Ree model reservoir unit representing the lake.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_1469_1a	7.35	9.44	10.8	12.1	13.9	15.2	16.4	19.4
26_2818_2	1.32	1.71	1.97	2.22	2.55	2.79	3.03	3.59
26_784_1a	0.30	0.47	0.59	0.70	0.85	0.95	1.06	1.31
26_784_1	0.10	0.16	0.20	0.24	0.29	0.33	0.37	0.45
26_784_2	0.35	0.56	0.70	0.84	1.01	1.14	1.27	1.57
26_4030_1	0.29	0.46	0.58	0.69	0.83	0.93	1.04	1.29
26_4030_2	0.61	0.98	1.22	1.46	1.76	1.99	2.21	2.73
26_676_1	5.40	6.80	7.73	8.62	9.78	10.6	11.5	13.5
26_676_7	0.17	0.21	0.24	0.27	0.31	0.33	0.36	0.42
26_1460_3	1.61	2.02	2.30	2.57	2.91	3.17	3.42	4.02
26_1461_1	0.38	0.48	0.54	0.60	0.69	0.75	0.81	0.95
26_4018_4	0.32	0.41	0.46	0.52	0.59	0.64	0.69	0.81
26_1459_1	2.69	3.50	4.04	4.55	5.22	5.72	6.21	7.37
26_1459_2	0.15	0.19	0.22	0.25	0.29	0.32	0.34	0.41

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3750_1	1.44	1.85	2.12	2.38	2.72	2.98	3.23	3.82
26_3750_2	0.05	0.07	0.08	0.08	0.10	0.11	0.11	0.14
26_3750_3	0.18	0.23	0.26	0.30	0.34	0.37	0.40	0.47
26_3750_5	0.35	0.45	0.52	0.58	0.67	0.73	0.79	0.94
26_294_2	0.76	0.98	1.12	1.26	1.44	1.58	1.71	2.02

Table B10.13 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N10 Model Extent (Tributaries) (Lower/Middle Shannon Reaches 4, 5, 6, 7, 8 and 9).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_1415_2a	113	136	154	173	204	232	264	364
26_1415_2	1.25	1.51	1.71	1.93	2.27	2.58	2.94	4.05
26_3824_5	1.15	1.56	1.83	2.08	2.42	2.67	2.91	3.49
26_3831_2	8.97	10.8	12.2	13.8	16.3	18.5	21.1	29.0
26_1393_1	2.42	2.92	3.30	3.72	4.38	4.98	5.67	7.82

Table B10.14 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N10 Model Extent (Tributaries) (River Suck Reach 4)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_3598_7a	10.1	14.4	17.2	19.8	23.3	25.9	28.5	34.5
26_3598_13	0.42	0.61	0.73	0.84	0.98	1.09	1.20	1.46

Table B10.15 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N10 Model Extent (Tributaries) (River Hind Reach)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_608_10	5.92	7.28	8.10	8.87	9.76	10.5	11.1	12.6
25_281_6	0.47	0.57	0.64	0.70	0.77	0.82	0.88	0.99

Table B10.16 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N10 Model Extent (Tributaries) (River Brosna Reach 4)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
26_941_3a	78.6	97.2	108	118	131	140	150	171
26_919_4	14.7	18.2	20.3	22.2	24.6	26.3	28.1	32.2
26_883_2	1.38	1.71	1.90	2.07	2.30	2.46	2.63	3.01

Table B10.17 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N10 Model Extent (Tributaries) (Inny Catchment Reach 2)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3879_8	49.1	61.8	70.1	78.1	88.5	96.3	104	122
25_3879_13	3.83	4.81	5.47	6.09	6.90	7.51	8.12	9.52

Table B10.18 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N10 Model Extent (Tributaries) (Little Brosna Reach 2)

The design hydrograph estimation for the N10 main stem (River Shannon) and tributaries is described in Appendix A, in the chapters indicated in Table B10.1 above.

As an example, to get details on the estimation of design hydrographs on the Little Brosna (the downstream end of which is part of the N10 model), the reader is referred to Chapter A7. However, to understand the inflow hydrographs allowed for from the Little Brosna to obtain the critical flood on the River Shannon, Chapter A6 should be consulted.

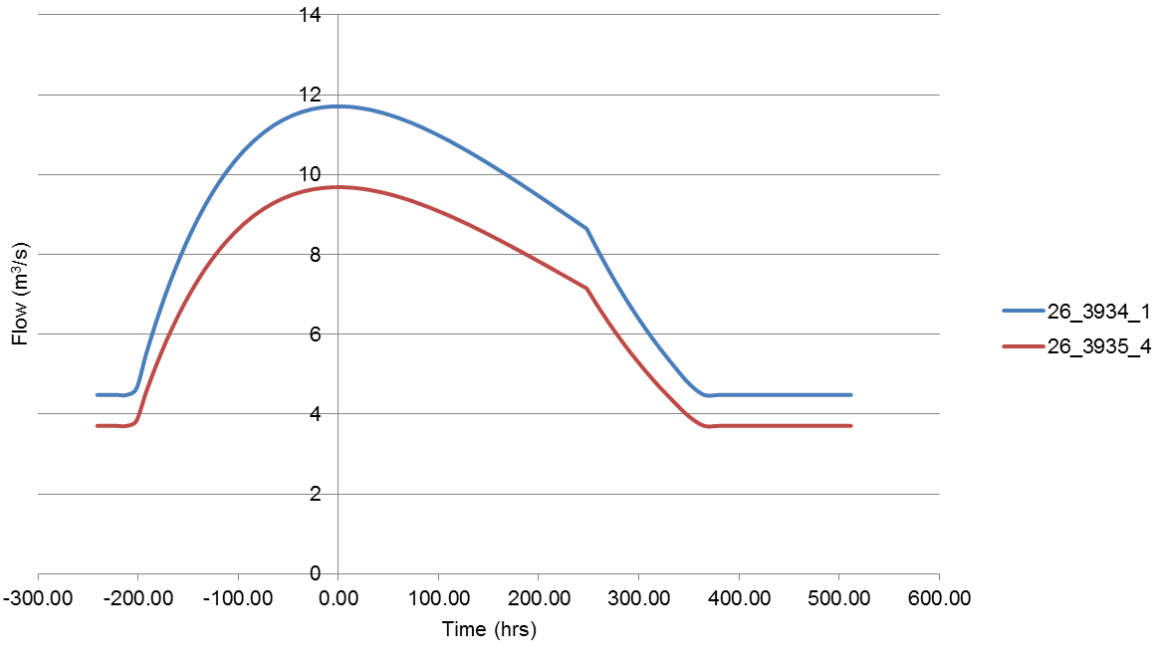

Figure B10.2 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Main Stem) (Upper Shannon Reach 4)

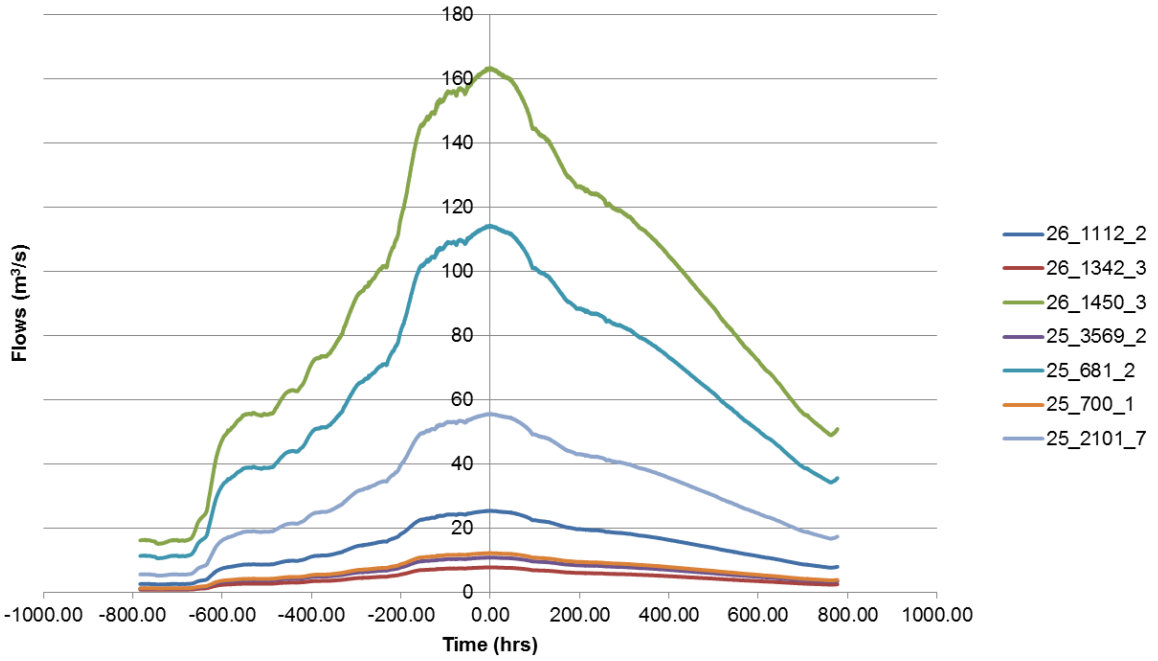

Figure B10.3 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Main Stem) (Lower/Middle Shannon Reaches 1, 2 and 3)

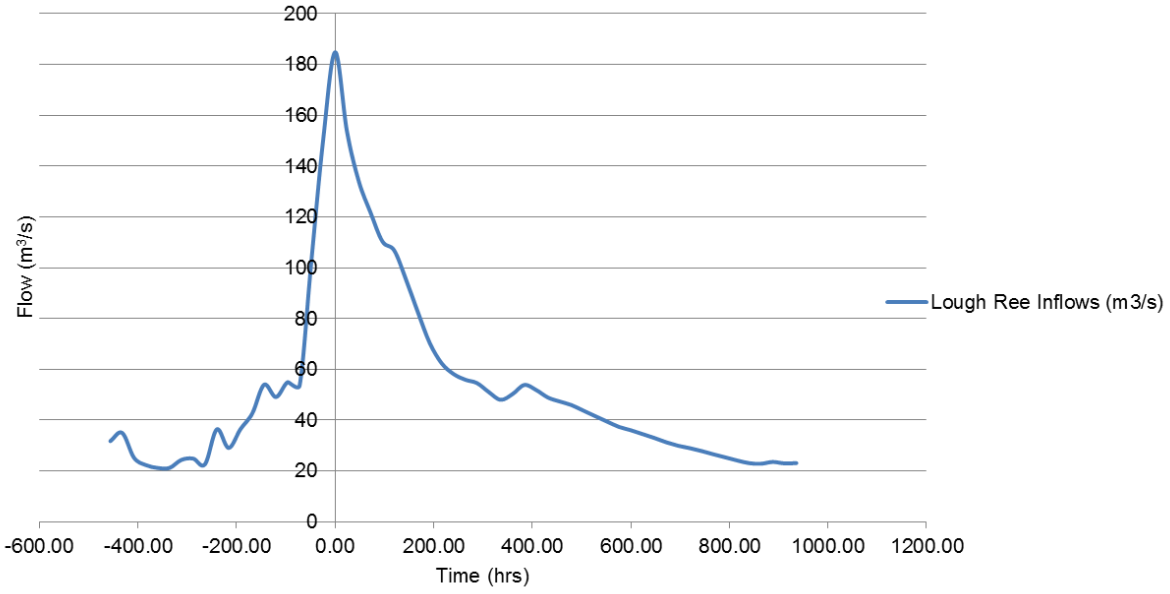

Figure B10.4 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Main Stem) (Lough Ree lateral inflows)

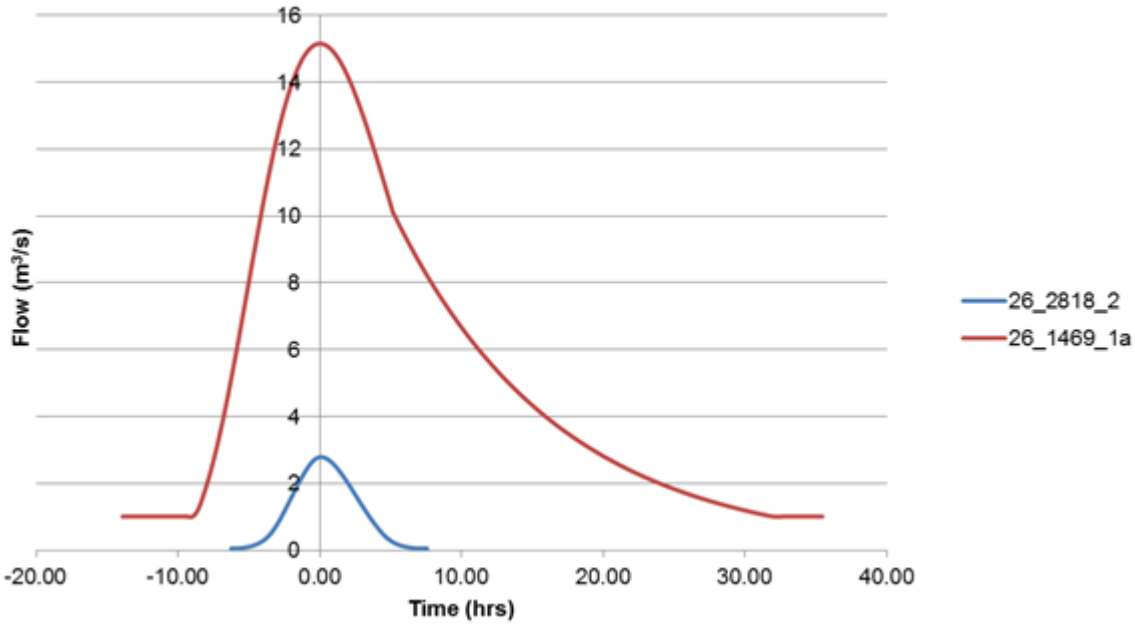

Figure B10.5 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Lower/Middle Shannon Reaches 4, and 5)

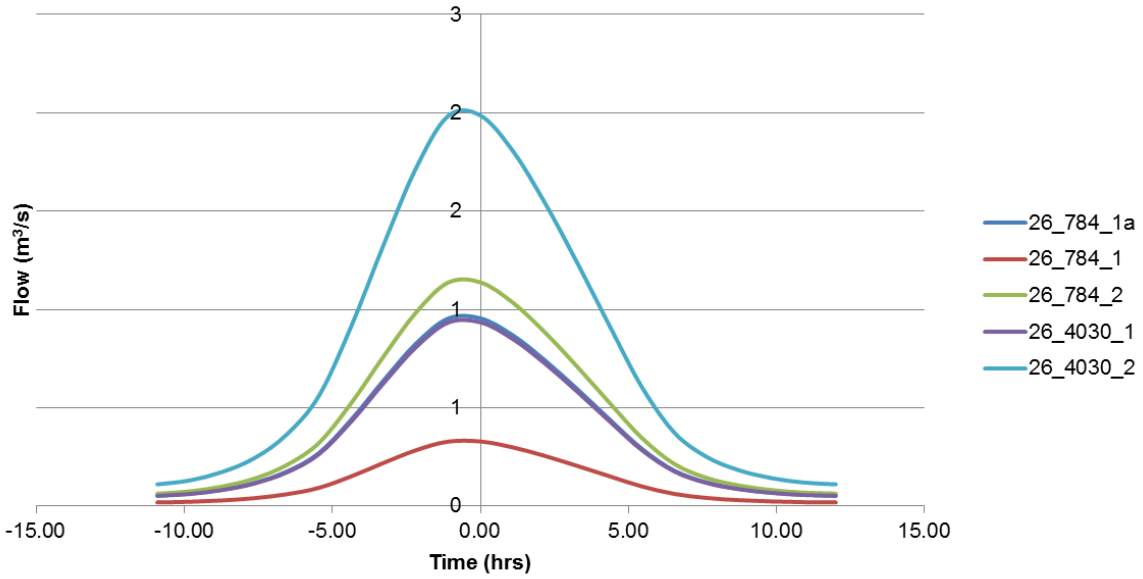

Figure B10.6 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Lower/Middle Shannon Reach 6)

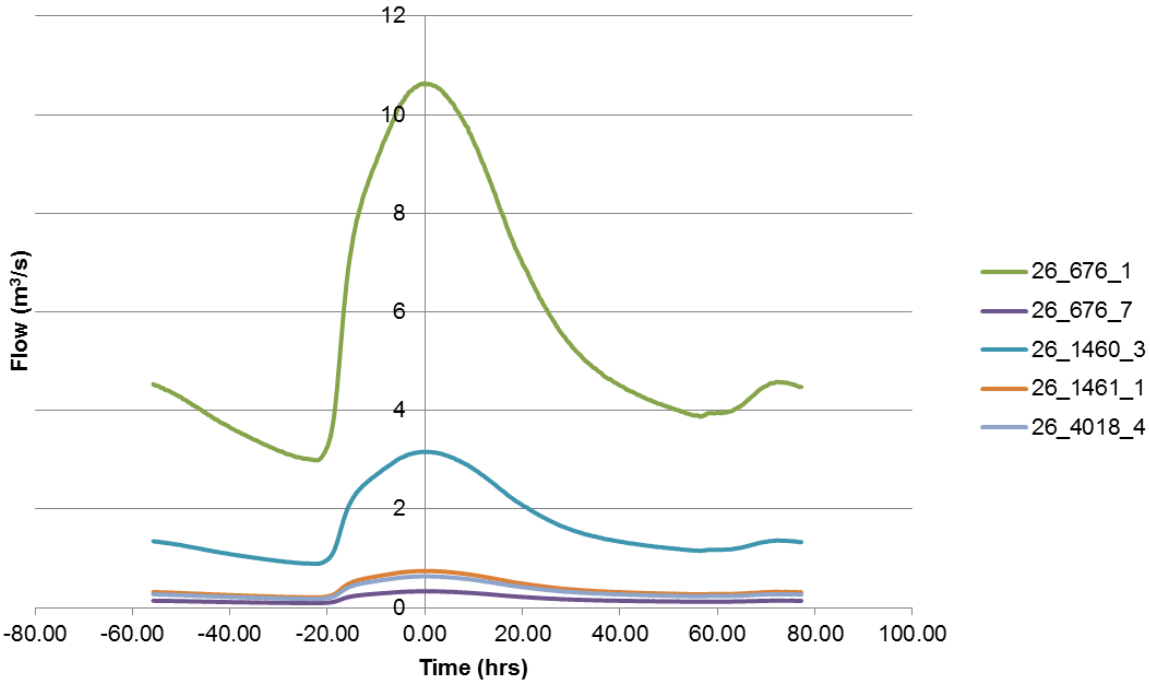

Figure B10.7 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Lower/Middle Shannon Reach 7)

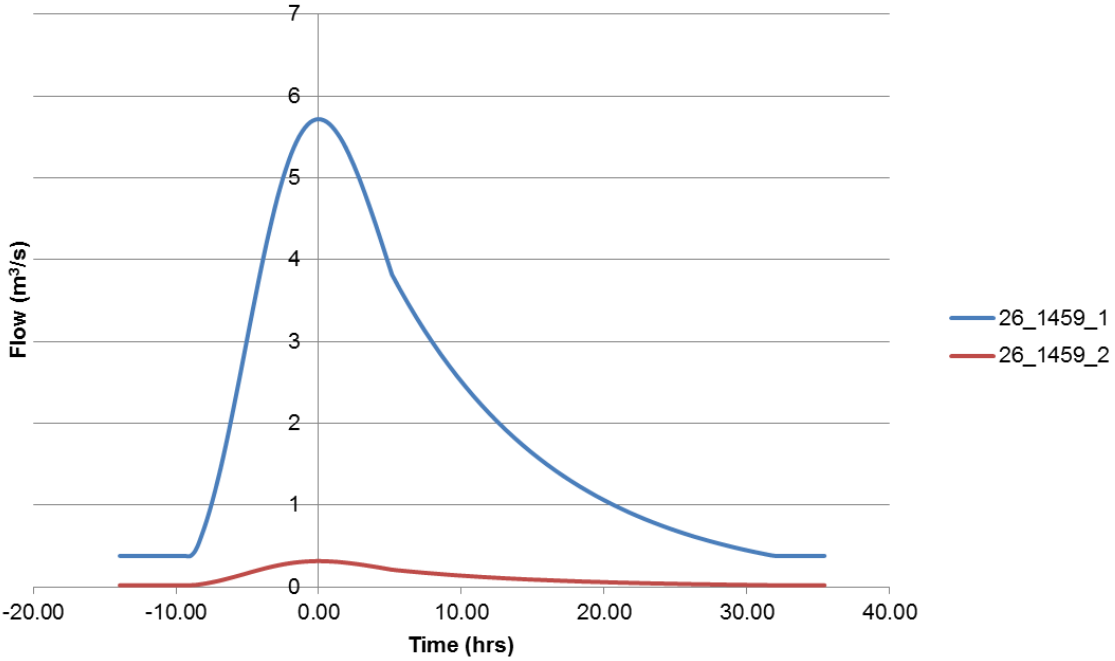

Figure B10.8 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Lower/Middle Shannon Reach 8)

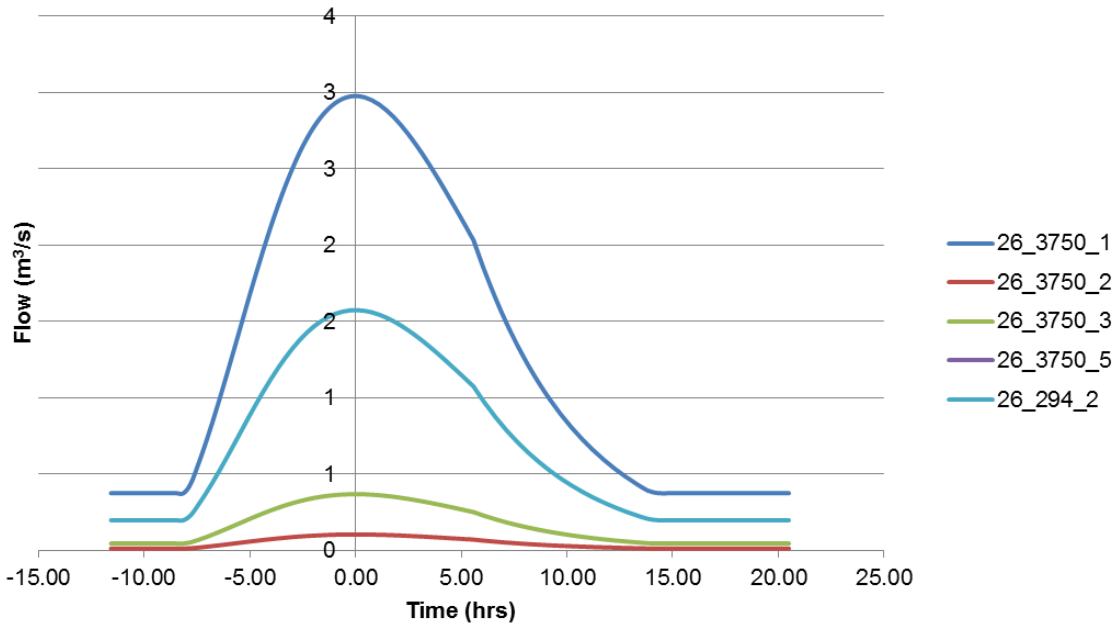

Figure B10.9 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Lower/Middle Shannon Reach 9)

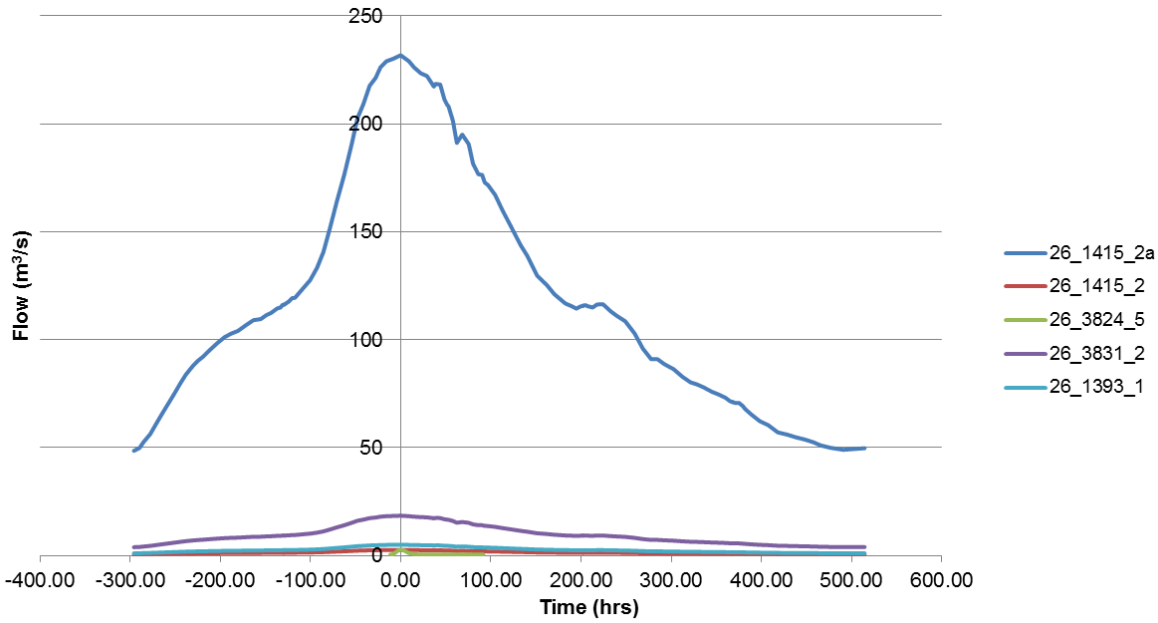

Figure B10.10 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributary) (River Suck Reach 4)

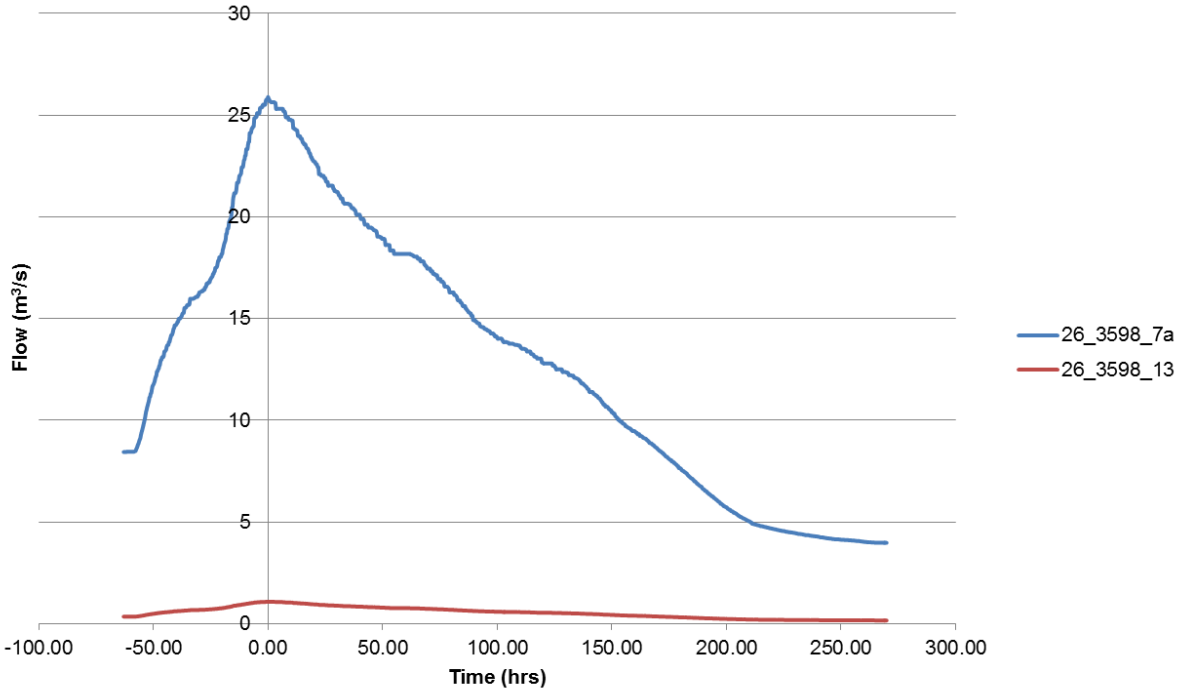

Figure B10.11 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributary) (River Hind Reach 1)

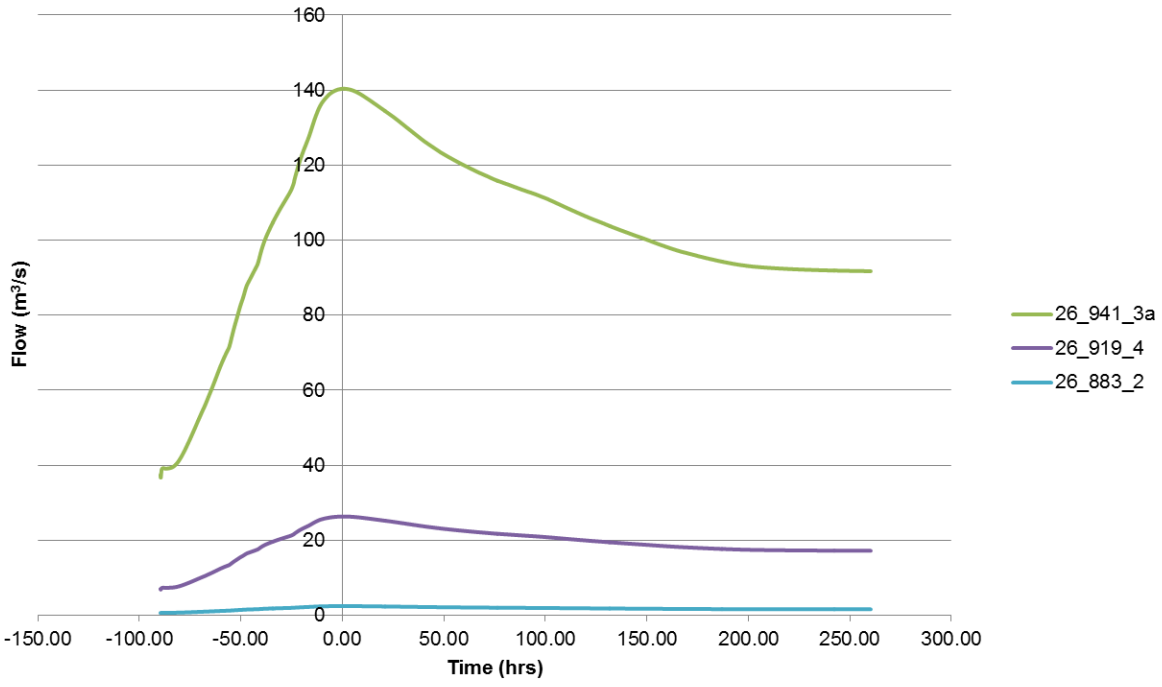

Figure B10.12 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributary) (Inny Catchment Reach 2)

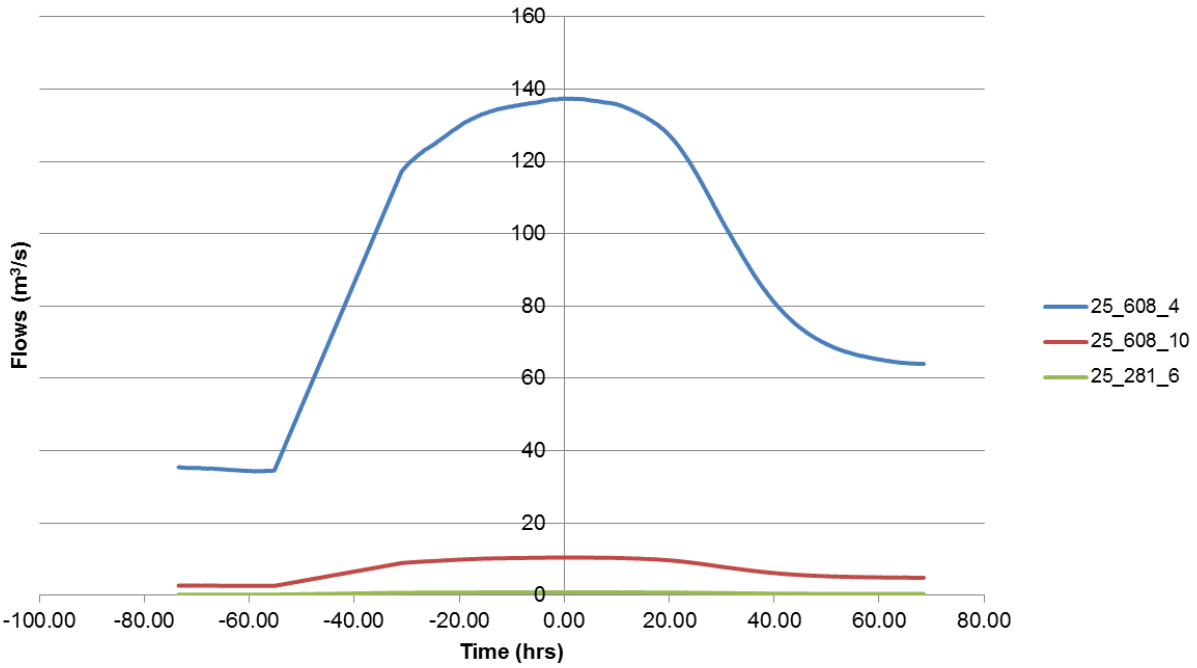

Figure B10.13 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributary) (River Brosna Reach 4)

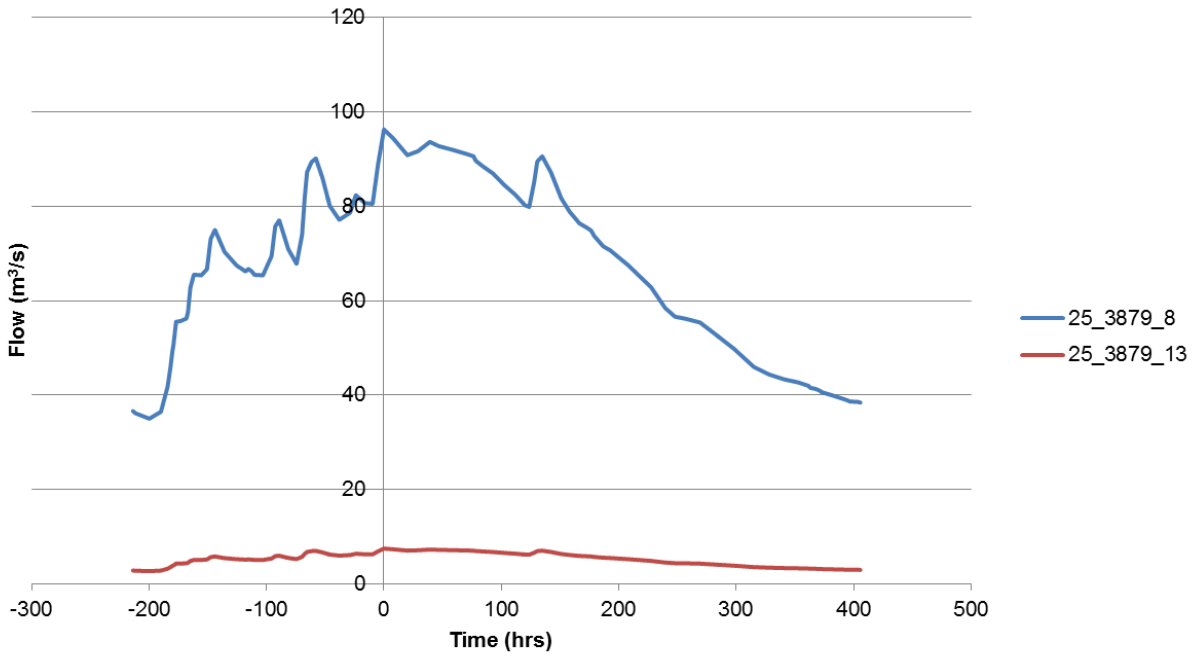

Figure B10.14 N10 Preliminary Design Inflow Hydrographs for 1% AEP (Tributary) (Little Brosna Reach 1)

B10.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B10.12 to B10.18 for calibrating the model to the HEP target flows presented in Tables B10.2 to B10.11.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N10.

B11 Model N11

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods and the inflow design hydrographs required to ensure that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B11.1, and shown on Figure B11.1

Model Attribute	Comment
Rivers included in model	River Little Brosna River Bunnow (trib. of Little Brosna) River Srahanbregagh (trib. of Little Brosna) River Camcor (trib. of Little Brosna) River Scart-Cornville (trib. of Bunnow) River Clonghil (trib. of Camcor)
Areas for Further Assessment (AFA)	Roscrea Birr

Table B11.1 Model Extent coverage

The estimation of QMED adjustment factors, growth curve and hydrograph shapes are all documented in Appendix A, Chapter A7.

B11.1 Hydrology for Hydraulic Model Calibration

Limited historic data for verification and calibration is available for this model. Although there are three gauging stations, namely, 25023 on the Little Brosna main stem, 25022 on the Camcor and 25040 on the Bunnow to provide inflow hydrograph for model calibration, the 25023 and 25021 stations on the Little Brosna main stem are located approximately 20km apart and there are no sufficient gauges to provide inflow hydrographs from the intervening tributaries other than Bunnow and Camcor. Along the River Camcor, station 25022 has good quality data to inform event hydrograph, yet, there are no records of flood levels at Birr for the historic flooding event to calibrate the model. Similarly, there are no historic flood levels at Roscrea to calibrate the Bunnow River using the event hydrograph from Station 25040. Therefore, calibration is not possible for this model.

Post-design broad verification could be carried out using the as photos of historical floods are available to verify the location of flooding. The calibration strategy is explained in Appendix F. The process is discussed in the hydraulic modelling report for N11.

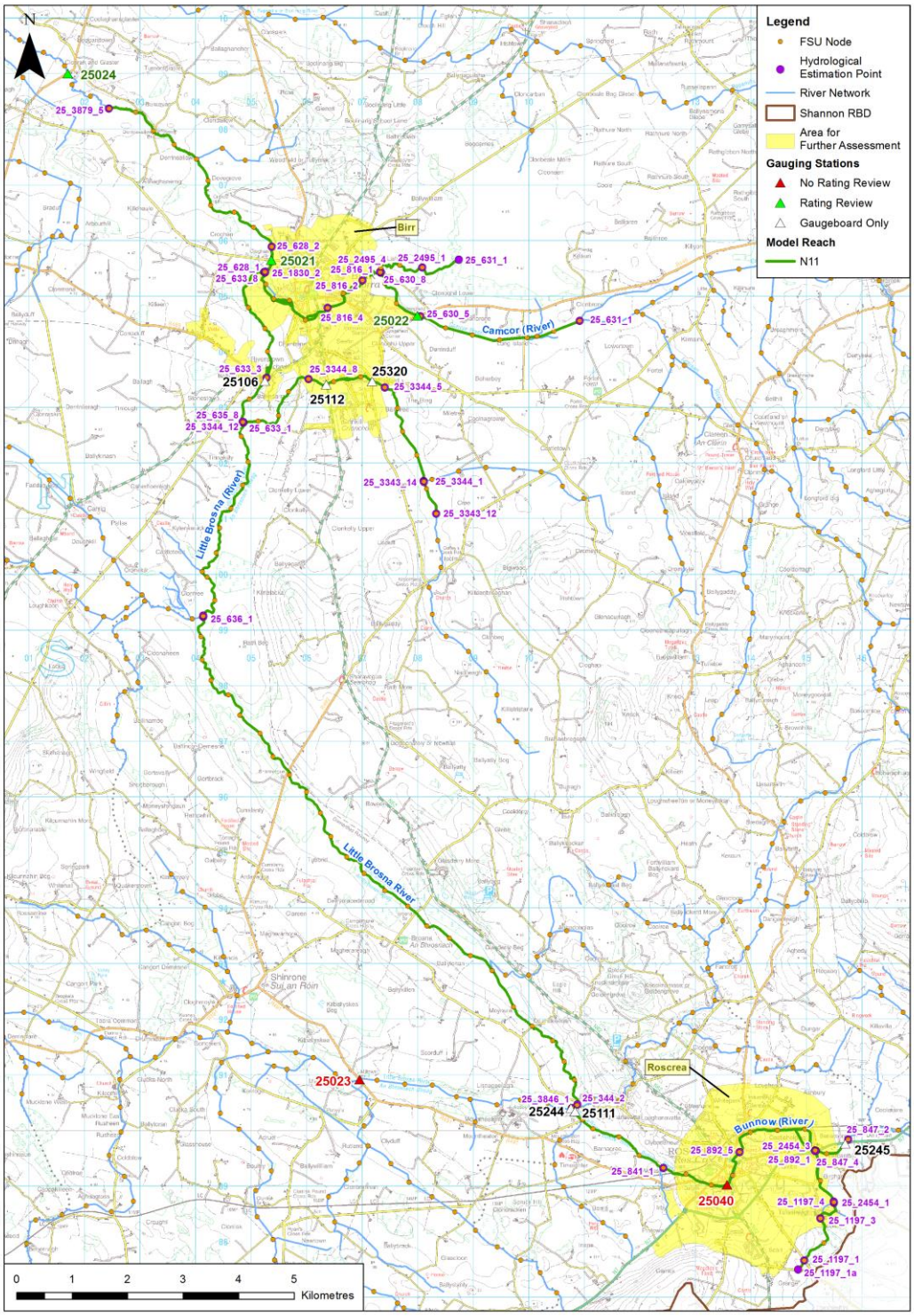

Figure B11.1 N11 Model Extent[1]

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B11.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in the main report and Appendix A7. The target flows at the HEP nodes for model N11 are shown in Tables B11.2 and B11.3.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
25_847_4	3.5	4.5	5.2	5.8	6.6	7.2	7.8	9.1
25_892_1	3.6	4.7	5.4	6.0	6.8	7.4	8.0	9.4
25_892_5	3.6	4.7	5.4	6.0	6.9	7.5	8.1	9.5
25_841_1	4.1	5.3	6.1	6.8	7.7	8.4	9.1	10.6
25_344_2	4.4	5.7	6.5	7.3	8.3	9.0	9.7	11.4
25_3846_1	21.2	26.7	30.3	33.8	38.3	41.7	45.0	52.8
25_3572_20	22.5	28.3	32.1	35.8	40.5	44.1	47.7	55.9
25_636_1	25.7	32.3	36.6	40.8	46.2	50.3	54.4	63.7
25_635_8	25.9	32.6	37.0	41.2	46.7	50.8	54.9	64.3
25_3343_14	1.6	2.0	2.3	2.6	2.9	3.2	3.4	4.0
25_3344_1	2.2	2.8	3.2	3.6	4.0	4.4	4.7	5.6
25_3344_5	2.4	3.0	3.4	3.7	4.2	4.6	5.0	5.8
25_3344_8	2.7	3.4	3.9	4.3	4.9	5.4	5.8	6.8
25_3344_12	3.1	3.9	4.4	4.9	5.5	6.0	6.5	7.6
25_633_1	27.8	35.0	39.7	44.3	50.2	54.6	59.0	69.1
25_633_3[1]	27.8	35.0	39.7	44.3	50.2	54.6	59.0	69.1
25_633_8[1]	27.8	35.0	39.7	44.3	50.2	54.6	59.0	69.1
25_628_1	48.0	60.3	68.5	76.3	86.5	94.1	101.6	119.2
25_628_2	48.2	60.7	68.9	76.8	87.0	94.6	102.2	119.9
25_3879_5[1]	48.2	60.7	68.9	76.8	87.0	94.6	102.2	119.9

[1] In some places the target flow estimated using the FSU regression equation at a node is lower than that at the node immediately upsteam. In most cases this is an anomaly of the regression equation method (an exception being downstream of large lakes where flood flows are routed). As peak design flows here should not decrease moving downstream the river, we have copied the upstream HEP peak flow to the downstream HEP.

Table B11.2 Target Flows at HEP Locations on the N11 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
25_1197_1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
25_1197_3	0.2	0.3	0.4	0.4	0.5	0.5	0.5	0.6
25_1197_4[1]	0.2	0.3	0.4	0.4	0.5	0.5	0.5	0.6
25_2454_1[1]	0.2	0.3	0.4	0.4	0.5	0.5	0.5	0.6
25_2454_3	0.5	0.7	0.8	0.9	1.0	1.1	1.2	1.4
25_630_5	27.1	34.1	38.8	43.2	48.9	53.2	57.5	67.5
25_630_8[1]	27.1	34.1	38.8	43.2	48.9	53.2	57.5	67.5
25_2495_1	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3
25_2495_4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3
25_816_1[1]	27.1	34.1	38.8	43.2	48.9	53.2	57.5	67.5
25_816_2[1]	27.1	34.1	38.8	43.2	48.9	53.2	57.5	67.5
25_816_4[1]	27.1	34.1	38.8	43.2	48.9	53.2	57.5	67.5
25_1830_2[1]	27.1	34.1	38.8	43.2	48.9	53.2	57.5	67.5

[1] In some places the target flow estimated using the FSU regression equation at a node is lower than that at the node immediately upsteam. In most cases this is an anomaly of the regression equation method (an exception being downstream of large lakes where flood flows are routed). As peak design flows here should not decrease moving downstream the river, we have copied the upstream HEP peak flow to the downstream HEP.

Table B11.3 Target Flows at HEP Locations on the N11 Model Extent (Tributaries)

B11.3 Preliminary Design Flows

To obtain the target flows shown in Table B11.2 and Table B11.3, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, two separate runs were undertaken for each AEP. One run to match the target flows in the main stem, and a separate independent run to obtain the target flows on the tributaries.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A7. The HEPs are shown on Figure B11.1. Tables B11.4 and B11.5 present the peak values of the preliminary lateral inflows inserted into the model in the reach immediately upstream of the HEP in the hydraulic model for the main stem and tributary runs.

Preliminary design inflow hydrographs of are shown in Figures B11.2 to B11.7 for the 1% AEP flows.

HEP reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_847_2	3.5	4.5	5.2	5.8	6.6	7.2	7.8	9.1
25_847_4	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3
25_892_1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25_892_5	0.4	0.6	0.7	0.7	0.8	0.9	1.0	1.2
25_841_1	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8
25_344_2	16.9	21.0	23.8	26.5	30.0	32.7	35.3	41.4
25_3846_1	1.2	1.6	1.8	2.0	2.2	2.4	2.6	3.1
25_3572_20	3.2	4.0	4.5	5.0	5.7	6.2	6.7	7.9
25_636_1	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6
25_3343_12	1.6	2.0	2.3	2.6	2.9	3.2	3.4	4.0
25_3343_14	0.6	0.8	0.9	1.0	1.1	1.2	1.3	1.5
25_3344_1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3
25_3344_5	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9
25_3344_8	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8
25_633_8	19.3	24.3	27.5	30.7	34.8	37.8	40.9	47.9

Table B11.4 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N11 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.50%	0.10%
25_1197_1a	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
25_1197_1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3
25_1197_3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7
25_631_1	27.1	34.1	38.8	43.2	48.9	53.2	57.5	67.5
25_2495_1a	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3

Table B11.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N11 Model Extent (Tributaries)

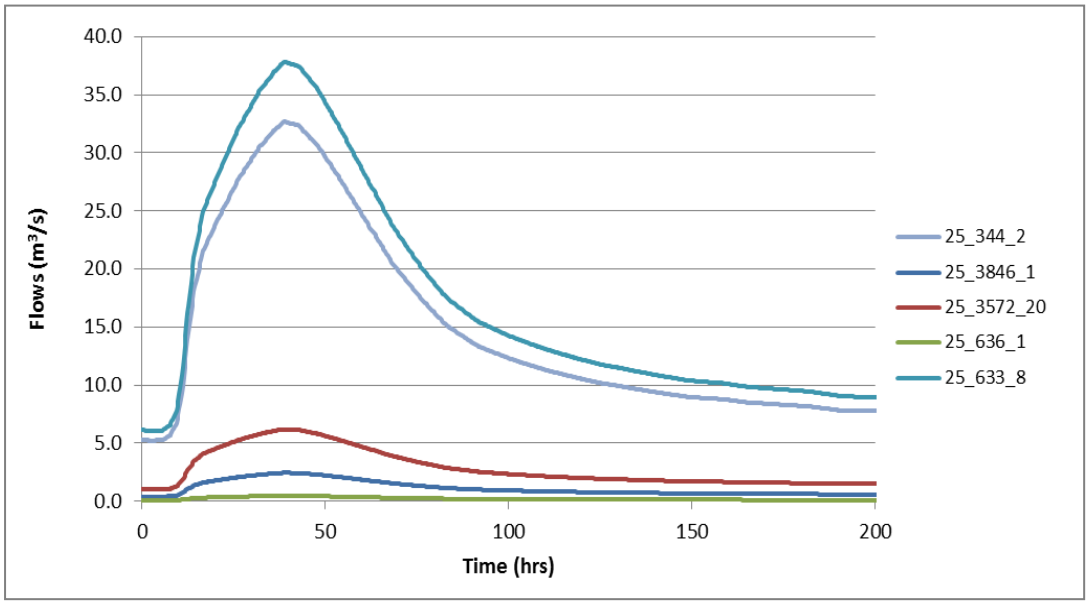

Figure B11.2 1% AEP Preliminary Design Inflow Hydrographs for Reach 1 Little Brosna Main Stem

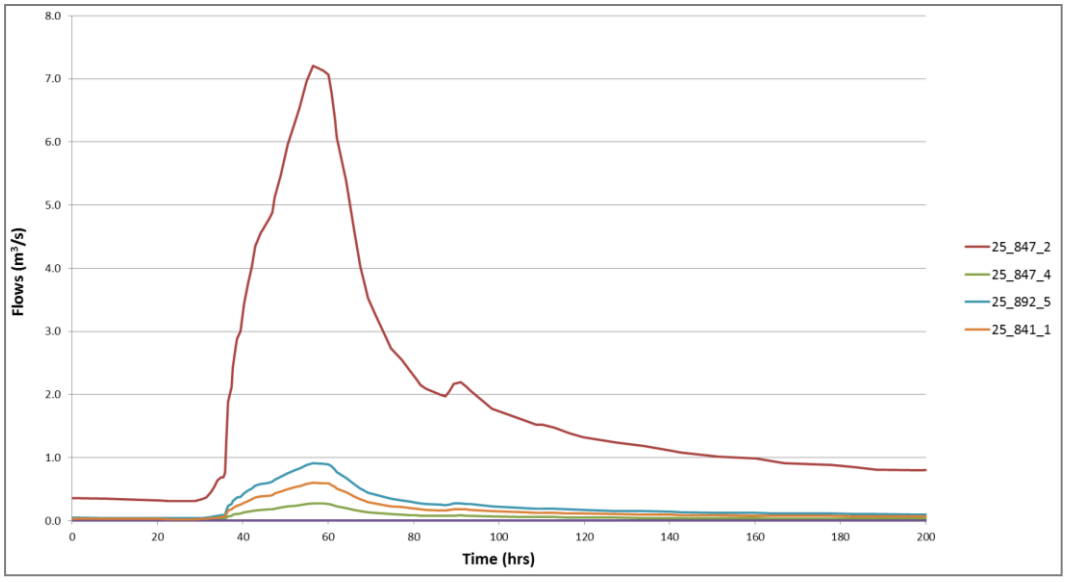

Figure B11.3 1% AEP Preliminary Design Inflow Hydrographs for Reach 2 Bunnow Main Stem

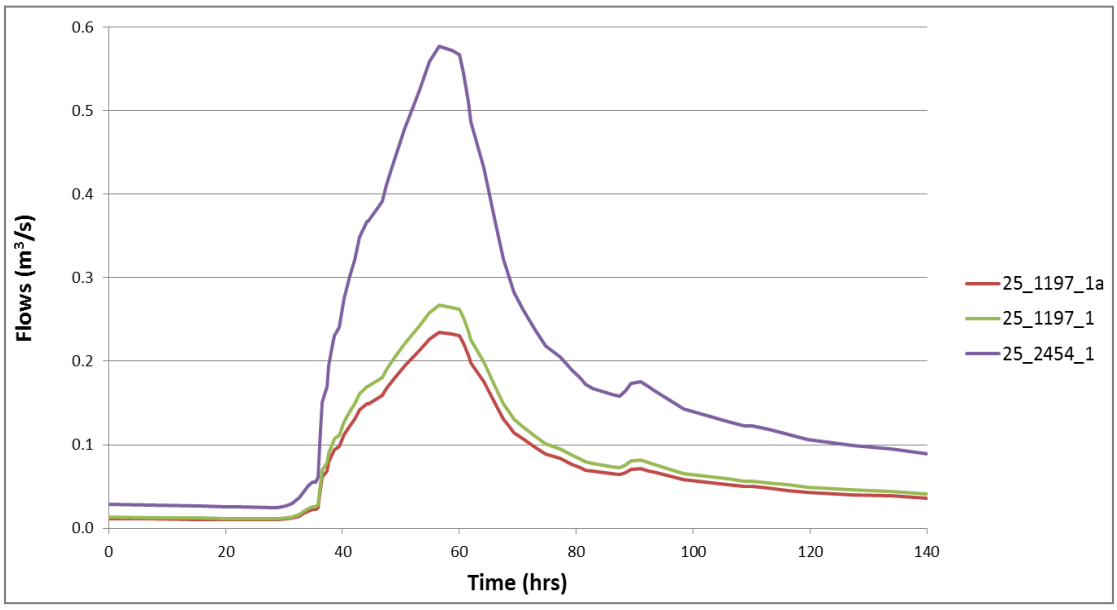

Figure B11.4 1% AEP Preliminary Design Inflow Hydrographs for Reach 3 Tributary (Scart-Cornville)

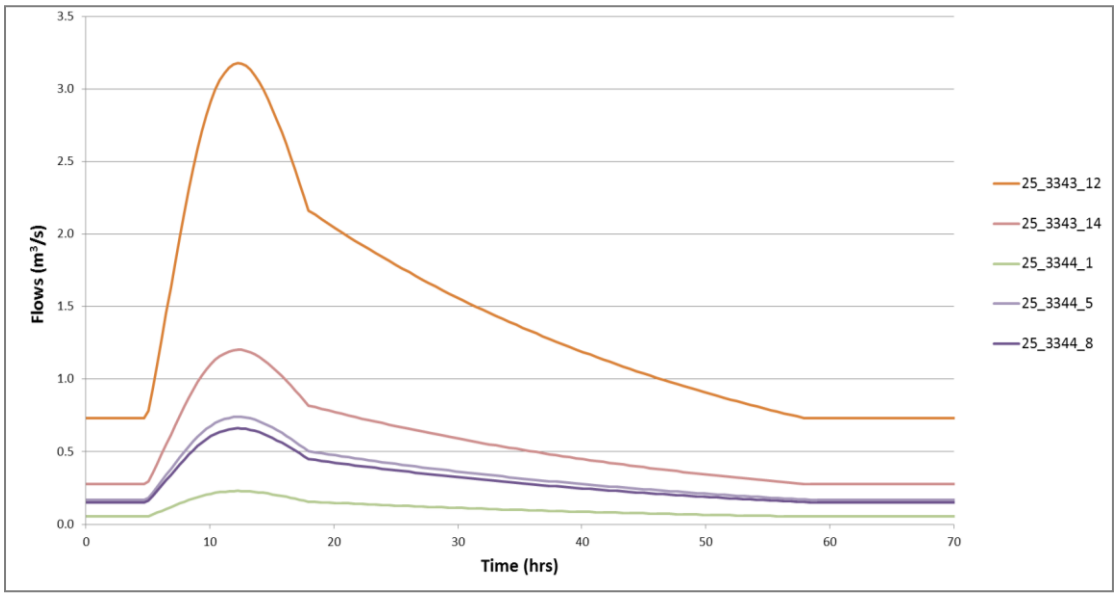

Figure B11.5 1% AEP Preliminary Design Inflow Hydrographs for Reach 4 Srahanbregagh Main Stem

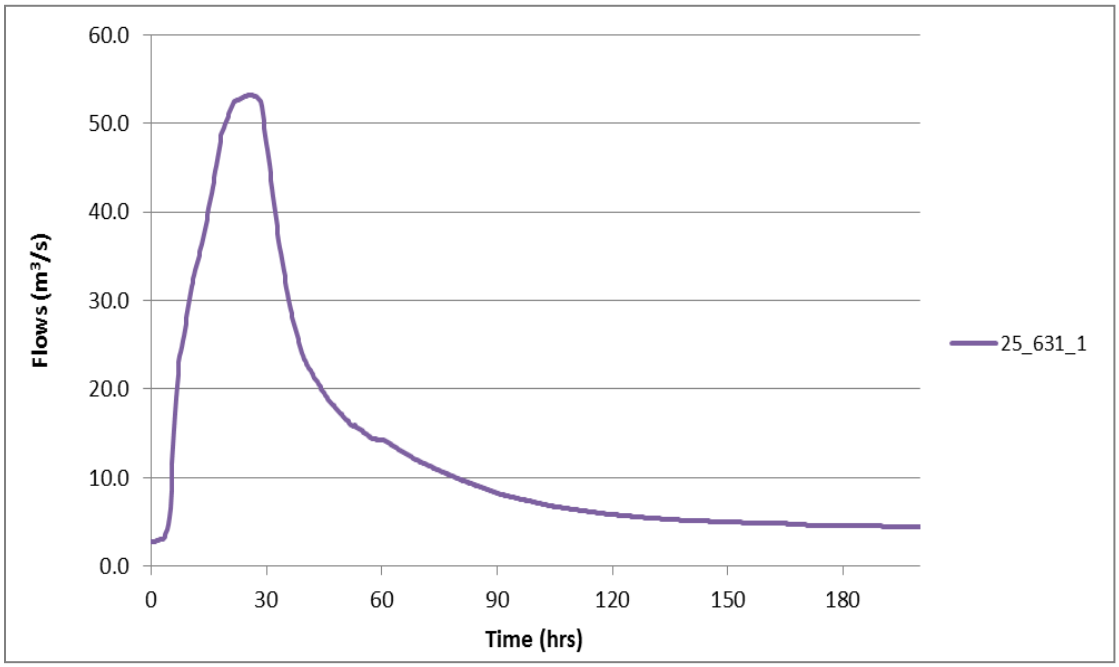

Figure B11.6 1% AEP Preliminary Design Inflow Hydrographs for Reach 5 Tributary (Camcor)

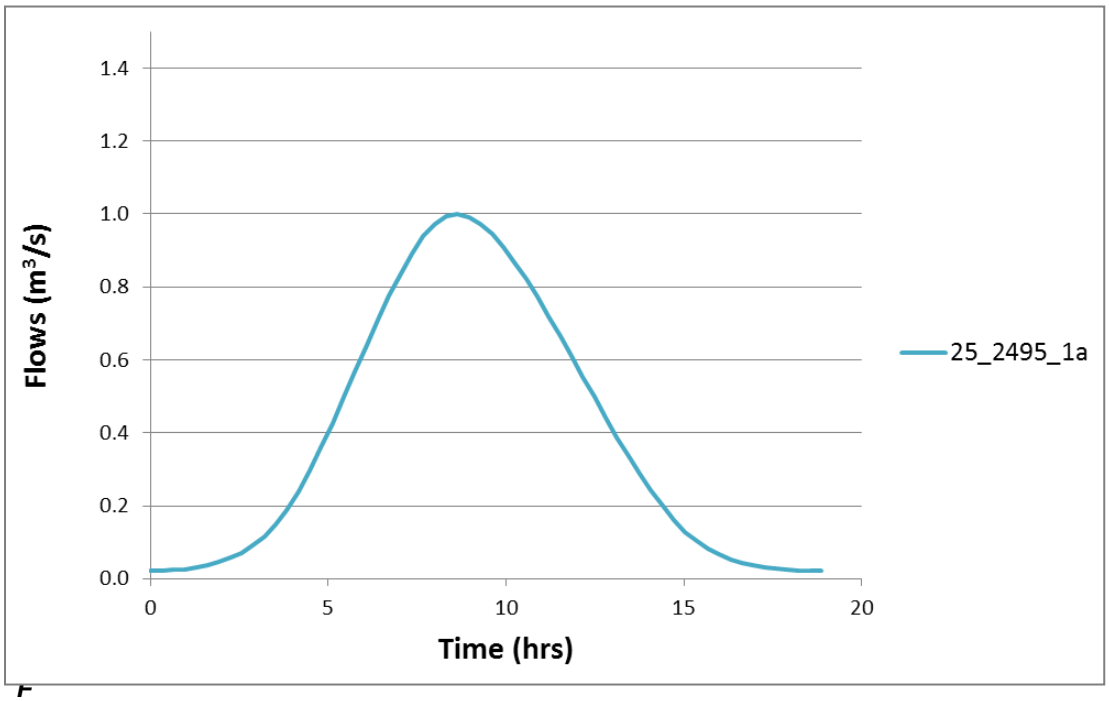

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Figure B11.7 1% AEP Preliminary Design Inflow Hydrographs for Reach 6 Tributary (Clonghil)

B12 Model N12

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods and the inflow design hydrographs required to ensure that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B12.1, and shown on Figures B12.1a to b.

Model Attribute	Comment
Watercourses and water bodies included in model	River Shannon (including The Crabbies) Fairyhill tributary Deerpark & Lickmolassy tributaries Drumbane tributary Grange tributary River Killmastulla Stradbally East and Cederwood tributary Lough Derg
Areas for Further Assessment (AFA)	Portumna, Killaloe/Ballina, O'Briens Bridge, Castleconnell, Springfield
Hydrological subcatchments (see Main Report and Appendix A)	Lower and Middle Shannon (Chapter A6), Little Brosna (Chapter A7)

Table B12.1 Model Extent coverage

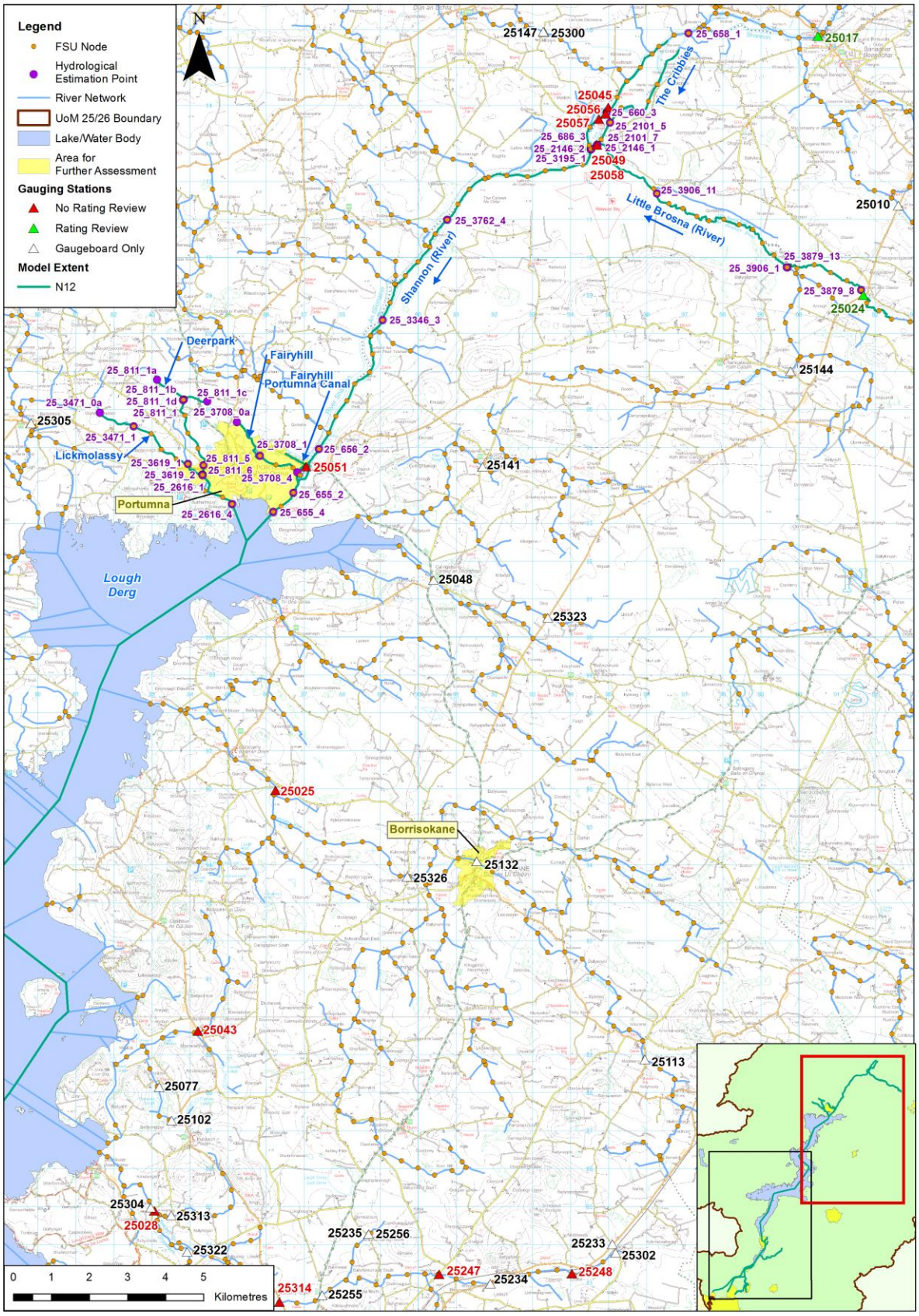

Figure B12.1a N12 Model Extent [1]

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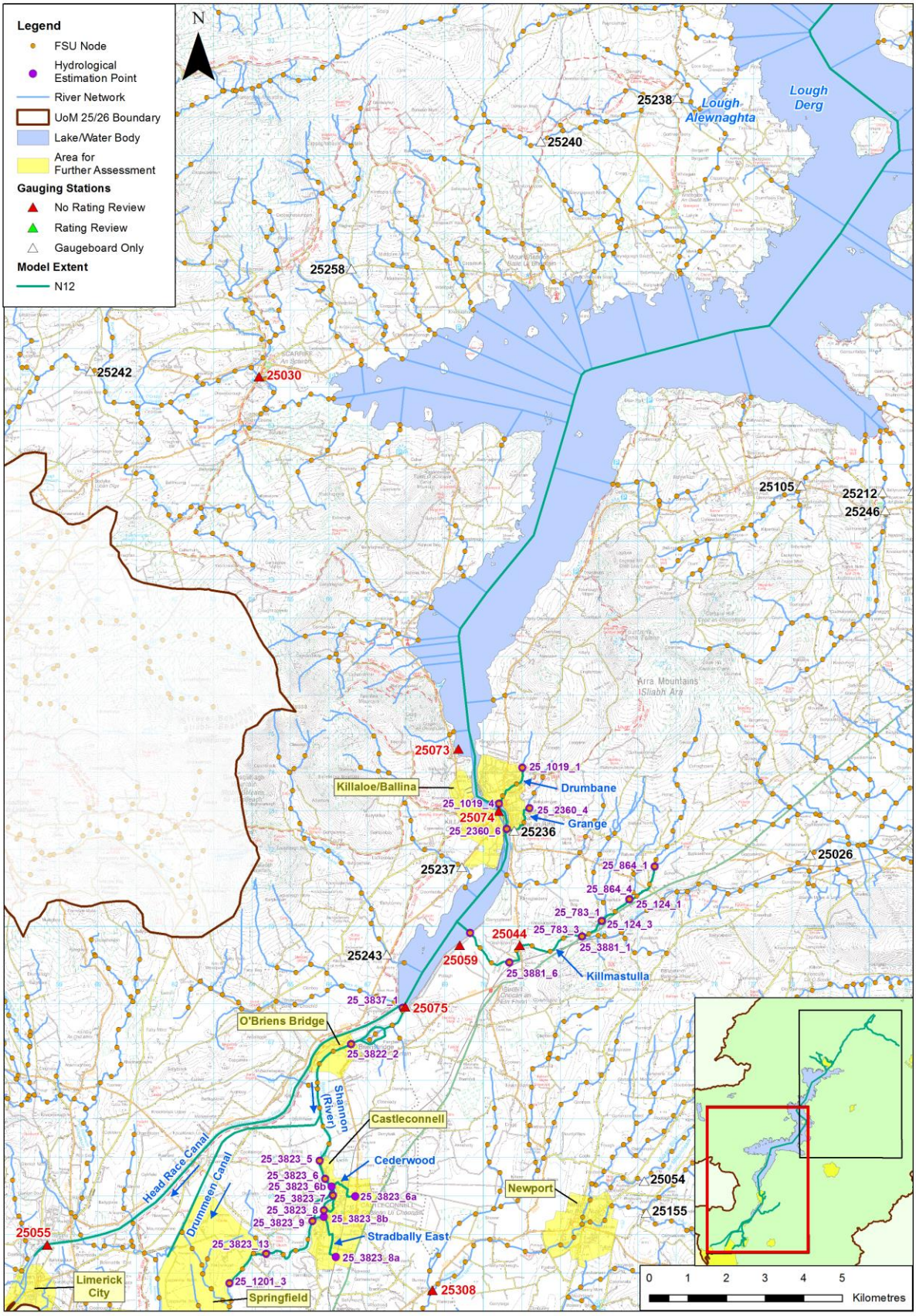

Figure B12.1b N12 Model Extent

B12.1 Hydrology for Hydraulic Model Calibration

Model N12 was calibrated using historic flood information for the November/December 2009 flood. Gauged flow and level data was used to undertake this calibration.

The section of N12 between its upstream model extent (the boundary with N10) and Parteen Weir was calibrated by applying flow hydrographs to the model at the main Shannon upstream extent (recorded at Banagher GS) and at gauged tributaries. The 2009 calibration run included flow allowances for ungauged catchments (using a pivotal catchment hydrograph scaled to the catchment area) into the Shannon and Lough Derg. Direct rainfall was considered but was found to have a negligible contribution to the volume balance of the lake. The downstream boundary condition for the calibration run was set to the Parteen (Upper) gauged water levels. These water levels are affected by the operation of the gates at Parteen Weir. During floods the gates are gradually opened until all gates are fully opened during periods of very high flows.

Apart from the inflows from the Rivers Ballyfinboy and Nenagh a large portion of the lateral inflows into Lough Derg is from ungauged watercourses. Following the initial estimate of these ungauged inflows described above, to replicate the observed water levels in Lough Derg these lateral inflows had to be reduced in peak and volume as part of the hydrological calibration process. The result of this calibration was used to determine the lateral design inflows into Lough Derg, see Section B12.3 below.

The design run flood outlines were compared with the 2009 event flood outline to verify the model results throughout the N12 domain. The results of this comparison are discussed in the hydraulic modelling report for N12.

B12.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A, Chapters A6 and A7, which is where the reach numbers shown below are defined. The target flows at the HEP nodes for model N12 are shown in Tables B12.2 to B12.4.

The peak flow estimation process for the N12 main stem (River Shannon) and tributaries is described in Appendix A, in the chapters indicated in Table B12.1 above.

To get details of the design peak flow estimation on the Little Brosna (the downstream end of which is part of the N12 model), the reader is referred to Chapter A7. However, to understand the inflow allowed for from the Little Brosna to obtain the critical flood on the River Shannon, Chapter A6 should be consulted.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_660_3	438	504	562	617	689	743	797	922
25_686_3*	438	504	562	618	690	743	797	922
25_2101_5	0.29	0.33	0.37	0.41	0.46	0.49	0.53	0.61
25_2146_1	31.2	35.9	40.1	44.0	49.2	53.0	56.9	65.7
25_2146_2*	31.2	35.9	40.1	44.0	49.2	53.0	56.9	65.7
25_3195_1	469	540	602	662	739	796	854	987
25_3762_4	471	542	604	664	742	800	858	992
25_3346_3	473	544	607	667	745	803	861	995
25_656_2	475	546	609	669	747	806	864	999
25_655_2*	475	546	609	670	748	806	864	999
25_655_4	475	546	609	670	748	806	865	1000
25_3837_1**	200	268	330	389	466	524	581	714
25_3822_2**	200	268	330	390	466	524	581	714
25_3823_5**	201	269	331	391	468	525	583	716
25_3823_6**	201	269	331	391	468	525	583	716
25_3823_7**	201	269	331	391	468	525	583	716
25_3823_8**	201	269	331	391	468	526	583	716
25_3823_9**	201	269	331	391	468	526	583	716
25_3823_13**	202	270	332	391	468	526	584	717
25_1201_3*/**	202	270	332	392	469	526	584	717

** Where the target design flow estimate is less than that in the node upstream, then the target flow from the upstream node was adopted to avoid having decreasing target flows where this is not physically realistic.*

***The target flows in these nodes exclude a peak flow of 345 m^3/s to represent the flow that is diverted into the Head Race Canal for Ardnacrusha Power Station for all design events, as discussed in Chapter A6 in Appendix A.*

Table B12.2 Target Flows (m^3/s) at HEP Locations on the N12 Model Extent (Main Stem) (Lower/Middle Shannon Reaches 3 and 16).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3708_1	0.39	0.57	0.69	0.81	0.96	1.07	1.18	1.45
25_3708_4	0.57	0.84	1.02	1.20	1.42	1.59	1.76	2.14
25_811_1b	0.19	0.25	0.29	0.33	0.38	0.42	0.45	0.54
25_811_1d	0.09	0.12	0.14	0.16	0.19	0.20	0.22	0.26
25_811_1	0.29	0.38	0.44	0.49	0.57	0.62	0.68	0.80
25_811_5	0.59	0.77	0.89	1.01	1.15	1.27	1.38	1.63
25_811_6	0.64	0.84	0.97	1.09	1.25	1.37	1.49	1.77
25_3471_1	0.32	0.42	0.48	0.55	0.63	0.69	0.75	0.89
25_3619_1	0.95	1.24	1.43	1.61	1.85	2.03	2.21	2.62
25_3619_2	1.05	1.37	1.58	1.78	2.04	2.24	2.44	2.89
25_2616_1	1.65	2.15	2.49	2.81	3.22	3.54	3.85	4.56
25_2616_4	1.88	2.45	2.83	3.20	3.67	4.02	4.38	5.19
25_1019_4	1.48	2.19	2.65	3.10	3.68	4.12	4.55	5.56
25_2360_6	2.90	3.80	4.40	4.97	5.71	6.26	6.81	8.09
25_864_4	3.77	4.94	5.71	6.45	7.41	8.13	8.84	10.5
25_124_1	4.96	6.50	7.52	8.49	9.76	10.7	11.6	13.8
25_124_3	5.17	6.77	7.83	8.84	10.2	11.1	12.1	14.4
25_783_1	7.65	10.0	11.6	13.1	15.0	16.5	18.0	21.3
25_783_3	7.73	10.1	11.7	13.2	15.2	16.7	18.1	21.5
25_3881_1	19.4	23.7	26.3	28.6	31.5	33.6	35.7	40.3
25_3881_6	19.4	23.7	26.3	28.6	31.5	33.6	35.7	40.3
25_3881_9	20.2	24.6	27.3	29.7	32.7	34.9	37.0	41.8
25_3823_6b	0.59	0.77	0.89	1.00	1.15	1.27	1.38	1.64
25_3823_8b	0.74	0.97	1.12	1.27	1.45	1.60	1.74	2.06

Table B12.3 Target Flows (m^3/s) at HEP Locations on the N12 Model Extent (Tributaries) (Lower/Middle Shannon Reaches 10, 11, 12, 13, 14, 15 and 17)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3879_13	49.1	61.8	70.1	78.1	88.5	96.3	104	122
25_3906_1	52.5	66.0	74.9	83.5	94.6	103	111	130
25_3906_11	52.9	66.6	75.6	84.2	95.4	104	112	132
25_2101_7	52.9	66.6	75.6	84.2	95.4	104	112	132

Table B12.4 Target Flows (m^3/s) at HEP Locations on the N12 Model Extent (Tributary - Little Brosna River) (Little Brosna, Reach 1 in Chapter A7)

B12.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B12.2 to B12.4, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, two separate independent runs were undertaken for each AEP, one run to match the target flows in the main stem and a second run to obtain the target flows on the tributaries. For modelling purposes the tributaries are defined as the short downstream section of the Little Brosna down to 25_2101_7, the Fairyhill tributary down to 25_3708_4, the Deerpark and Lickmolassy tributaries down to 25_2616_4, the Drumbane tributary down to 25_1019_4, the Grange tributary down to 25_2360_6, the Killmastulla River down to 25_3881_9, the Stradbally East and Cederwood tributaries down to 25_3823_6b.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapters A6 and A7. The HEPs are shown on Figures B12.1a/b. Tables B12.5 to B12.7 present the peak values of the preliminary lateral inflows applied to the model in the reach immediately upstream of the HEP in the hydraulic model for the main stem and tributary runs.

Preliminary design inflow hydrographs are shown in Figures B12.2 to B12.9 for the 1% AEP design runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_658_1	438	504	562	617	689	743	797	922
25_660_3	31.3	36.1	40.2	44.2	49.3	53.2	57.0	65.9
25_3195_1	5.74	6.60	7.36	8.09	9.03	9.74	10.4	12.1
Lough Derg (Upper)	161	186	207	228	254	274	294	340
25_3822_2	1.65	1.86	2.05	2.23	2.46	2.64	2.81	3.21

Table B12.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N12 Model Extent (Main Stem) (Lower/Middle Shannon Reaches 3 and 16).

The reference 'Lough Derg (Upper)' in Table B12.5 above represents the inflow that was applied to the model to represent the lateral tributaries to the lake (i.e. all inflows except the Shannon). It was applied to the Lough Derg model reservoir unit representing the lake. It is referred to with 'Upper' to reflect that it was applied to the large natural lake upstream of Killaloe, not the man-made part downstream of Killaloe (Parteen Basin).

The lateral inflows for design events were estimated using the ratio of the peak of the calibrated lateral inflow hydrograph into Lough Derg during the November/December 2009 event (see Section B12.1 above) and the peak inflow from the Shannon (0.34). This ratio was multiplied with the design event target flows in the Shannon immediately upstream of the lake to obtain suitable lateral inflows into Lough Derg for the design event runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3708_0a	0.39	0.57	0.69	0.81	0.96	1.07	1.18	1.45
25_3708_1	0.19	0.27	0.33	0.39	0.46	0.52	0.57	0.91
25_811_1a	0.19	0.25	0.29	0.33	0.38	0.42	0.45	0.54
25_811_1c	0.09	0.12	0.14	0.16	0.19	0.20	0.22	0.26
25_811_1	0.30	0.39	0.45	0.51	0.59	0.64	0.70	0.83
25_811_5	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.14
25_3471_0a	0.32	0.42	0.48	0.55	0.63	0.69	0.75	0.89
25_3471_1	0.63	0.82	0.95	1.07	1.23	1.35	1.46	1.74
25_3619_1	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.27
25_2616_1	0.23	0.30	0.34	0.39	0.45	0.49	0.53	0.63
25_1019_1	1.48	2.19	2.65	3.10	3.68	4.12	4.55	5.56
25_2360_4	2.90	3.80	4.40	4.97	5.71	6.26	6.81	8.09
25_864_1	3.77	4.94	5.71	6.45	7.41	8.13	8.84	10.5
25_864_4	1.19	1.56	1.81	2.04	2.35	2.57	2.80	3.33
25_124_1	0.20	0.27	0.31	0.35	0.40	0.44	0.48	0.57
25_124_3	2.56	3.35	3.88	4.38	5.04	5.53	6.01	7.14
25_783_3	11.7	13.6	14.6	15.4	16.3	17.0	17.5	18.7
25_3881_6	0.74	0.90	1.00	1.09	1.20	1.28	1.36	1.54
25_3823_6a	0.59	0.77	0.89	1.00	1.15	1.27	1.38	1.64
25_3823_8a	0.74	0.97	1.12	1.27	1.45	1.60	1.74	2.06

Table B12.6 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N12 Model Extent (Tributaries) (Reaches 10, 11, 12, 13, 14, 15 and 17).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3879_8	49.1	61.8	70.1	78.1	88.5	96.3	104	122
25_3879_13	3.83	4.81	5.47	6.09	6.90	7.51	8.12	9.52

Table B12.7 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N12 Model Extent (Tributary) (Little Brosna Reach 2, see Chapter A7)

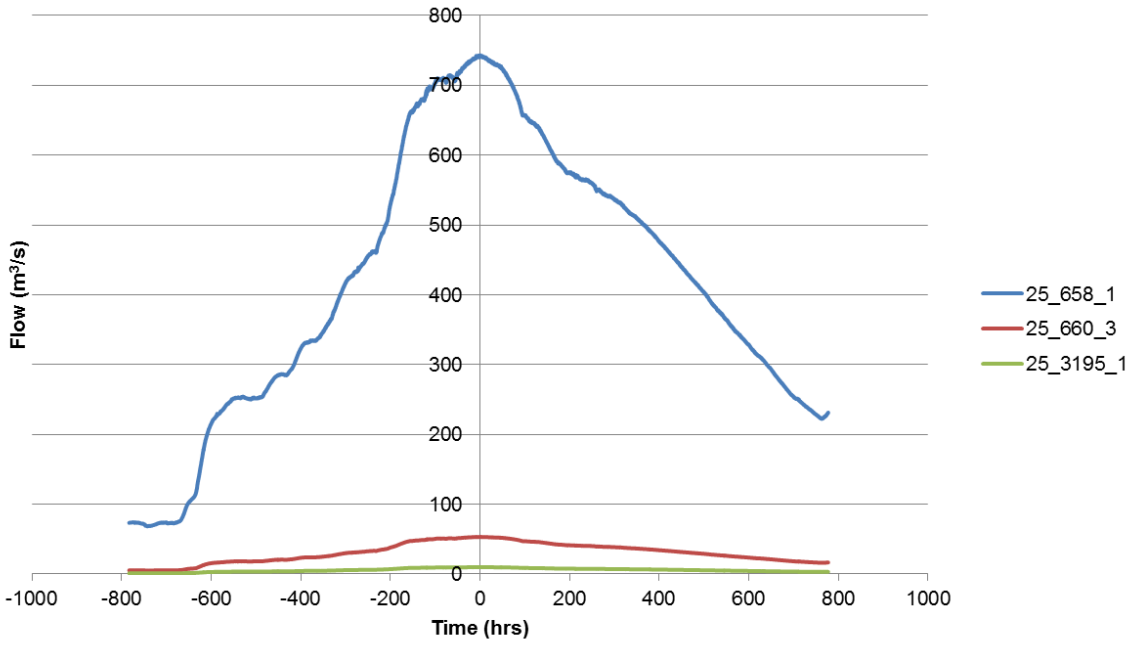

Figure B12.2 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Main Stem) (Reach 3)

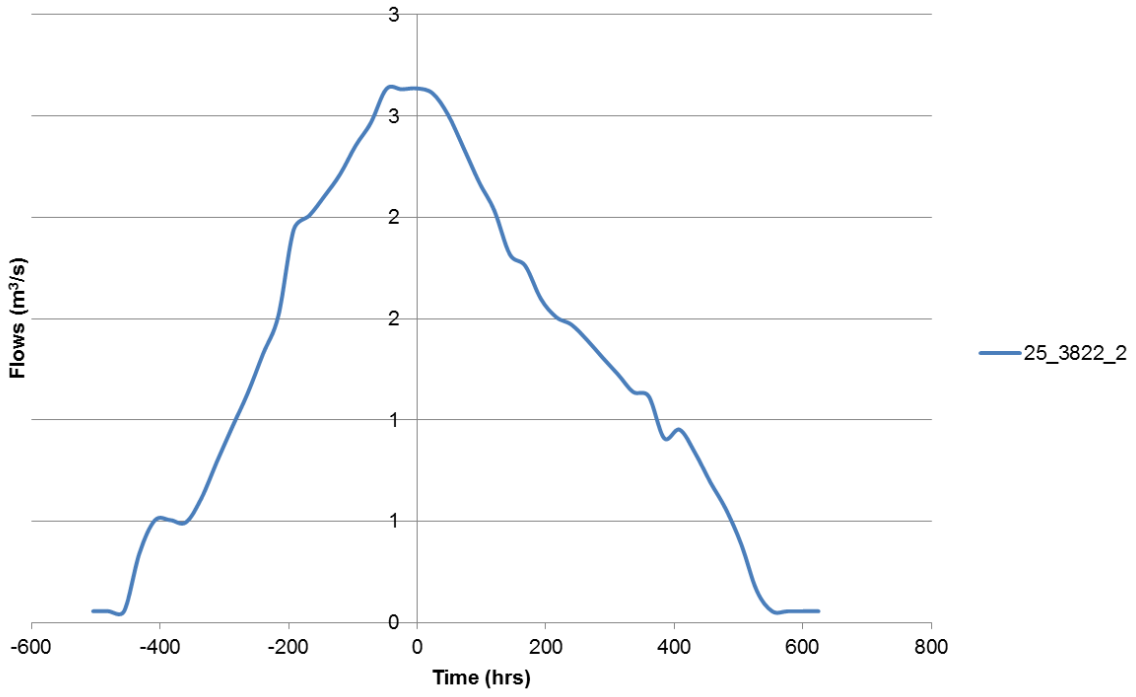

Figure B12.3 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Main Stem) (Reach 16)

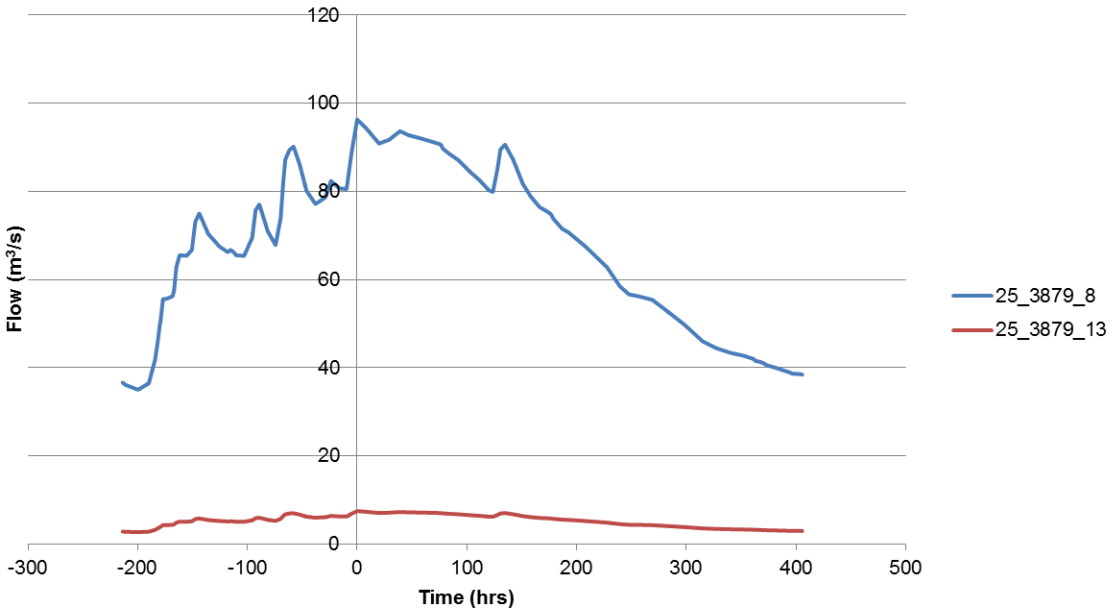

Figure B12.4 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Little Brosna Reach 1, see Chapter A7)

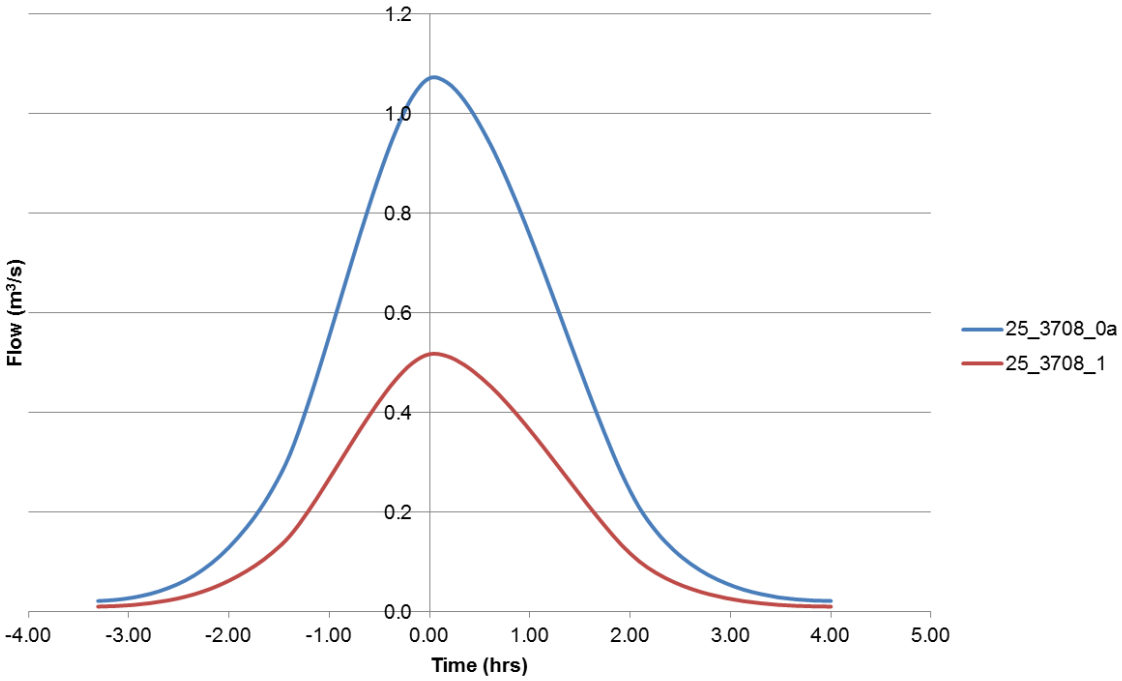

Figure B12.5 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Reach 10)

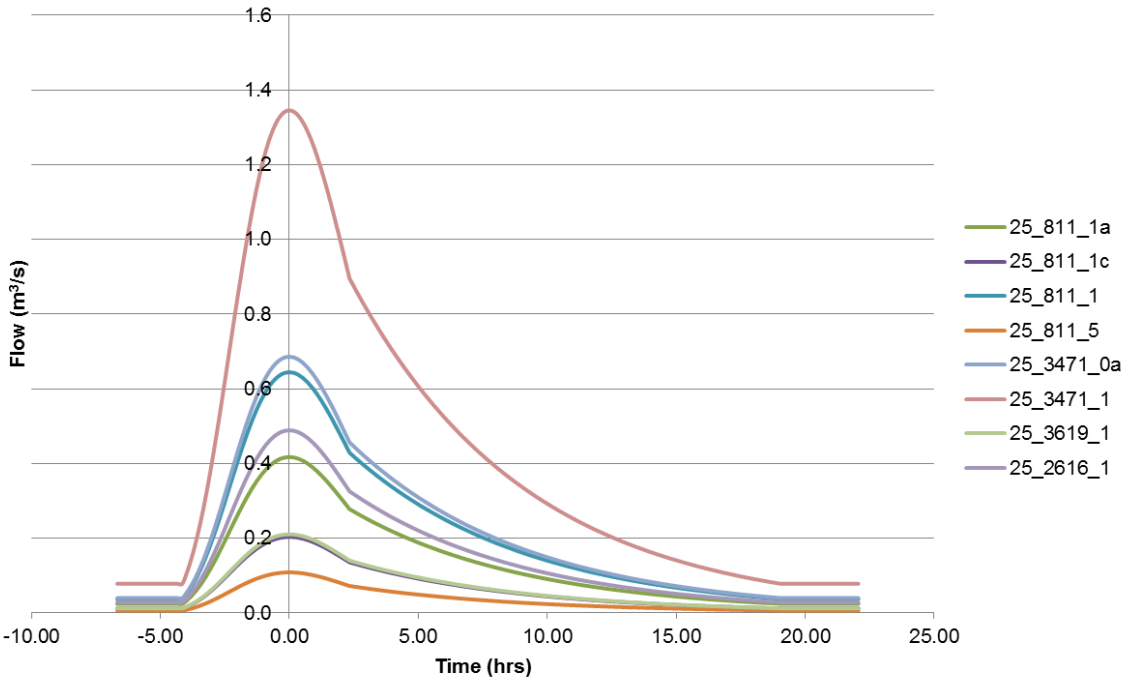

Figure B12.6 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Reach 11)

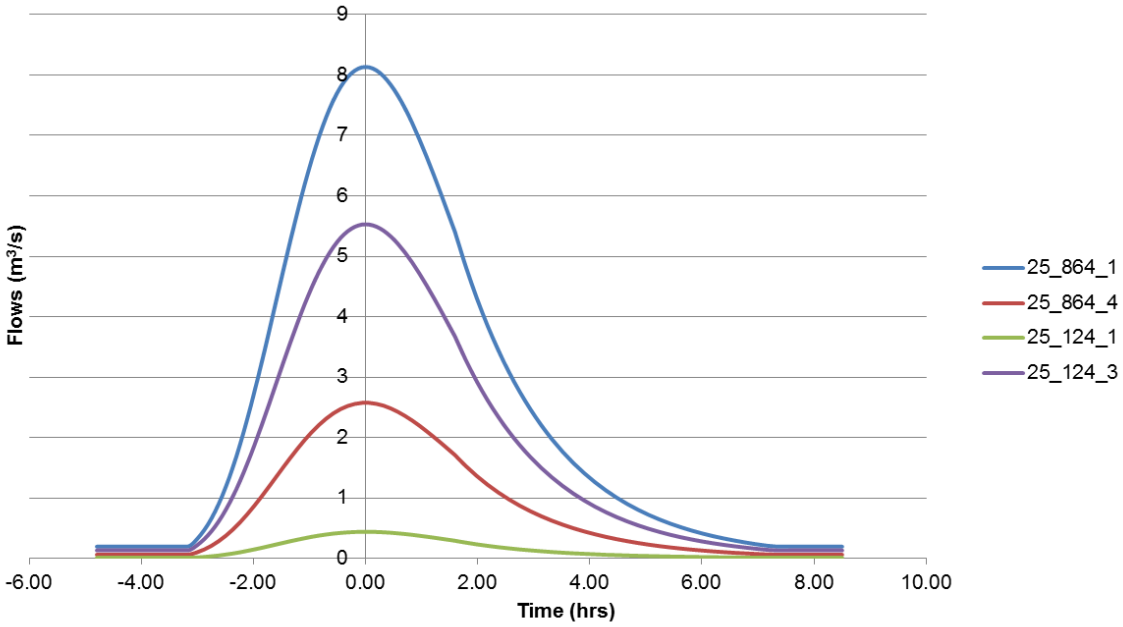

Figure B12.7 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Reach 14)

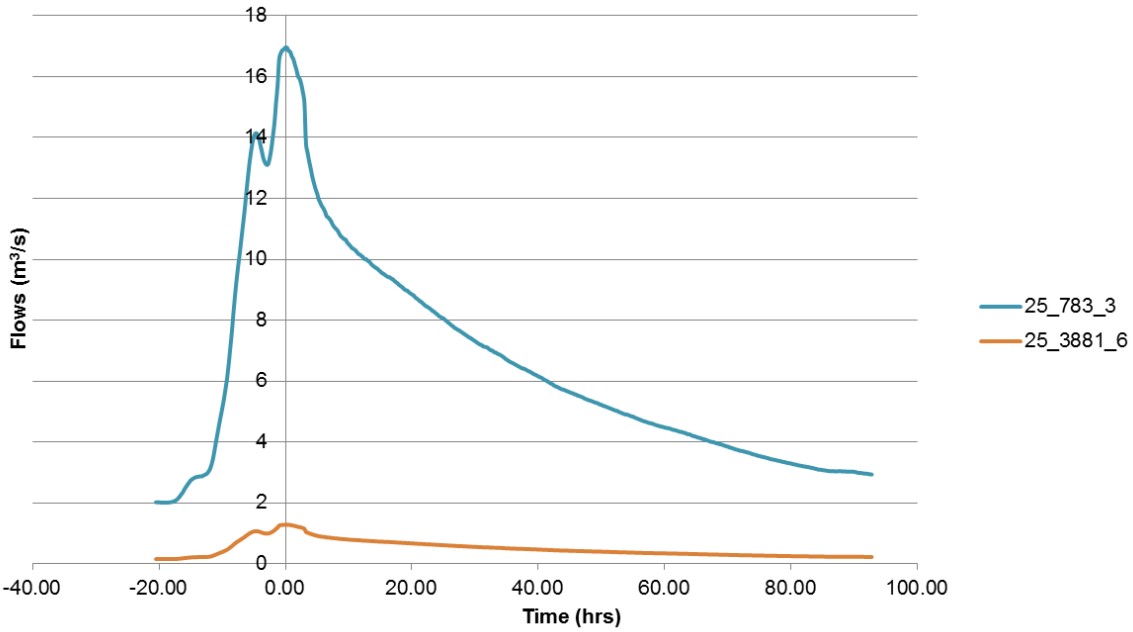

Figure B12.8 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Reach 15)

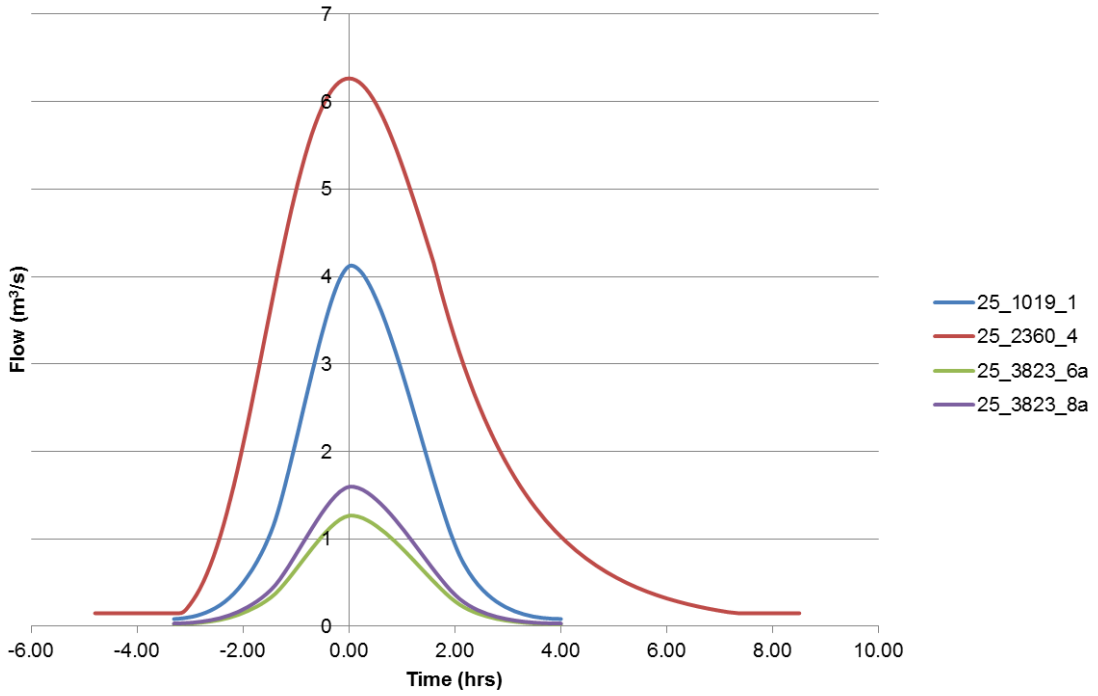

Figure B12.9 N12 Preliminary Design Inflow Hydrographs for 1% AEP (Tributaries) (Reaches 12, 13 and 17)

B12.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B12.5 to B12.7 for calibrating the model to the HEP target flows presented in Tables B12.2 to B12.4.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N12.

B13 Model N13

The N13 model extent covers the Ballyfinboy River section from HEP node 25_3530_2a to its inflow into Lough Derg at its most downstream point, refer to Figure B13.1. There is one Area for Further Assessment (AFA) located within the N13 model extent (Borrisokane). There is only one recorder gauging station located on the Ballyfinboy River (Ballyhooney, number 25025). This has been used for the flood frequency analysis in this catchment.

The estimation of a Qmed adjustment factor, growth curve and hydrograph shape are all documented in Appendix A8. The model calibration and design inflow hydrographs are summarised below.

B13.1 Calibration

The N13 model could not be calibrated because there was insufficient historic observational information available. Also, there is only one recorder gauge (Ballyhooney – 25025) located on this model extent along with two staff gauges, which is insufficient to undertake calibration with gauged data only.

A flood outline for the November 2009 was considered for verification of the model as outlined in the calibration strategy for N13. A SERTIT (Service Régional de Traitement d'Image et de Télédétection) satellite image is available from floodmaps.ie but the image was taken ten days after the flood due to the fact that the coverage over Ireland during the event was impeded by clouds and rainfall. The satellite outline indicates that the flood levels had receded to below the modelled 10% AEP flood outline when the satellite image was taken. The flood outline could therefore not be used to verify this model.

B13.2 Target Flows

The target flows are the total flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A, Chapter A8. The target flows at the HEP nodes for the N13 model are shown in Table B13.1 below. It should be noted that only the nodes that were found to be suitable for comparing the modelled total flows with the target flows have been tabulated. Some HEP nodes are excluded from the tables as the modelled flows in some nodes are affected by localised 2D flow patterns at nearby confluences and can therefore not be meaningfully compared with the target flows.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3530_5	4.84	6.09	6.92	7.72	8.75	9.52	10.29	12.07
25_3530_6	9.84	12.39	14.08	15.70	17.80	19.37	20.93	24.56
25_1855_1	11.36	14.30	16.25	18.13	20.55	22.36	24.17	28.35
25_3589_1	11.73	14.77	16.79	18.72	21.22	23.09	24.96	29.28
25_1853_3	11.73	14.77	16.79	18.72	21.22	23.09	24.96	29.28

Table B13.1 Target Flows at HEP Locations on the N13 Model Extent – Ballyfinboy River

B13.3 Preliminary Design Flows

The inflow hydrographs shown below in Figure B13.2 to Figure B13.9 were derived by the implementation of the procedure outlined in Chapter 2 and using the adjustment factor, growth curve and hydrograph shape specified in Appendix A, Chapte A8. The HEPs are shown in Figure B13.1. Section B13.4 below explains that these inflows are also the final design inflows for this model. The peak flows for the design hydrographs at each selected HEP on the N13 model extent are tabulated in Table B13.2 below.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3530_2a/b [1]	4.8	6.1	6.9	7.7	8.8	9.5	10.3	12.1
25_3530_6	5.0	6.3	7.2	8.0	9.1	9.9	10.7	12.5
25_1855_1	1.5	1.9	2.2	2.4	2.8	3.0	3.2	3.8
25_3589_1	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9

Table B13.2 Preliminary and Final Design Hydrographs Peak Flows for Gauging Station 25025 (flows in m^3/s)

Table B13.2 Comment:

1. This flow was split between two parallel channels in the model. This split is specified in the hydraulic modelling report for model N13.

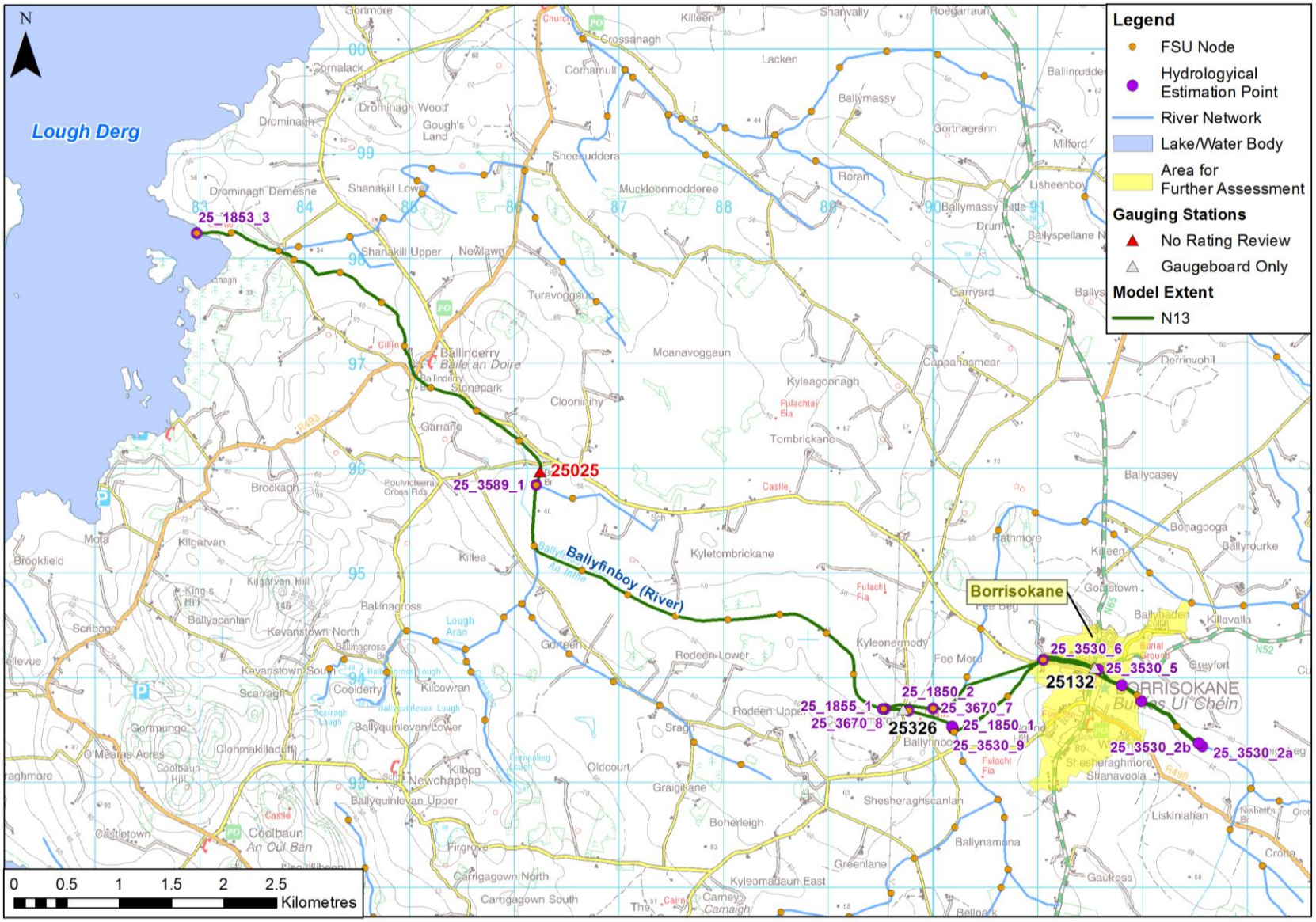

Figure B13.1 N13 Model Extent

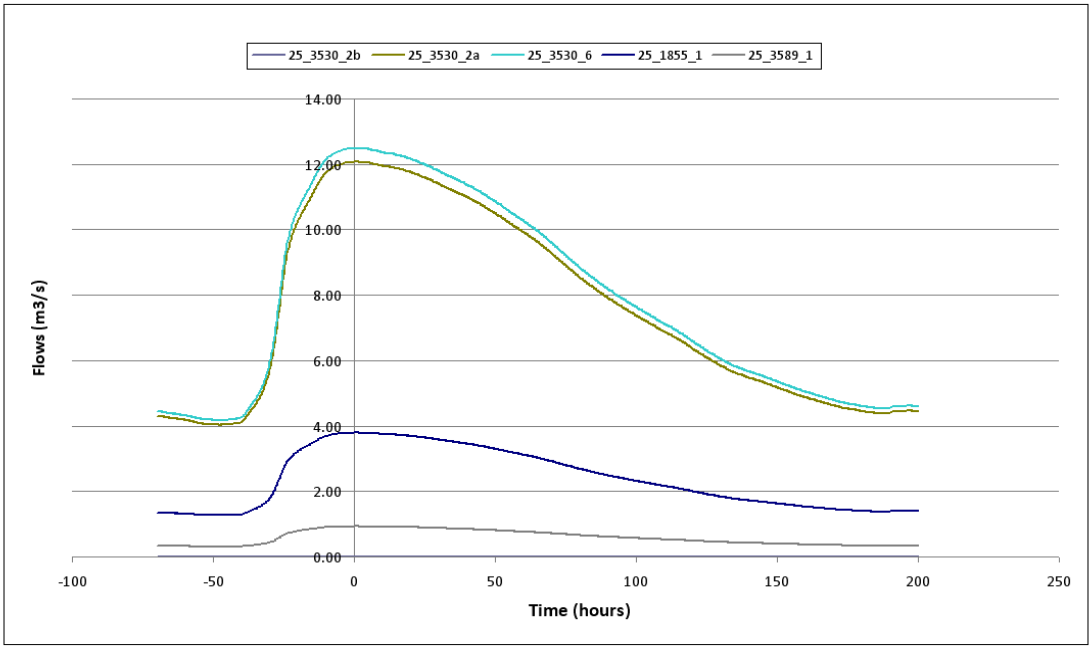

Figure B13.2 N13 Preliminary and Final Inflow Hydrographs – 0.1% AEP

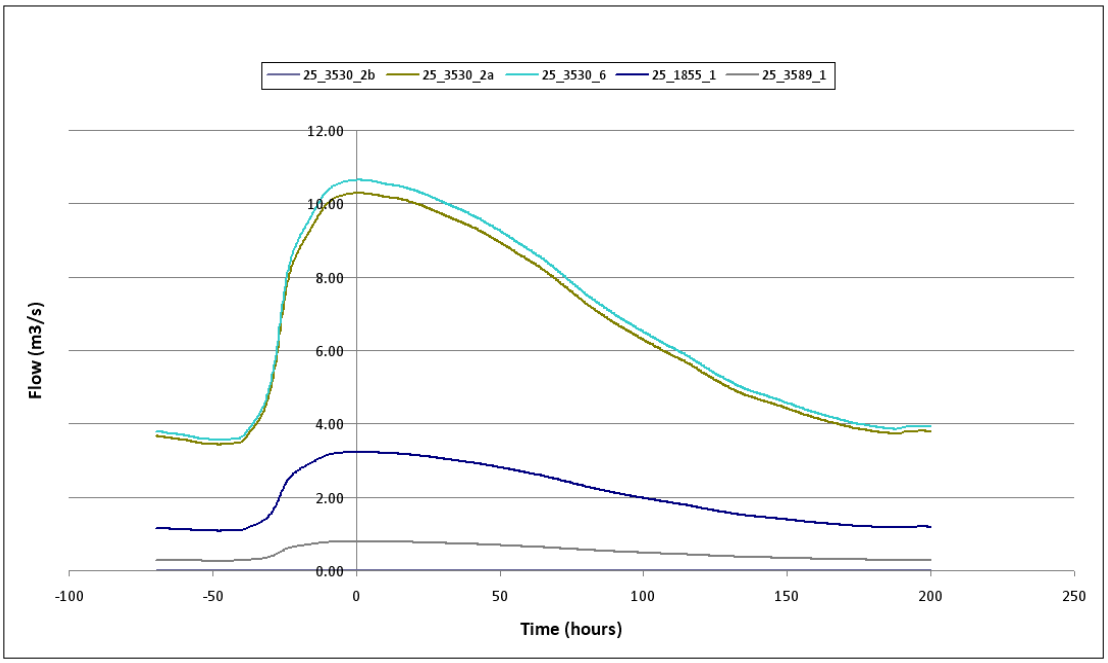

Figure B13.3 N13 Preliminary and Final Inflow Hydrographs – 0.5% AEP

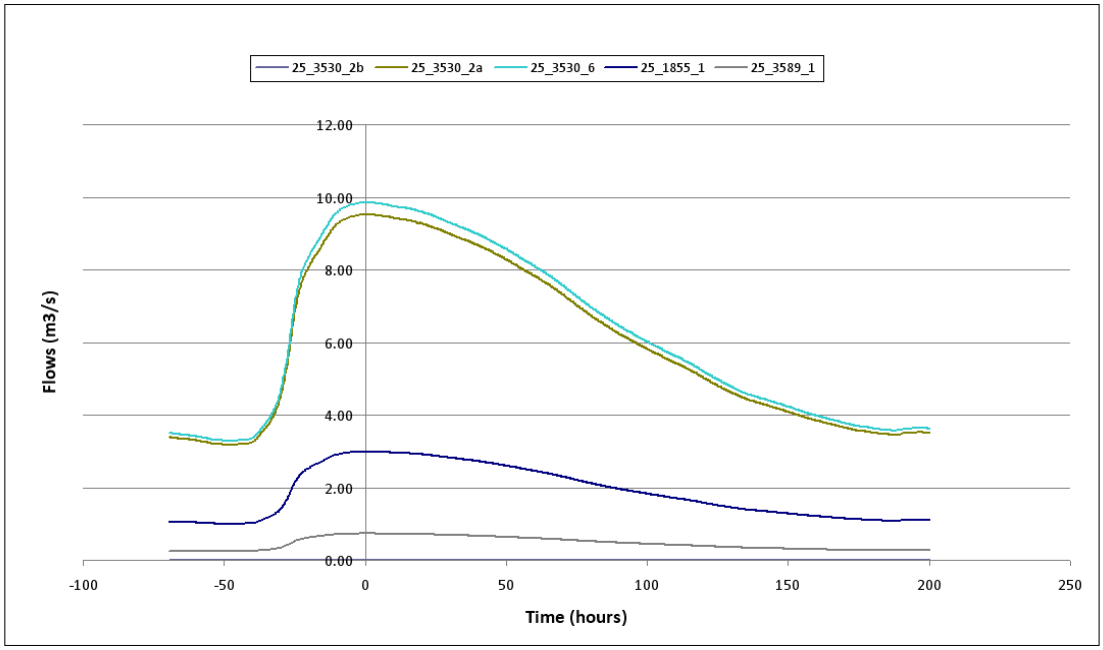

Figure B13.4 N13 Preliminary and Final Inflow Hydrographs – 1% AEP

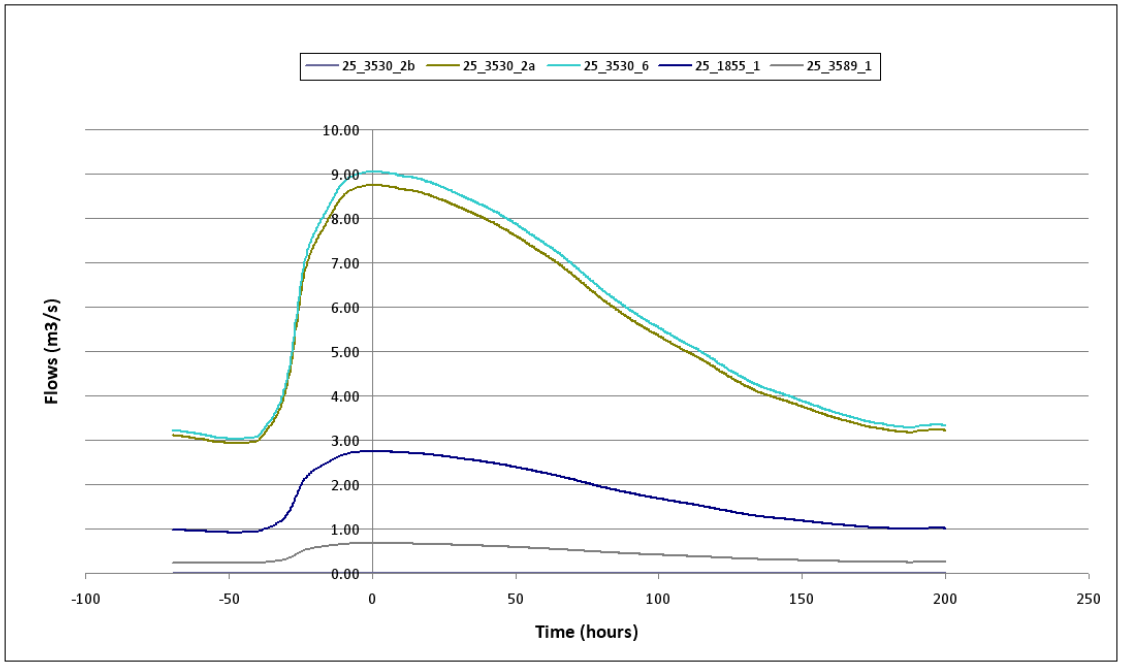

Figure B13.5 N13 preliminary and Final Inflow Hydrographs – 2% AEP

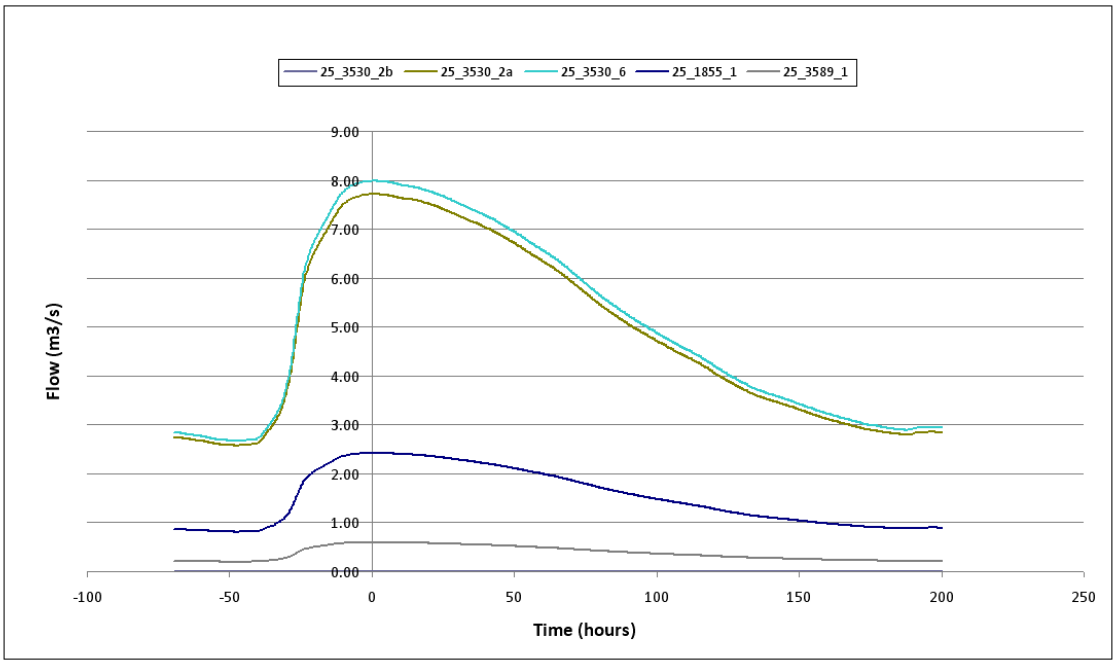

Figure B13.6 N13 Preliminary and Final Inflow Hydrographs – 5%

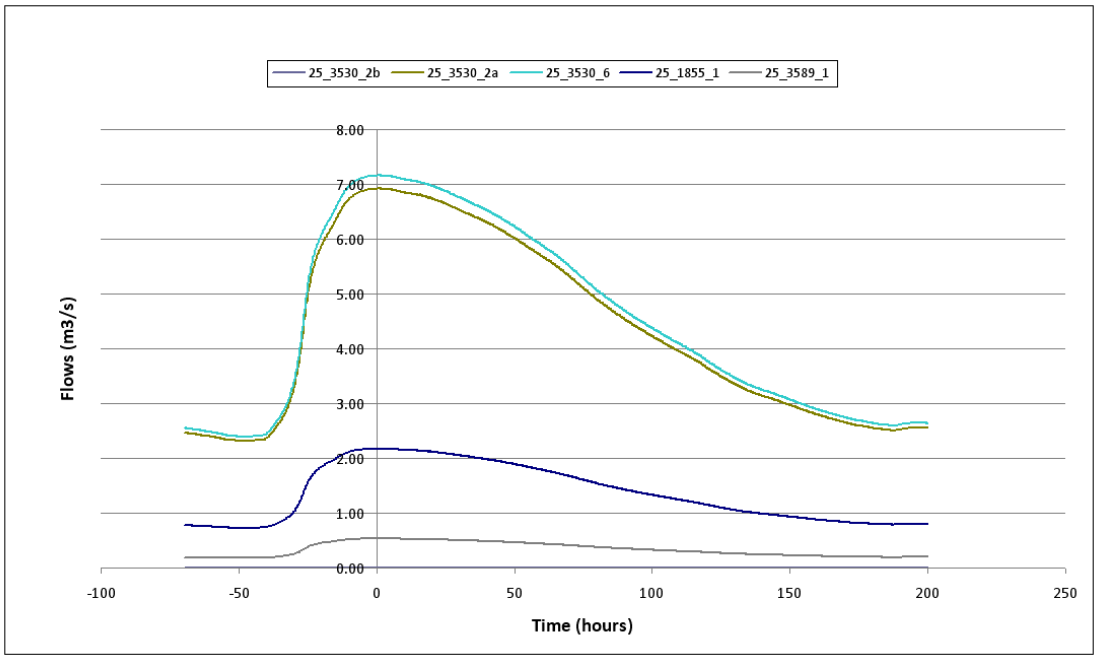

Figure B13.7 N13 Preliminary and Final Inflow Hydrographs – 10% AEP

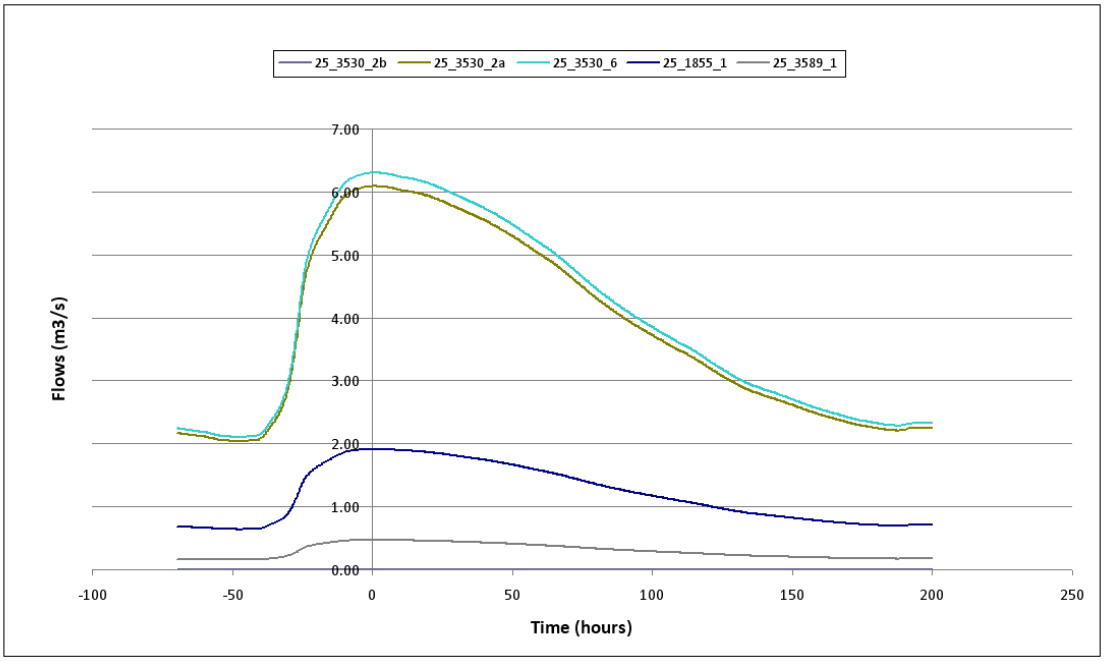

Figure B13.8 N13 Preliminary and Final Inflow Hydrographs – 20% AEP

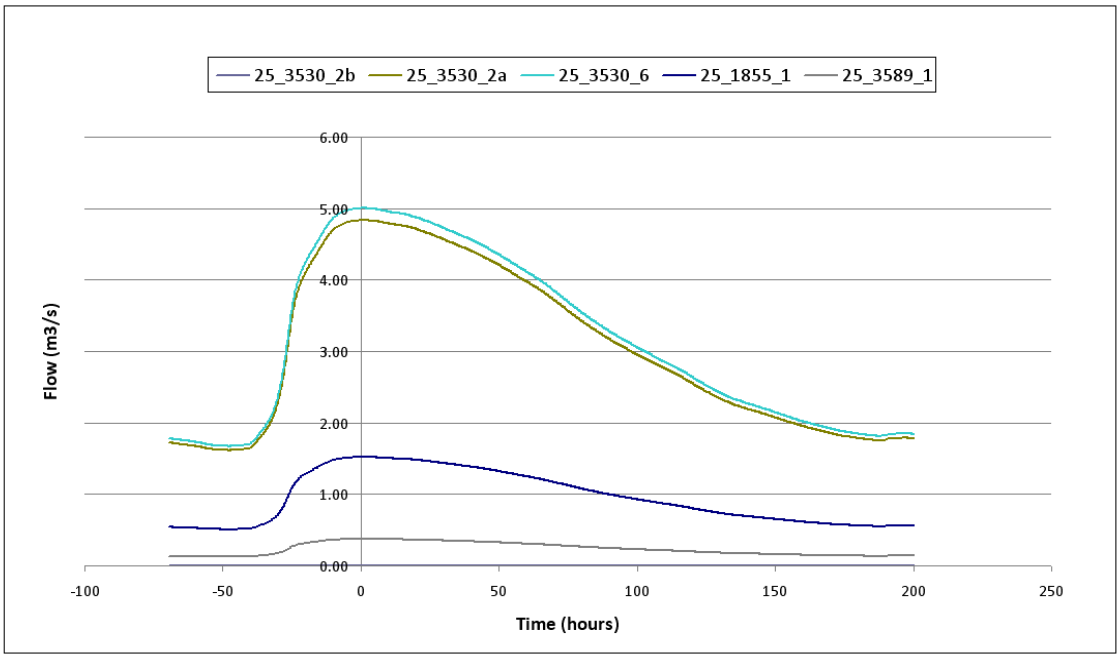

Figure B13.9 N13 Preliminary and Final Inflow Hydrographs – 50% AEP

B13.4 Final Design Hydrographs

The process of establishing the final design flows involves extracting from the hydraulic model the total flows at HEPs along the watercourse and comparing these total modelled flows with the total flows anticipated at each HEP from the hydrological analysis detailed in Appendix A8. If modelled flows at a node is more than 10% different than the target flows , then the model inflows are adjusted by the

right amount for the modelled flows to accord with the anticipated flows from the hydrological analysis. The required adjustment has to be estimated, and may result in revised modelled flows that still deviate from the anticipated total flows. The model is then re-run with the adjusted flows and a further comparison is made. A few iterations may be required until the modelled flows are within 5% of the target flows.

For N13 the model was run with the initial design inflows for the full range of AEPs. All the modelled total flows were within 10% of the flows anticipated at the HEPs after the first preliminary flow runs. Small deviations for some high exceedance probabilities (low return periods) are attributed to limitations of the hydrological method rather than the model. Adjustments to the inflows are therefore not required.

Therefore, the peak inflows in Table B13.2 and the inflow hydrographs in Figures B13.2 - B13.9 in Section B13.3 represent the final design inflows.

B14 Model N14

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods and the inflow design hydrographs required to ensure that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B14.1, and shown on Figure B14.1

Model Attribute	Comment
Rivers included in model	River Nenagh River Ollatrim Moyroe Stream Benedin Stream
Areas for Further Assessment (AFA)	Nenagh

Table B14.1 Model Extent Coverage

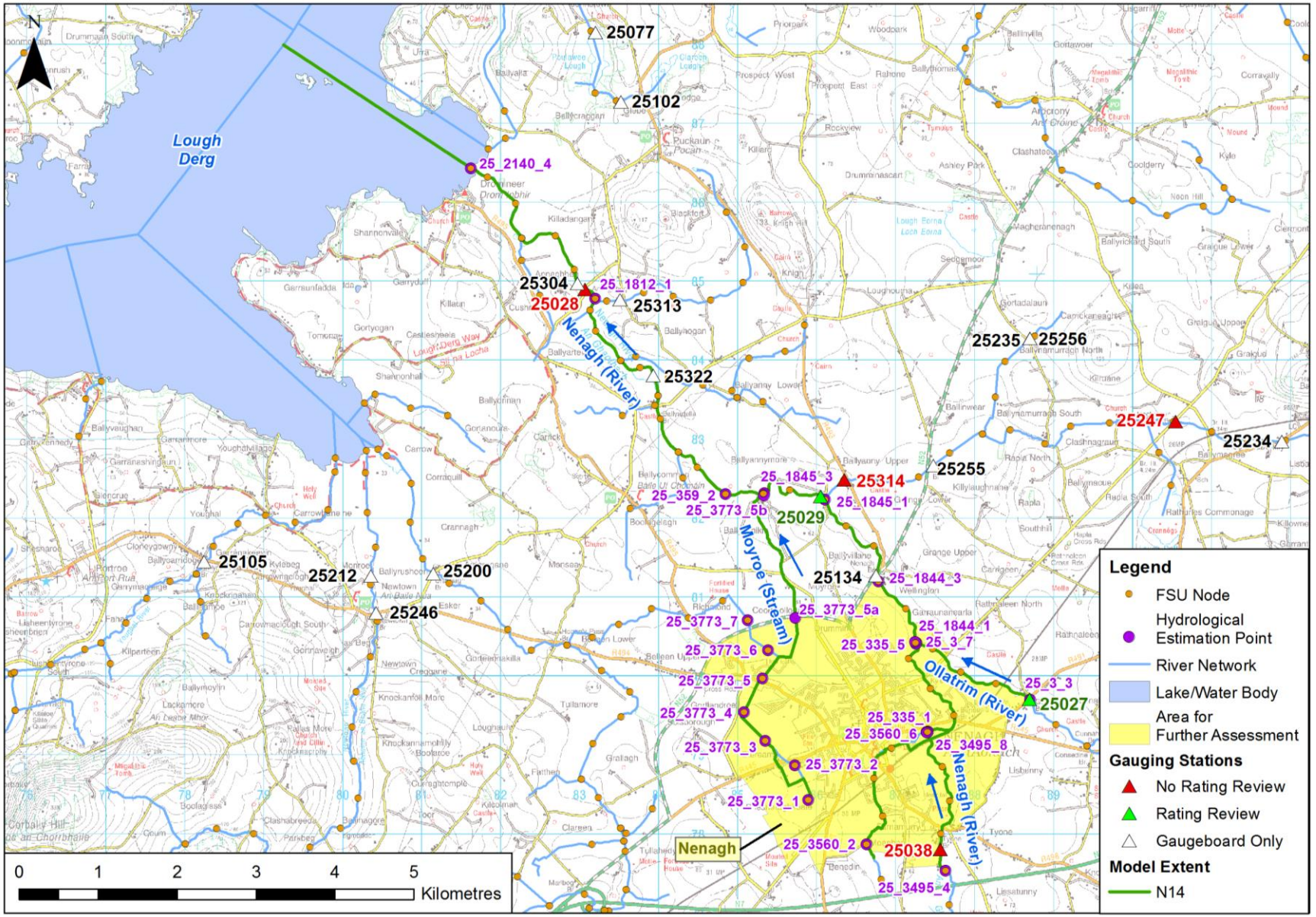

Figure B14.1 N14 Model Extent

B14.1 Hydrology for Hydraulic Model Calibration

There was sufficient hydrometric data for calibration and verification against a number of flood events for the N14 model. There was also a small amount of historic flood information that may be used for broad-brush verification of the modelled flood extents.

Out-of-bank and in-bank calibration and verification was undertaken along the Nenagh River and Ollatrim River reaches between gauging stations 25027, 25029 and 25038. This was undertaken by applying gauged flows at gauging stations 25038 and 25027 and then comparing the resulting modelled flows and water levels at the downstream station (25029) with the gauged flows and water levels at that station. The flows from station 25038 were scaled up proportionally with area to allow for lateral inflows to occur from the ungauged surface catchment between stations 25038 and 25029.

Four events were selected for event-based calibration/verification:

- 03/11/2000 (Out-of-bank) – Calibration
- 08/01/2005 (Out-of-bank) – Verification
- 20/11/2009 (In-bank) – Calibration
- 31/01/2009 (In-bank) – Verification

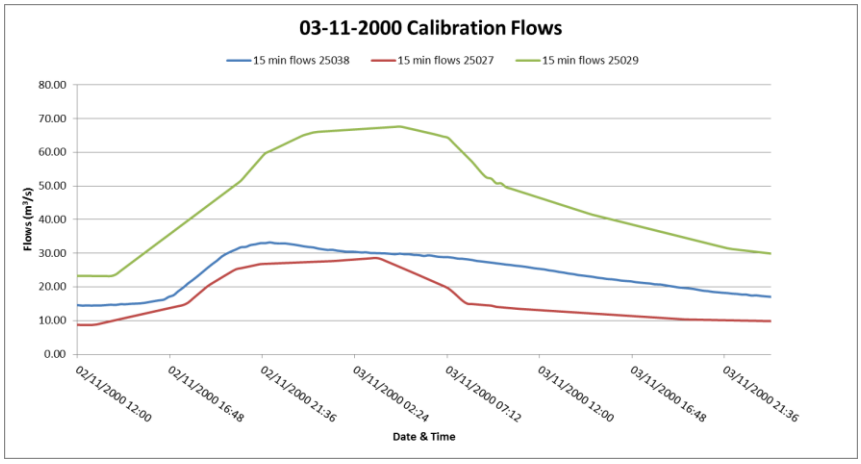

Figure B14.2 Model Calibration/Verification Flow Data November 2000

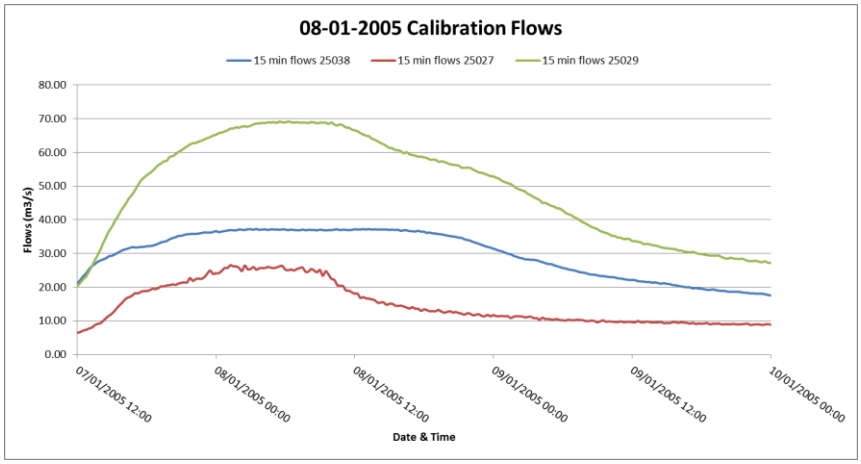

Figure B14.3 Model Calibration/Verification Flow Data January 2005

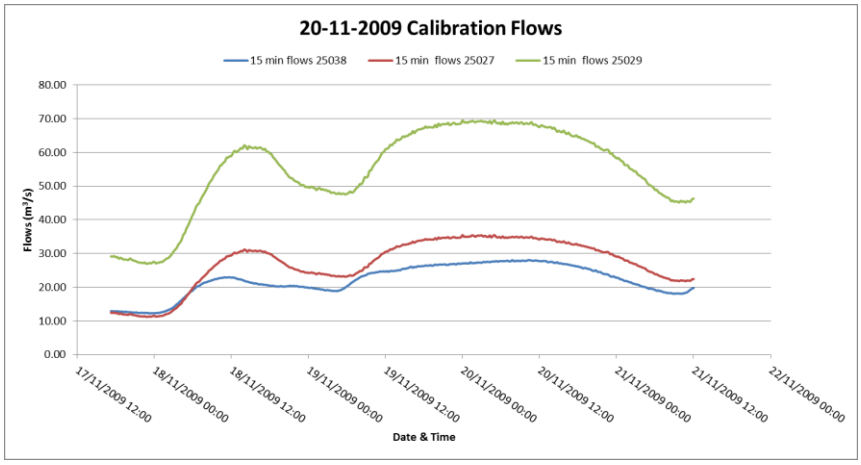

Figure B14.4 Model Calibration/Verification Flow Data November 2009

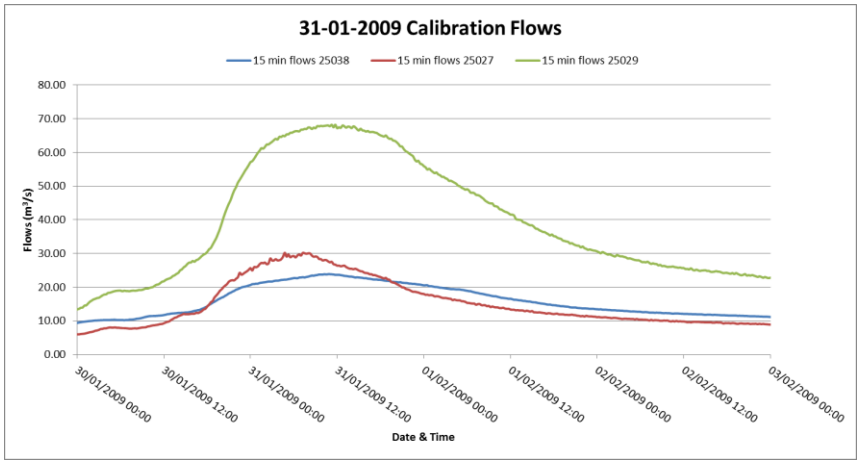

Figure B14.5 Model Calibration/Verification Flow Data January 2009

Figures B14.2–5 show the inflow and outflow hydrographs for the calibration/ verification events. The hydrographs for station 25038 include the allowance for lateral inflows between stations 25038 and 25029 as described above.

There was historic anecdotal evidence available that was analysed by the hydraulic modellers in an attempt to broadly verify the model with such information. Details of the verification data can be found in the calibration strategy for Model N14 in Appendix F.

Refer to the hydraulic modelling report for Model N14 for the results of the calibration and verification.

B14.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A9. The target flows at the HEP nodes for model N14 are shown in Tables B14.2 (main stem) and B14.3 (tributaries).

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3495_8	26.0	32.3	36.1	39.6	43.9	47.1	50.2	57.2
25_335_1	26.3	32.5	36.4	39.9	44.3	47.5	50.6	57.7
25_335_5	26.3	32.5	36.4	39.9	44.3	47.5	50.6	57.7
25_1844_1	52.9	63.6	70.7	77.5	86.3	92.9	99.5	114.7
25_1844_3	53.0	63.7	70.8	77.6	86.4	93.0	99.6	114.9
25_1845_1	56.9	68.4	76.0	83.3	92.8	99.8	106.9	123.3
25_1845_3[1]	56.9	68.4	76.0	83.3	92.8	99.8	106.9	123.3
25_359_2	57.7	69.4	77.2	84.6	94.2	101.4	108.6	125.2
25_1812_1[1]	57.7	69.4	77.2	84.6	94.2	101.4	108.6	125.2
25_2140_4[1]	57.7	69.4	77.2	84.6	94.2	101.4	108.6	125.2

[1] In some places the target flow estimated using the FSU regression equation at a node is lower than that at the node immediately upsteam. In most cases this is an anomaly of the regression equation method (an exception being downstream of large lakes where flood flows are routed). As peak design flows on the N14 main stem should not decrease moving downstream the river, we have copied the upstream HEP peak flow to the downstream HEP.

Table B14.2 Target Flows (m^3/s) at HEP Locations on the N14 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3_7	22.8	28.2	31.5	34.6	38.3	41.1	43.8	49.8
25_3560_6	1.2	1.8	2.2	2.6	3.0	3.4	3.8	4.6
25_3773_2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7
25_3773_4	0.6	0.9	1.1	1.3	1.6	1.8	1.9	2.4
25_3773_5	0.7	1.0	1.3	1.5	1.8	2.0	2.2	2.7
25_3773_6	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6
25_3773_5a	1.5	2.1	2.6	3.0	3.6	4.0	4.5	5.4
25_3773_5b	1.7	2.4	3.0	3.5	4.1	4.6	5.1	6.2

Table B14.3 Target Flows (m^3/s) at HEP Locations on the N14 Model Extent (Tributaries)

B14.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B14.2 and B14.3, an initial set of inflow hydrographs was produced and run through the model. The main Nenagh and all its tributaries were modelled in a single run for each return period.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A9. The HEPs are shown on Figure B14.1. Tables B14.4 and B14.5 present the peak values of the preliminary inflows inserted into the model.

Preliminary design inflow hydrographs are shown on Figures B14.6 and B14.7 for the 1% AEP design runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3495_4	26.0	32.3	36.1	39.6	43.9	47.1	50.2	57.2
25_335_5	2.9	3.5	4.0	4.3	4.8	5.2	5.5	6.3
25_1844_3	3.9	4.7	5.3	5.8	6.4	6.9	7.4	8.5

Table B14.4 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N14 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3_3	22.8	28.2	31.5	34.6	38.4	41.1	43.8	49.9
25_3560_2	1.2	1.8	2.2	2.6	3.0	3.4	3.8	4.6
25_3773_1	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7
25_3773_2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3
25_3773_3	0.4	0.5	0.7	0.8	0.9	1.0	1.1	1.4
25_3773_4	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3
25_3773_5	0.6	0.9	1.0	1.2	1.4	1.6	1.8	2.2
25_3773_6	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6
25_3773_5a	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.8

Table B14.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N14 Model Extent (Tributaries)

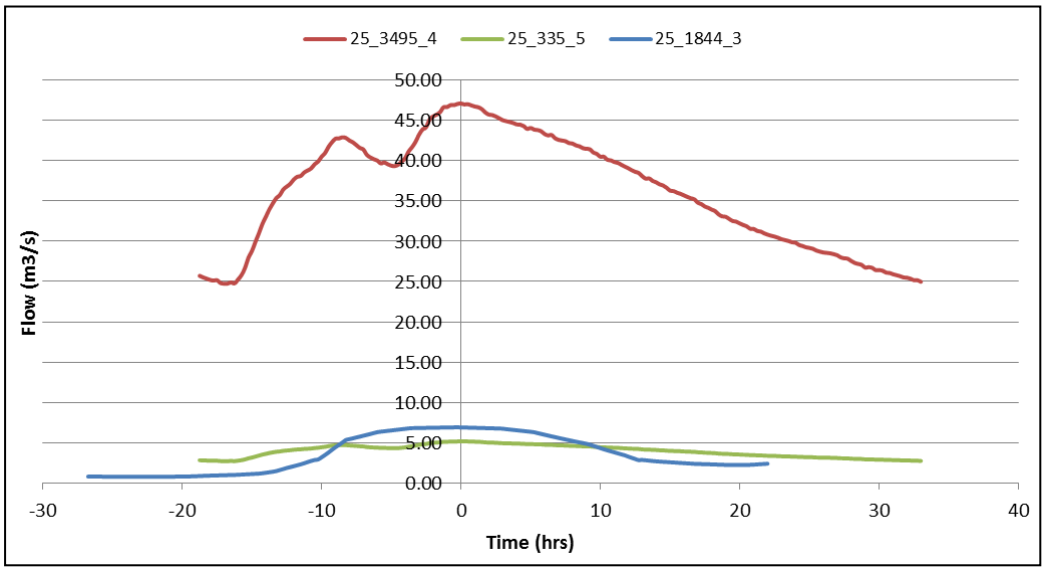

Figure B14.6 N14 Preliminary Design Inflow Hydrographs for 1% AEP (Reaches 1 and 2)

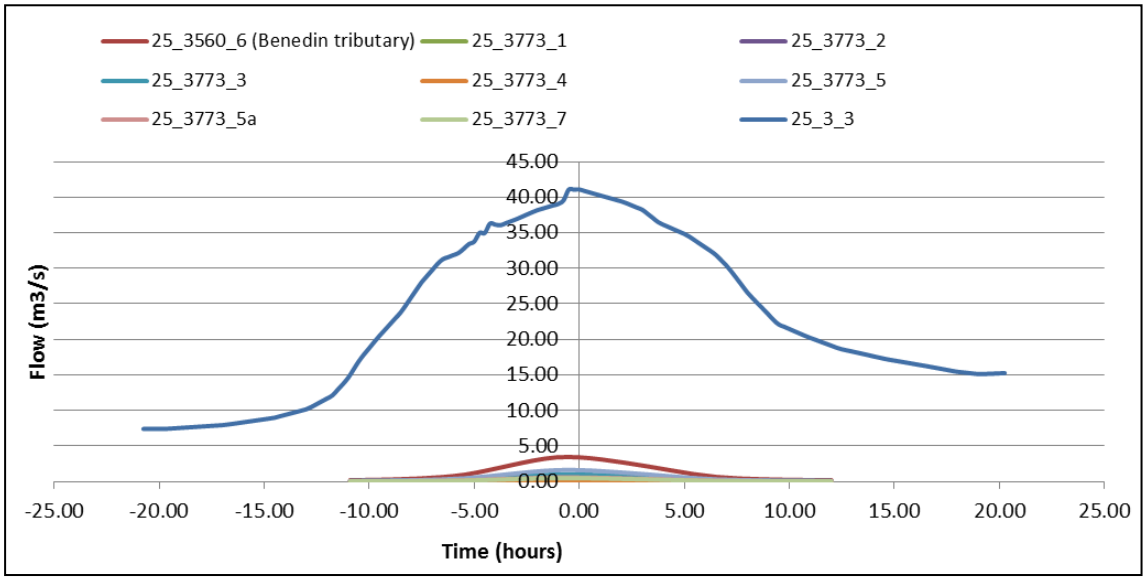

Figure B14.7 N14 Preliminary Design Inflow Hydrographs for 1% AEP (Reaches 3, 4 and 5)

B14.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B14.4 and B14.5 for calibrating the model to the HEP target flows presented in Tables B14.2 and B14.3.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N14.

B15 Model N15

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods and the inflow design hydrographs required to ensure that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B15.1, and shown on Figure B15.1

Model Attribute	Comment
Rivers included in model	River Mulkear River Bilboa (Tributary of Mulkear) Unnamed Tributary (Tributary of River Mulkear) River Newport (Tributary of Kileenagarriff) River Kileenagarrif (Tributary of Mulkear) River Small (Tributary of River Newport) Unnamed tributary of River Newport
Areas for Further Assessment (AFA)	Newport and Cappamore

Table B15.1 Model Extent coverage

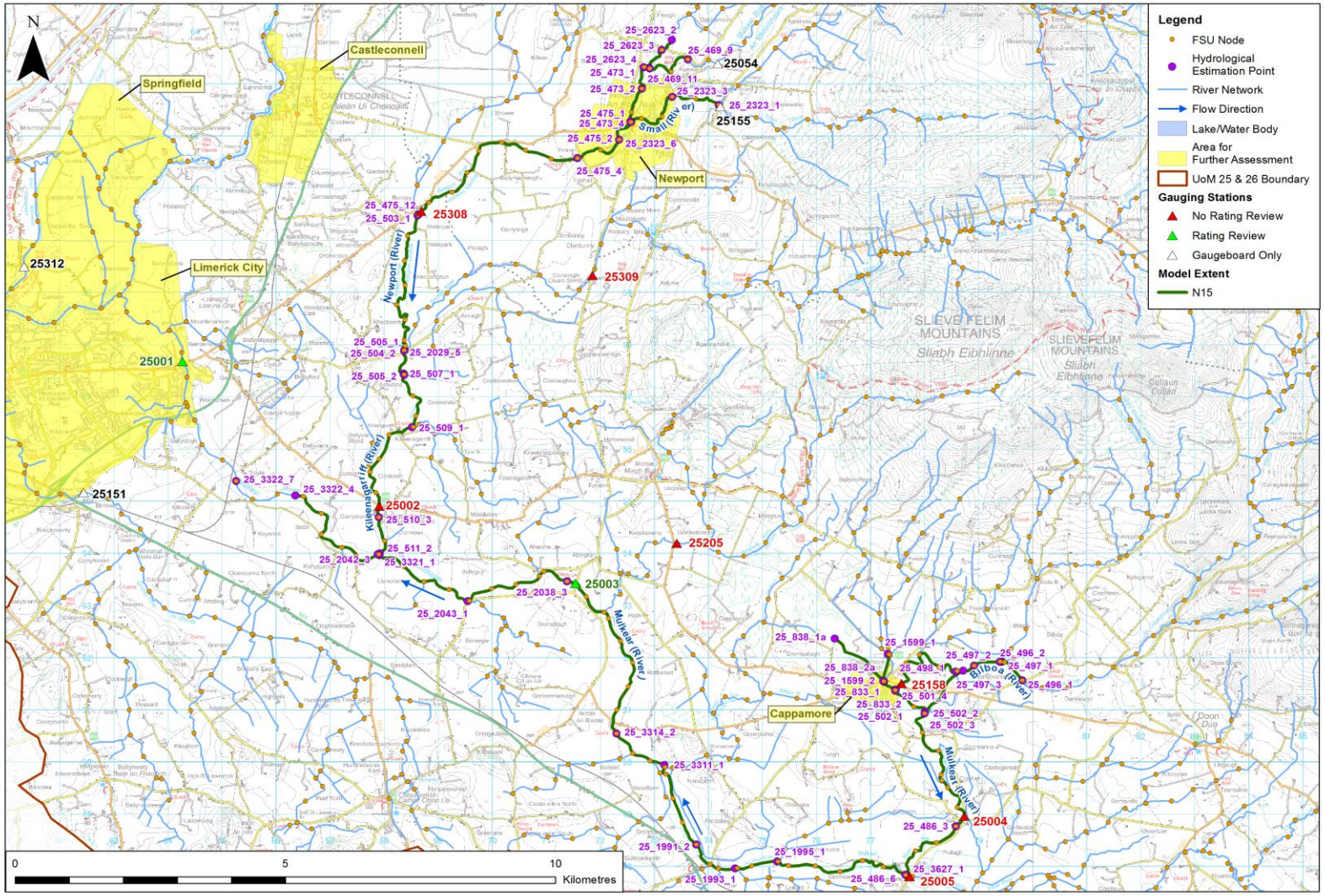

Figure B15.1 N15 Model Extent [1]

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B15.1 Hydrology for Hydraulic Model Calibration

There were insufficient hydrometric data to calibration model N15 on the River Mulkear. However, sufficient hydrometric data was available for calibration and verification against a number of flood events on the River Newport from the Newport AFA to the River Kileenagariff.

(Refer to the calibration strategy in Appendix F and the hydraulic modelling report for N15 for details on the calibration/verification).

B15.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A11. The target flows at the HEP nodes for model N15 are shown in Tables B15.2 and B15.3.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_1599_1	3.55	4.17	4.54	4.87	5.30	5.62	5.93	6.66
25_1599_2	3.55	4.17	4.54	4.87	5.30	5.62	5.93	6.66
25_833_1	3.61	4.24	4.61	4.95	5.38	5.71	6.03	6.76
25_833_2	3.65	4.29	4.66	5.01	5.44	5.77	6.09	6.84
25_502_1	28.10	33.04	35.92	38.58	41.96	44.46	46.95	52.69
25_502_2	28.10	33.04	35.92	38.58	41.96	44.46	46.95	52.69
25_502_3	28.41	33.40	36.32	39.01	42.42	44.95	47.46	53.27
25_486_3	28.87	33.94	36.90	39.64	43.10	45.67	48.23	54.13
25_486_6	28.87	33.94	36.90	39.64	43.10	45.67	48.23	54.13
25_3627_1	57.87	68.04	73.99	79.47	86.41	91.57	96.69	108.52
25_1995_1	61.98	72.87	79.24	85.11	92.55	98.07	103.56	116.23
25_1993_1	62.98	74.04	80.52	86.48	94.04	99.65	105.23	118.10
25_1991_2	66.22	77.85	84.66	90.93	98.88	104.78	110.64	124.18
25_3311_1	68.51	80.54	87.58	94.07	102.29	108.40	114.46	128.47
25_3314_2	71.50	84.06	91.41	98.18	106.76	113.14	119.46	134.08
25_2038_3	74.37	87.43	95.08	102.12	111.05	117.68	124.26	139.46
25_2043_1	74.37	87.43	95.08	102.12	111.05	117.68	124.26	139.46
25_2042_3	74.37	87.43	95.08	102.12	111.05	117.68	124.26	139.46
25_3321_1	115.32	135.58	147.43	158.35	172.19	182.47	192.67	216.25
25_3322_1	115.32	135.58	147.43	158.35	172.19	182.47	192.67	216.25

Table B15.2 Target Flows (m^3/s) at HEP Locations on the N15 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_496_1	22.23	26.13	28.42	30.52	33.19	35.17	37.14	41.68
25_496_2	22.23	26.13	28.42	30.52	33.19	35.17	37.14	41.68
25_497_1	24.57	28.89	31.41	33.74	36.69	38.88	41.05	46.08
25_497_2	24.57	28.89	31.41	33.74	36.69	38.88	41.05	46.08
25_497_3	24.57	28.89	31.41	33.74	36.69	38.88	41.05	46.08
25_498_1	24.57	28.89	31.41	33.74	36.69	38.88	41.05	46.08
25_501_4	24.57	28.89	31.41	33.74	36.69	38.88	41.05	46.08
25_838_1a	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.11
25_838_2a	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.11
25_469_9	23.68	27.84	30.28	32.52	35.36	37.47	39.57	44.41
25_469_11	23.68	27.84	30.28	32.52	35.36	37.47	39.57	44.41
25_473_1	26.20	30.81	33.50	35.98	39.13	41.46	43.78	49.14
25_473_2	26.20	30.81	33.50	35.98	39.13	41.46	43.78	49.14
25_473_4	26.35	30.98	33.69	36.18	39.35	41.70	44.03	49.42
25_475_1	29.99	35.26	38.35	41.19	44.79	47.46	50.11	56.25
25_475_2	29.99	35.26	38.35	41.19	44.79	47.46	50.11	56.25
25_475_4	29.99	35.26	38.35	41.19	44.79	47.46	50.11	56.25
25_475_12	31.17	36.64	39.84	42.79	46.54	49.31	52.07	58.44
25_503_1	35.56	41.81	45.46	48.83	53.10	56.27	59.41	66.68
25_504_2	35.88	42.18	45.87	49.27	53.57	56.77	59.95	67.28
25_505_1	58.58	68.87	74.89	80.44	87.47	92.69	97.88	109.85
25_505_2	58.58	68.87	74.89	80.44	87.47	92.69	97.88	109.85
25_507_1	58.58	68.87	74.89	80.43	87.46	92.69	97.87	109.84
25_509_1	59.30	69.72	75.81	81.43	88.55	93.83	99.08	111.20
25_510_3	59.30	69.72	75.81	81.43	88.55	93.83	99.08	111.20
25_511_2	59.30	69.72	75.81	81.43	88.55	93.83	99.08	111.20
25_2323_1	6.81	8.01	8.71	9.35	10.17	10.78	11.38	12.77
25_2323_3	6.81	8.01	8.71	9.35	10.17	10.78	11.38	12.77
25_2323_6	6.97	8.19	8.91	9.57	10.40	11.02	11.64	13.07
25_2623_2	4.47	5.25	5.71	6.14	6.67	7.07	7.47	8.38
25_2623_3	4.47	5.25	5.71	6.14	6.67	7.07	7.47	8.38
25_2623_4	4.47	5.25	5.71	6.14	6.67	7.07	7.47	8.38

Table B15.3 Target Flows (m^3/s) at HEP Locations on the N15 Model Extent (Tributaries)

B15.3 Preliminary Design Inflows

To obtain the target flows shown in Tables B15.2 and B15.3, an initial set of inflow hydrographs was produced and run through the model. To be able to model the critical events on the tributaries independently from the critical events on the main stem, three separate runs were undertaken for each AEP, one run to match the target flows in the main stem, and two separate independent runs to obtain the target flows on the tributaries. For modelling purposes the tributaries are defined as the River Bilboa, unnamed tributary (i.e. from nodes 25_838_1a to 25_838_2a), River Small, unnamed tributary (i.e. from nodes 25_2623_2 to 25_2623_4), River Newport and River Kileenagarrif.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A11. The QMED adjustment factor, growth curve and hydrograph shape are specified in Appendix A11. The HEPs are shown on Figure B15.1. Tables B15.4 and B15.5 below present the peak values of the preliminary lateral inflows inserted into the model in the reach immediately upstream of the HEP in the hydraulic model for the main stem and tributary runs.

Preliminary design inflow hydrographs are shown in Figures B15.2 to B15.5 for the 1% AEP design runs.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_1599_1	3.55	4.17	4.54	4.87	5.30	5.61	5.93	6.65
25_1599_2	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.11
25_833_2	24.44	28.73	31.24	33.55	36.48	38.66	40.82	45.82
25_502_1	0.31	0.36	0.39	0.42	0.46	0.49	0.51	0.58
25_502_3	0.46	0.54	0.59	0.63	0.68	0.73	0.77	0.86
25_486_3	29.01	34.10	37.08	39.83	43.31	45.90	48.46	54.39
25_3627_1	4.11	4.83	5.25	5.64	6.14	6.50	6.87	7.71
25_1995_1	1.00	1.17	1.28	1.37	1.49	1.58	1.67	1.87
25_1993_1	3.24	3.81	4.14	4.45	4.84	5.13	5.42	6.08
25_1991_2	2.29	2.69	2.92	3.14	3.41	3.62	3.82	4.29
25_3311_1	2.99	3.52	3.83	4.11	4.47	4.74	5.00	5.61
25_3314_2	2.87	3.37	3.67	3.94	4.28	4.54	4.79	5.38
25_2038_3	40.95	48.14	52.35	56.23	61.15	64.79	68.42	76.79

Table B15.4 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N15 Model Extent (Main Stem)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_838_1a	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.11
25_496_1	22.23	26.14	28.43	30.53	33.20	35.18	37.15	41.70
25_496_2	2.34	2.75	2.99	3.21	3.49	3.70	3.90	4.38
25_469_9	23.68	27.84	30.28	32.52	35.36	37.47	39.57	44.41
25_469_11	2.52	2.97	3.22	3.46	3.77	3.99	4.21	4.73
25_475_1	0.45	0.53	0.58	0.62	0.67	0.71	0.75	0.85
25_475_2	0.04	0.03	0.05	0.07	0.08	0.08	0.07	0.06
25_475_12	4.39	5.17	5.62	6.03	6.56	6.95	7.34	8.24
25_503_1	0.32	0.37	0.41	0.44	0.47	0.50	0.53	0.60
25_504_2	20.60	24.22	26.34	28.29	30.76	32.60	34.42	38.63
25_505_1	2.10	2.46	2.68	2.88	3.13	3.32	3.50	3.93
25_507_1	0.72	0.85	0.93	0.99	1.08	1.15	1.21	1.36
25_2623_2	4.47	5.27	5.72	6.12	6.66	7.06	7.46	8.40
25_2323_1	6.81	8.01	8.71	9.35	10.17	10.78	11.38	12.77
25_2323_3	0.16	0.18	0.20	0.21	0.23	0.25	0.26	0.29

Table B15.5 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N15 Model Extent (Tributaries)

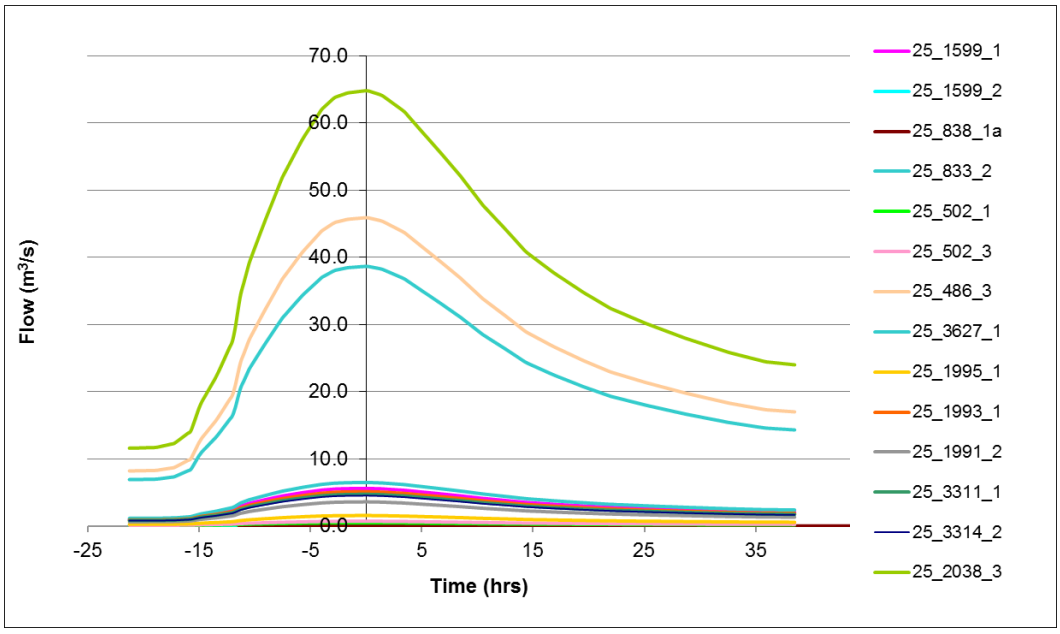

Figure B15.2 Main Stem Run 1 (Reaches 1, 2 and 72) Preliminary Design Inflow Hydrographs for 1% AEP

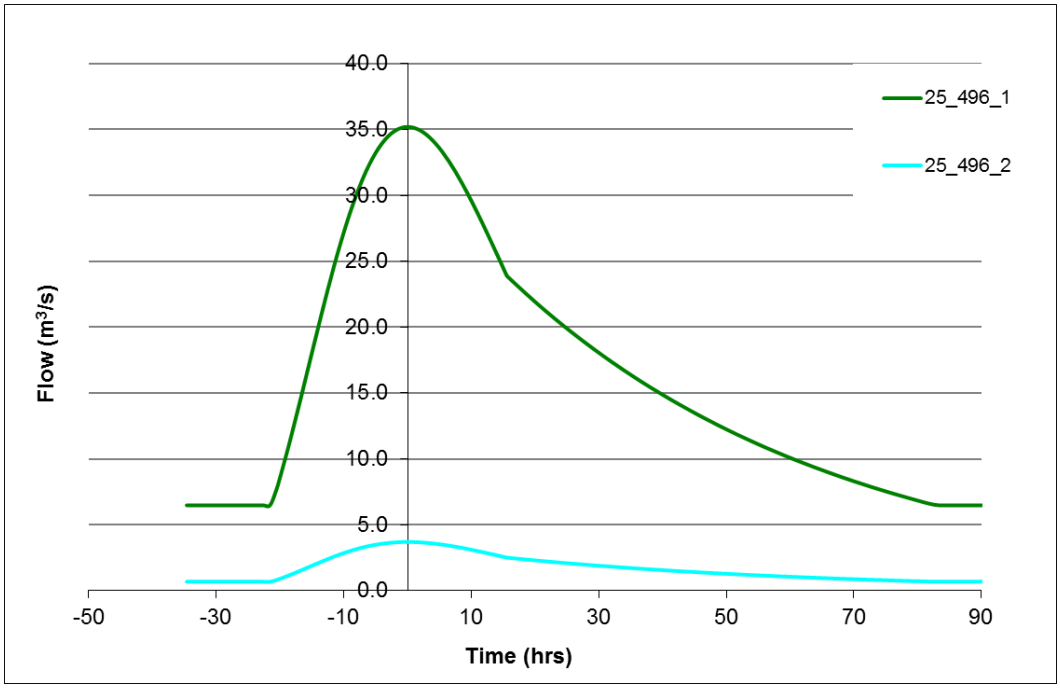

Figure B15.3 Tributary Run 2 (Reach 1 - River Bilboa) Preliminary Design Inflow Hydrographs for 1% AEP

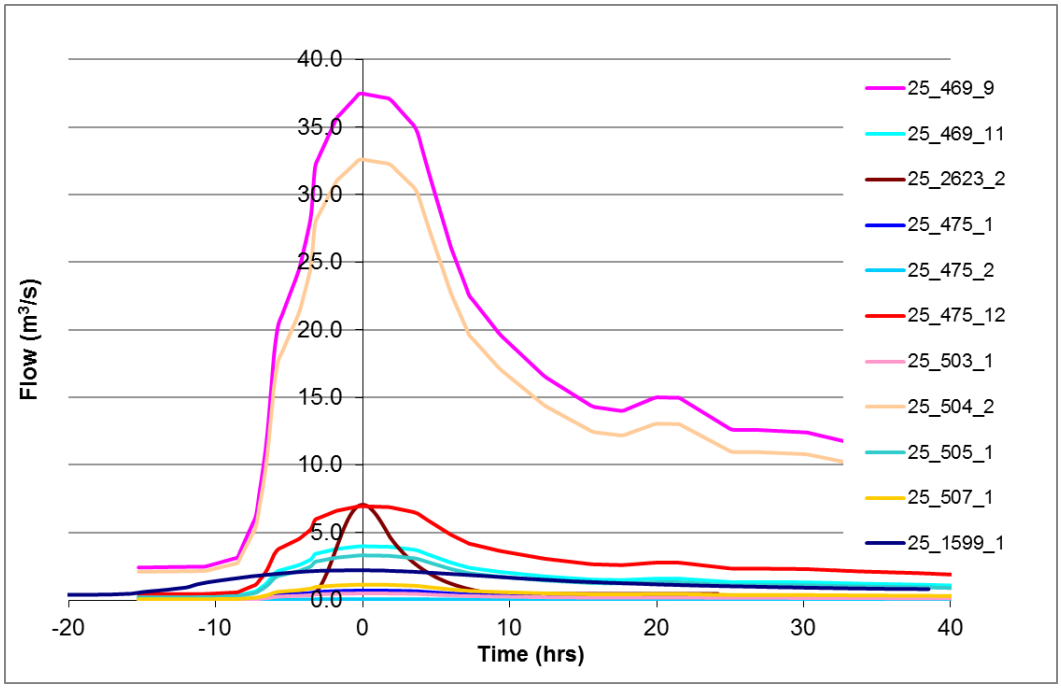

Figure B15.4 Tributary Run 2 (Reaches 3 and 4) Preliminary Design Inflow Hydrographs for 1% AEP

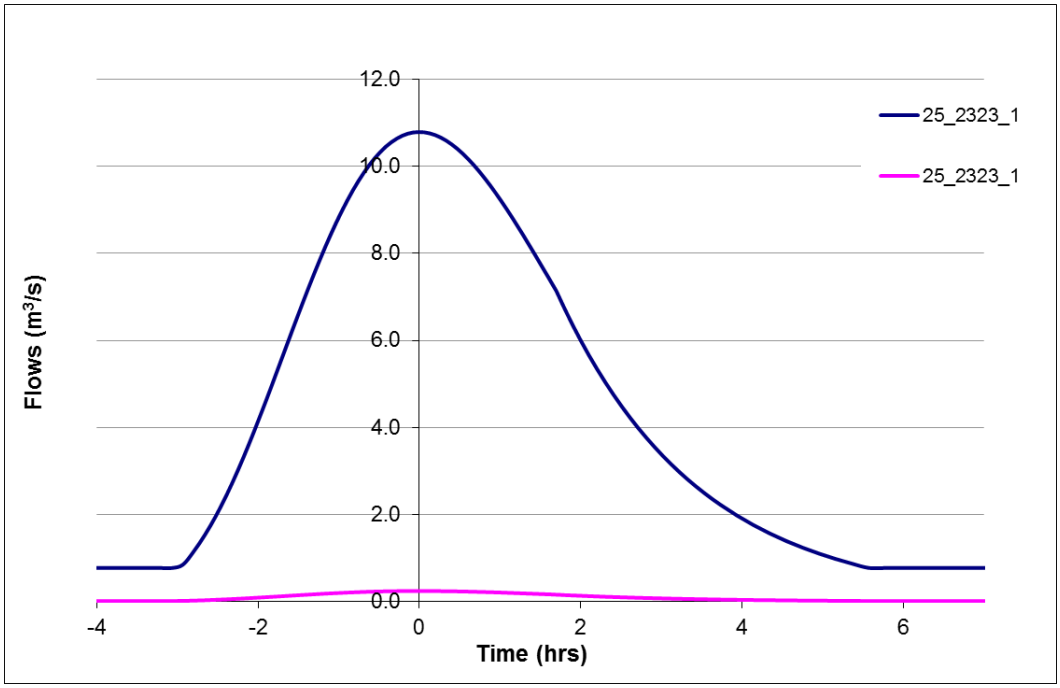

Figure B15.5 Tributary Run 3 (Reach 3 – River Small) Preliminary Design Inflow Hydrographs for 1% AEP

B15.4 Final Design Inflows

The hydraulic model uses the preliminary design inflows presented in Tables B15.4 and B15.5 for calibrating the model to the HEP target flows presented in Tables B15.2 and B15.3.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N15.

B16 Model N16

This appendix chapter summarises:

i) the hydrology for the hydraulic model calibration; and
ii) the target flows for the full range of modelled return periods, and the preliminary inflow design hydrographs used in the hydraulic modelling as the starting point in the process of ensuring that the river flows in the model agree with the target flows obtained from the hydrological techniques of the FSU (as described in Appendix A).

The model extent coverage is summarised in Table B16.1, and Figure B16.1

Model Attribute	Comment
Watercourses included in model	River Shannon and its tributaries including: River Mulkear; Cappavilla; Blackwater; Shannakyle; Groody; Towlerten; Ballykeelaun; Ballygrennan; Clonmacken; Ballincurra; Crompaun lower and a number of smaller tributary branches. Also included in the model is the Head Race Canal which diverts water from the main River Shannon to Ardnacrusha Power Station.
Areas for Further Assessment (AFA)	Limerick City, Springfield
Individual Risk Receptor (IRR)	None
Hydrological subcatchments (see Main Report and Appendix A)	Lower and Middle Shannon (Chapter A6), Mulkear (Chapter A10)

Table B16.1 Model Extent coverage

B16.1 Hydrology for Hydraulic Model Calibration

There was insufficient gauged data available to calibrate the N16 model in isolation. However, a cross model fluvial calibration of the River Mulkear was possible using the hydrographs at station 25001 in the N16 model, and 25002 and 25003 in the N15 model.

Based on the availability of 15-min interval level data, a tidal calibration/verification of the Ballincurra Creek Branch of the N16 model was possible, using the tidal event data at Station 25061 and the corresponding level data at stations 24047 and 24049.

Refer to the calibration strategy in Appendix F and the hydraulic modelling report for N16 for detail on the calibration/verification.

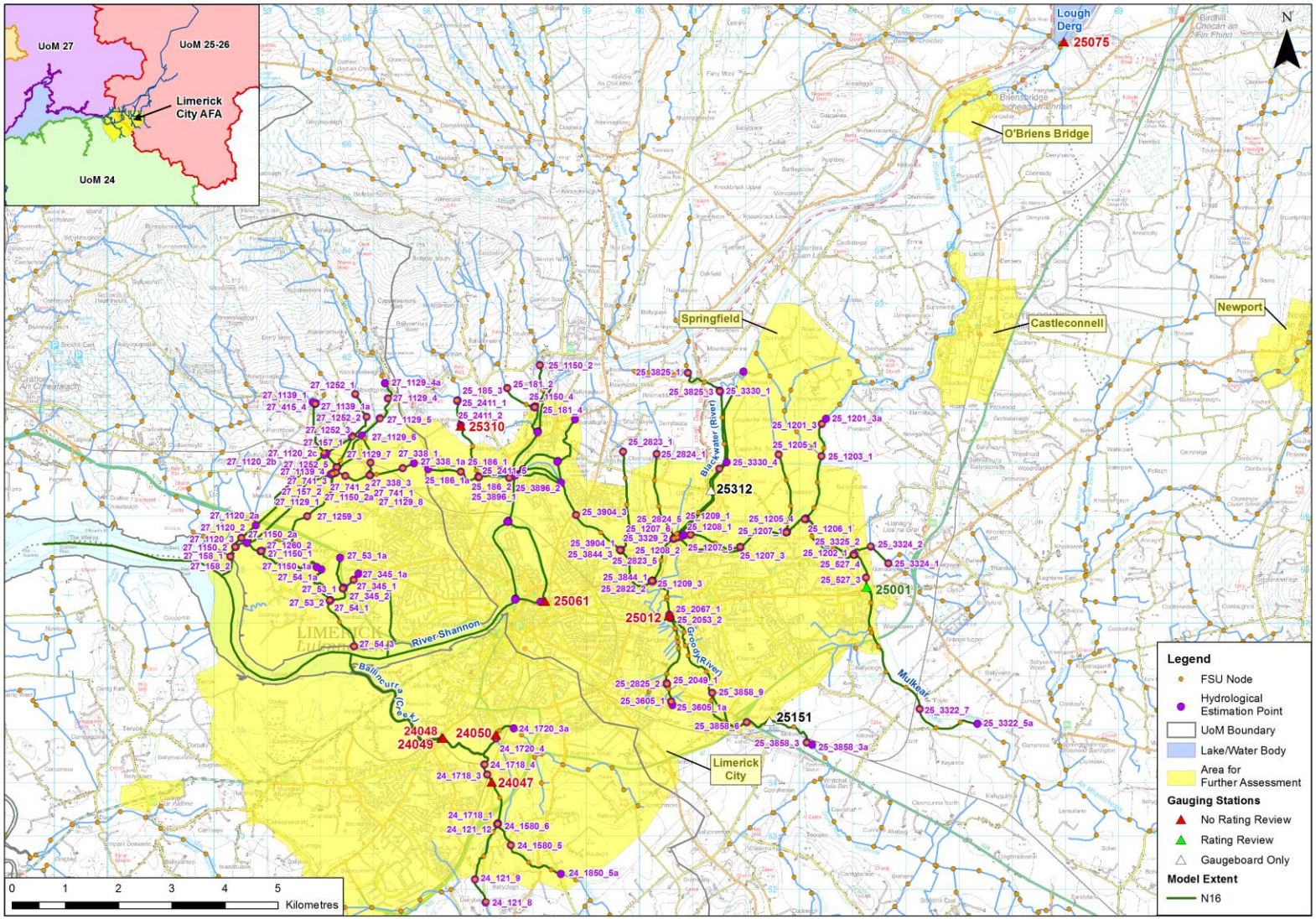

Figure B16.1 N16 Model Extent [1]

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B16.2 Target Design Flows

The target flows are the peak flows required at the HEP nodes which have been derived using the design hydrology process detailed in Appendix A6. The target flows at the HEP nodes for model N16 are shown in Tables B16.2 – B16.10.

The peak flow estimation process for the N16 main stem (River Shannon) and tributaries is described in Appendix A, in the chapters indicated in Table B16.1 above.

To get detail on the design peak flows on the River Mulkear (the downstream end of which is part of the N16 model), the reader is referred to Chapter A10. However, to understand the inflow allowed for from the Mulkear to obtain the critical flood on the River Shannon, Chapter A6 should be consulted.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_1203_1*	221	291	355	417	497	557	616	754
25_1203_4*	221	291	355	417	497	557	616	754
25_1206_1	272	349	419	486	574	639	704	854
25_1206_2*	272	349	419	486	574	639	704	854
25_1207_1	273	349	419	487	574	639	704	854
25_1207_3	273	350	420	488	575	640	705	856
25_1207_5	286	364	436	504	593	660	726	880
25_1207_6*	286	364	436	504	593	660	726	880
25_1208_1	291	370	442	511	601	668	735	890
25_1208_2	291	370	442	511	601	668	735	890
25_1209_1	291	370	442	511	601	668	735	890
25_1209_3	293	372	444	514	604	671	738	894
25_3844_1	298	378	451	521	612	680	748	905
25_3844_3	299	378	452	522	612	680	748	905
25_3904_1	299	379	452	522	613	681	749	906
25_3904_3*	299	379	452	522	613	681	749	906

** Where the target design flow estimate is less than that in the node upstream, then the target flow from the upstream node was adopted to avoid having decreasing target flows where this is not physically realistic.*

The target flows in all main stem nodes exclude a peak flow of 345 m^3/s to represent the flow that is diverted into the Head Race Canal for Ardnacrusha Power Station for all design events, as discussed in Chapter A6 in Appendix A.

Table B16.2 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (River Shannon) – Reach 16

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3324_2	1.1	1.3	1.4	1.6	1.7	1.8	1.9	2.2
25_3325_2	1.3	1.6	1.7	1.9	2.0	2.2	2.3	2.6
25_3322_7	125	148	160	172	187	198	209	235
25_527_3	126	149	162	173	188	200	211	238
25_527_4*	126	149	162	173	188	200	211	238
25_1202_1	127	150	162	174	189	200	212	238
25_1202_4	127	150	163	174	190	201	213	239

**Target flows are less than respective upstream nodes. Flow from upstream carried forward downstream.*

Table B16.3 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Mulkear and its tributary Thornfield). Refer to Chapter A10 in Appendix A

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_1205_4	0.43	0.58	0.68	0.77	0.89	0.98	1.1	1.3
25_3825_3	24.2	29.1	32.1	34.7	38.0	40.4	42.6	47.7
25_3330_1	24.2	29.1	32.1	34.8	38.1	40.4	42.7	47.8
25_3330_4*	24.2	29.1	32.1	34.8	38.1	40.4	42.7	47.8
25_3329_2*	24.2	29.1	32.1	34.8	38.1	40.4	42.7	47.8
25_2824_5	1.2	1.6	1.8	2.1	2.4	2.6	2.8	3.4

**Target flows are less than respective upstream nodes. Flow from upstream carried forward downstream.*

Table B16.4 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Cappavilla, Blackwater and Shannakyle) – Reaches 18, 19 and 20

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3858_3	5.7	7.5	8.6	9.8	11.2	12.3	13.3	15.8
25_3858_6	5.8	7.6	8.7	9.9	11.3	12.4	13.5	16.0
25_3858_9	6.0	7.8	9.0	10.1	11.6	12.8	13.9	16.5
25_2053_2	6.4	8.4	9.7	10.9	12.5	13.7	14.9	17.7
25_3605_1	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.27
25_2825_2	0.17	0.22	0.25	0.29	0.33	0.36	0.39	0.47
25_2049_1	0.57	0.75	0.86	0.98	1.1	1.2	1.3	1.6
25_1222_2	1.7	2.2	2.5	2.9	3.3	3.6	3.9	4.7
25_2067_1	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
25_2822_2	7.5	9.8	11.3	12.7	14.6	16.0	17.4	20.7

Table B16.5 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Groody and its tributary Towlerten) – Reaches 21 and 22

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_2823_5	1.5	2.0	2.3	2.7	3.1	3.4	3.7	4.4
25_181_4	3.0	4.0	4.7	5.3	6.2	6.8	7.4	8.9
25_1150_4	3.7	5.0	5.8	6.6	7.7	8.5	9.3	11.1

Table B16.6 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Ballykeelaun, Parteen and its tributary Coolnallira) – Reaches 23, 24 and 25

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_186_1	0.48	0.64	0.75	0.86	0.99	1.1	1.2	1.4
25_186_2	0.91	1.2	1.4	1.6	1.9	2.1	2.3	2.7
25_2411_1	3.9	5.2	6.1	7.0	8.1	8.9	9.7	11.6
25_2411_2	4.0	5.4	6.3	7.2	8.3	9.2	10.0	12.0
25_2411_5	4.1	5.5	6.4	7.3	8.4	9.3	10.2	12.2
25_3896_1	5.0	6.7	7.8	8.9	10.3	11.4	12.5	14.9
25_3896_2	5.0	6.8	7.9	9.0	10.4	11.5	12.6	15.0

Table B16.7 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Ballygrennan and its tributary Ballycannan) – Reaches 27 and 28

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
27_345_1	0.42	0.58	0.69	0.79	0.93	1.0	1.1	1.4
27_345_2	0.67	0.93	1.1	1.3	1.5	1.6	1.8	2.2
27_53_1	1.1	1.6	1.9	2.2	2.6	2.8	3.1	3.7
27_53_2	1.9	2.6	3.1	3.6	4.2	4.6	5.1	6.1
27_54_1	2.2	3.1	3.7	4.2	5.0	5.5	6.0	7.3

Table B16.8 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Clonmacken and its tributaries) – Reach 28

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
24_121_9	0.81	1.1	1.2	1.4	1.6	1.7	1.9	2.2
24_121_12	0.95	1.2	1.4	1.6	1.9	2.0	2.2	2.6
24_1580_5	2.7	3.5	4.0	4.5	5.2	5.7	6.2	7.4
24_1580_6	2.8	3.6	4.2	4.7	5.4	5.9	6.4	7.6
24_1718_1	3.5	4.6	5.3	6.0	6.9	7.6	8.2	9.8
24_1718_3	3.7	4.9	5.6	6.4	7.3	8.0	8.7	10.3
24_1718_4	3.8	4.9	5.7	6.4	7.4	8.1	8.8	10.4
24_1720_4	1.9	2.4	2.8	3.1	3.6	4.0	4.3	5.1

Table B16.9 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Ballincurra, its tributary Ballynaclogh, and Ballysheedy) – Reach 29, 30 and 31

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
27_1129_4	4.1	5.3	6.1	6.9	7.9	8.7	9.4	11.2
27_1129_5	4.2	5.4	6.3	7.1	8.1	8.9	9.7	11.5
27_1129_6	4.2	5.5	6.4	7.2	8.2	9.0	9.8	11.7
27_1252_5	4.3	5.6	6.5	7.3	8.4	9.2	10.0	11.9
27_1139_1	2.9	3.7	4.3	4.9	5.6	6.1	6.6	7.9
27_1139_4	3.0	4.0	4.6	5.1	5.9	6.5	7.0	8.4
27_157_1	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
27_157_2*	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
27_1259_1*	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
27_1259_3*	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
27_1260_2*	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
27_1150_1*	7.5	9.7	11.3	12.7	14.6	16.0	17.4	20.6
27_338_1	0.32	0.42	0.49	0.55	0.63	0.69	0.75	0.89
27_338_3	0.38	0.50	0.58	0.65	0.75	0.82	0.89	1.1
27_1129_7	0.08	0.10	0.12	0.13	0.15	0.16	0.18	0.21
27_1129_8*	0.08	0.10	0.12	0.13	0.15	0.16	0.18	0.21
27_741_1	1.2	1.6	1.8	2.1	2.4	2.6	2.8	3.4
27_741_2	1.3	1.8	2.0	2.3	2.6	2.9	3.1	3.7
27_741_3	1.4	1.9	2.2	2.4	2.8	3.1	3.4	4.0
27_1150_2a*	1.4	1.9	2.2	2.4	2.8	3.1	3.4	4.0
27_1150_2b*	1.4	1.9	2.2	2.4	2.8	3.1	3.4	4.0
27_1150_2	8.1	10.5	12.2	13.7	15.8	17.3	18.8	22.3
27_1252_2	1.4	1.8	2.1	2.3	2.7	2.9	3.2	3.8
27_1252_3	1.7	2.2	2.5	2.9	3.3	3.6	3.9	4.6
27_1120_2c	1.9	2.5	2.8	3.2	3.7	4.0	4.4	5.2
27_1120_2b*	1.9	2.5	2.8	3.2	3.7	4.0	4.4	5.2
27_1120_2	3.2	4.1	4.8	5.4	6.2	6.8	7.3	8.7
27_1120_3	3.3	4.3	5.0	5.6	6.4	7.1	7.7	9.1
27_158_1	11.2	14.6	16.8	19.0	21.8	23.9	26.0	30.8
27_158_2	11.2	14.6	16.8	19.0	21.8	23.9	26.0	30.8

**Target flows are less than respective upstream nodes. Flow from upstream carried forward downstream.*

Table B16.10 Target Flows (m^3/s) at HEP Locations on the N16 Model Extent (Crompaun) – Reaches 32 and 33

B16.3 Preliminary Design Inflows

To obtain the target flows at each HEP, as shown in Tables B16.2 – B16.10, an initial set of inflow hydrographs was produced and run through the model.

The inflow hydrographs at the various HEPs were derived using the procedure outlined in Chapter 2 of the main hydrology report and using the adjustment factor, growth curves and hydrograph shape specified in Appendix A, Chapter A6 for the Lower and Middle Shannon Subcatchment and A10 for the Mulkear Subcatchment. The HEPs are shown in Figure B16.1. Tables B16.11 – B16.19 present the preliminary peak inflows that were used at each HEP in the hydraulic model.

Preliminary design inflow hydrographs are shown in Figures B16.2 – B16.14 for the 1% AEP design run.

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_1201_3a	221	291	355	417	497	557	616	754
25_1203_4	51.6	58.0	63.8	69.5	76.7	82.2	87.6	100
25_1206_2	13.4	15.0	16.5	18.0	19.9	21.3	22.7	26.0
25_1207_5	4.8	5.4	5.9	6.4	7.1	7.6	8.1	9.3
25_1209_3	7.7	8.7	9.5	10.4	11.5	12.3	13.1	15.0
25_3844_3	0.66	0.74	0.81	0.89	0.98	1.0	1.1	1.3

Table B16.11 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (River Shannon)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3322_5a	125	148	160	172	187	198	209	235
25_3322_7	1.2	1.4	1.5	1.6	1.8	1.9	2.0	2.2
25_3324_1	1.1	1.3	1.4	1.6	1.7	1.8	1.9	2.2
25_3324_2	0.20	0.24	0.27	0.29	0.31	0.33	0.35	0.40

Table B16.12 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Mulkear and its tributary Thornfield)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_1205_1	0.43	0.58	0.68	0.77	0.89	0.98	1.1	1.3
25_3825_1	24.2	29.1	32.1	34.8	38.1	40.4	42.7	47.8
25_2824_1	1.2	1.6	1.8	2.1	2.4	2.6	2.8	3.4

Table B16.13 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Cappavilla, Blackwater and Shannakyle)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_3858_3a	5.7	7.5	8.6	9.8	11.2	12.3	13.3	15.8
25_3858_3	0.06	0.08	0.09	0.11	0.12	0.13	0.15	0.17
25_3858_6	0.17	0.22	0.25	0.28	0.33	0.36	0.39	0.46
25_3858_9	0.45	0.59	0.68	0.77	0.88	0.97	1.1	1.2
25_3605_1a	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.27
25_3605_1	0.07	0.09	0.11	0.12	0.14	0.15	0.16	0.19
25_2825_2	0.40	0.53	0.61	0.69	0.79	0.86	0.94	1.1
25_2049_1	1.1	1.5	1.7	1.9	2.2	2.4	2.6	3.1

Table B16.14 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Groody and its tributary Towlerten)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_2823_1	1.5	2.0	2.3	2.7	3.1	3.4	3.7	4.4
25_181_2	3.0	4.0	4.7	5.3	6.2	6.8	7.4	8.9
25_1150_2	3.7	5.0	5.8	6.6	7.7	8.5	9.3	11.1

Table B16.15 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Ballykeelaun, Parteen and its tributary Coolnallira)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
25_186_1a	0.48	0.64	0.75	0.86	0.99	1.1	1.2	1.4
25_186_1	0.43	0.58	0.68	0.77	0.89	0.99	1.1	1.3
25_185_3	3.9	5.2	6.1	7.0	8.1	8.9	9.7	11.6
25_2411_1	0.12	0.16	0.19	0.22	0.25	0.28	0.30	0.36
25_2411_2	0.06	0.08	0.10	0.11	0.13	0.14	0.15	0.18
25_3896_1	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.15

Table B16.16 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Ballygrennan and its tributary Ballycannan)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
27_54_1a	0.35	0.48	0.57	0.66	0.77	0.86	0.94	1.1
27_345_1a	0.42	0.58	0.69	0.79	0.93	1.0	1.1	1.4
27_345_1	0.25	0.35	0.41	0.47	0.55	0.61	0.67	0.81
27_53_1a	0.48	0.67	0.80	0.92	1.1	1.2	1.3	1.6
27_53_1	0.74	1.02	1.2	1.4	1.6	1.8	2.0	2.4

Table B16.17 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Clonmacken and its tributaries)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
24_121_8	0.81	1.1	1.2	1.4	1.6	1.7	1.9	2.2
24_121_9	0.14	0.18	0.21	0.24	0.27	0.30	0.32	0.38
24_1580_5a	2.7	3.5	4.0	4.5	5.2	5.7	6.2	7.4
24_1580_5	0.10	0.13	0.15	0.17	0.19	0.21	0.23	0.27
24_1718_1	0.07	0.09	0.11	0.12	0.14	0.15	0.16	0.19
24_1720_3a	1.9	2.4	2.8	3.1	3.6	4.0	4.3	5.1

Table B16.18 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Ballincurra and its tributary Ballynaclogh, and Ballysheedy)

HEP Reference	Annual Exceedance Probability							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
27_1129_4a	4.1	5.3	6.1	6.9	7.9	8.7	9.4	11.2
27_1129_4	0.11	0.15	0.17	0.19	0.22	0.24	0.26	0.31
27_1129_5	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.15
27_1129_6	0.07	0.09	0.11	0.12	0.14	0.15	0.16	0.19
27_1252_5	0.14	0.19	0.22	0.24	0.28	0.31	0.33	0.39
27_1139_1a	2.9	3.7	4.3	4.9	5.6	6.1	6.6	7.9
27_1139_1	0.17	0.22	0.26	0.29	0.33	0.37	0.40	0.47
27_1150_1a	0.45	0.58	0.67	0.76	0.87	0.95	1.0	1.2
27_338_1a	0.32	0.42	0.49	0.55	0.63	0.69	0.75	0.89
27_338_1	0.06	0.08	0.09	0.10	0.12	0.13	0.14	0.17
27_1129_7a	0.08	0.10	0.12	0.13	0.15	0.16	0.18	0.21
27_338_3	0.76	0.99	1.1	1.3	1.5	1.6	1.8	2.1
27_741_1	0.12	0.16	0.19	0.21	0.24	0.26	0.29	0.34
27_741_2	0.09	0.12	0.14	0.16	0.18	0.20	0.22	0.26
27_1150_2a	0.17	0.22	0.25	0.28	0.33	0.36	0.39	0.46
27_1252_1	1.4	1.8	2.1	2.3	2.7	2.9	3.2	3.8
27_1252_2	0.31	0.40	0.46	0.52	0.60	0.65	0.71	0.84
27_1252_3	0.21	0.27	0.31	0.35	0.40	0.44	0.48	0.57
27_1120_2b	1.3	1.7	1.9	2.2	2.5	2.7	3.0	3.5
27_1120_2	0.14	0.18	0.21	0.24	0.28	0.30	0.33	0.39

Table B16.19 Preliminary Design Hydrograph Peak Inflows (m^3/s) at HEP Locations on the N16 Model Extent (Crompaun)

The design hydrograph estimation for the N16 main stem (River Shannon) and tributaries is described in Appendix A. To get details on the estimation of design hydrographs on the Mulkear (the downstream end of which is part of the N16 model), the reader is referred to Chapter A10. However, to understand the inflow hydrographs allowed for from the Mulkear to obtain the critical flood on the River Shannon, Chapter A6 should be consulted.

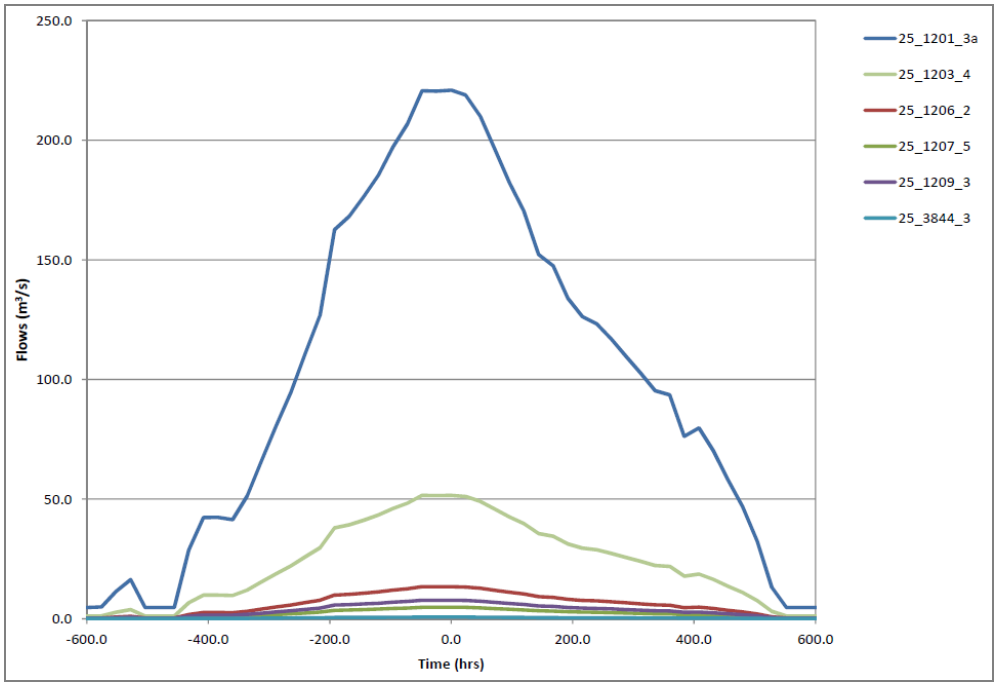


Figure B16.2 N16 Preliminary Design Inflow Hydrographs for 1% AEP (River Shannon Main Stem)

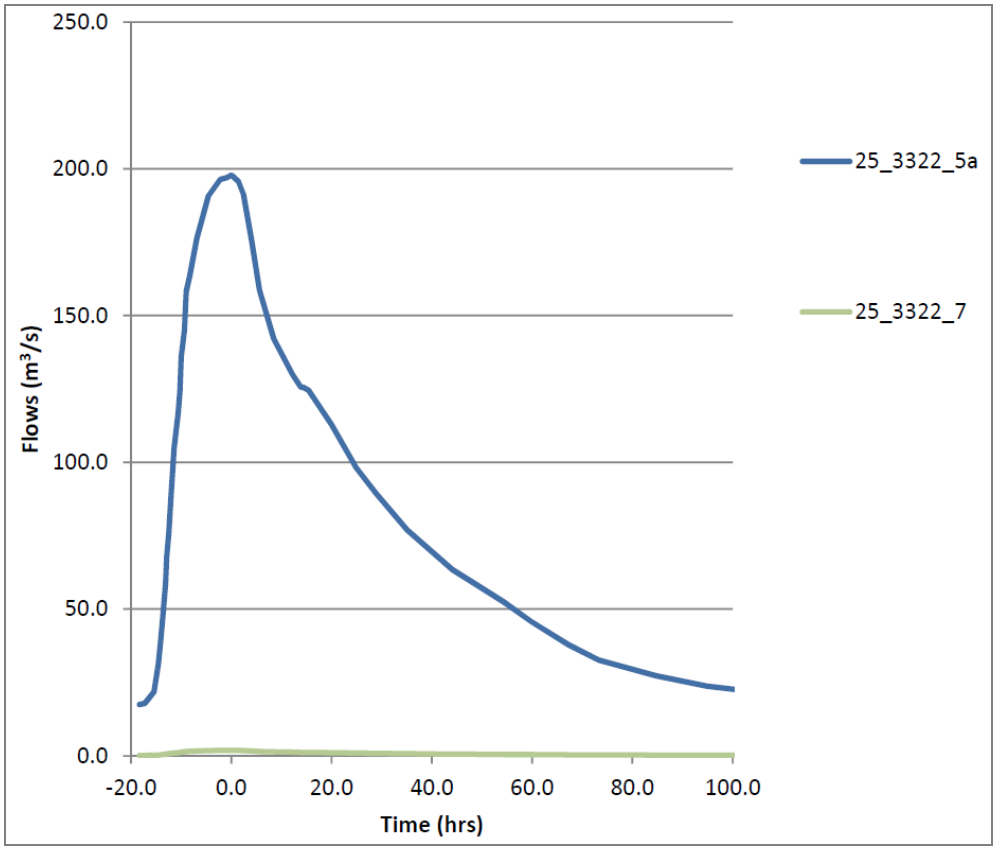


Figure B16.3 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Mulkear)

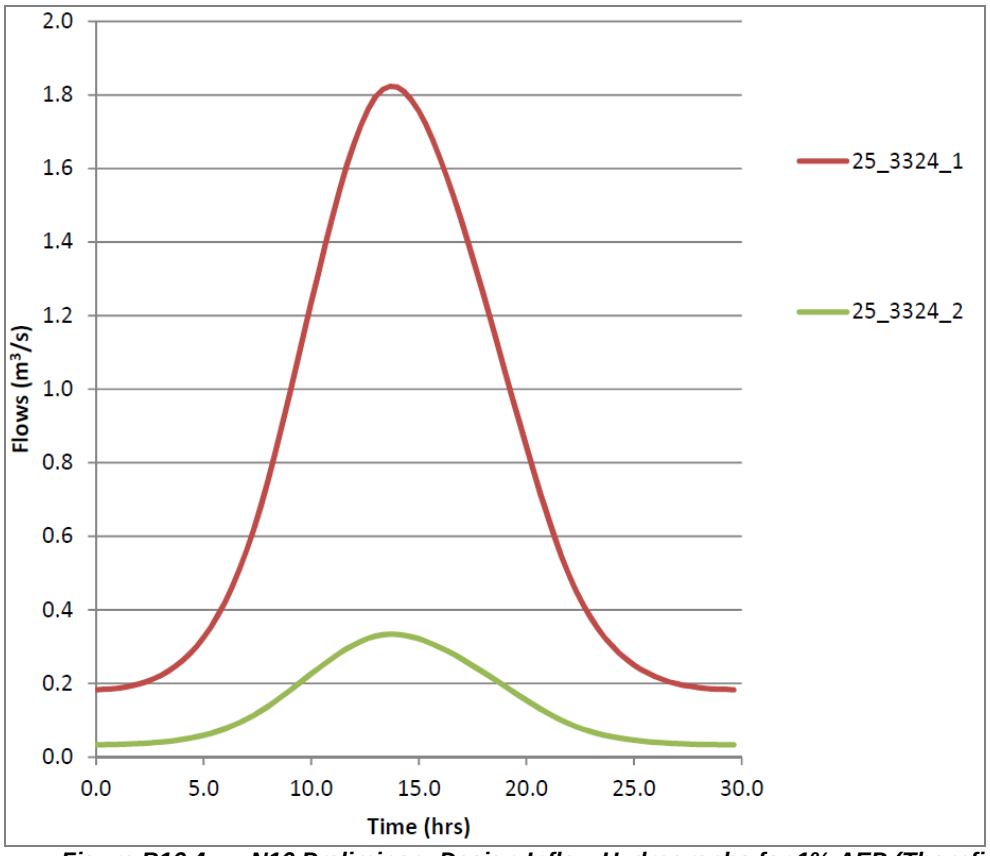


Figure B16.4 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Thornfield)

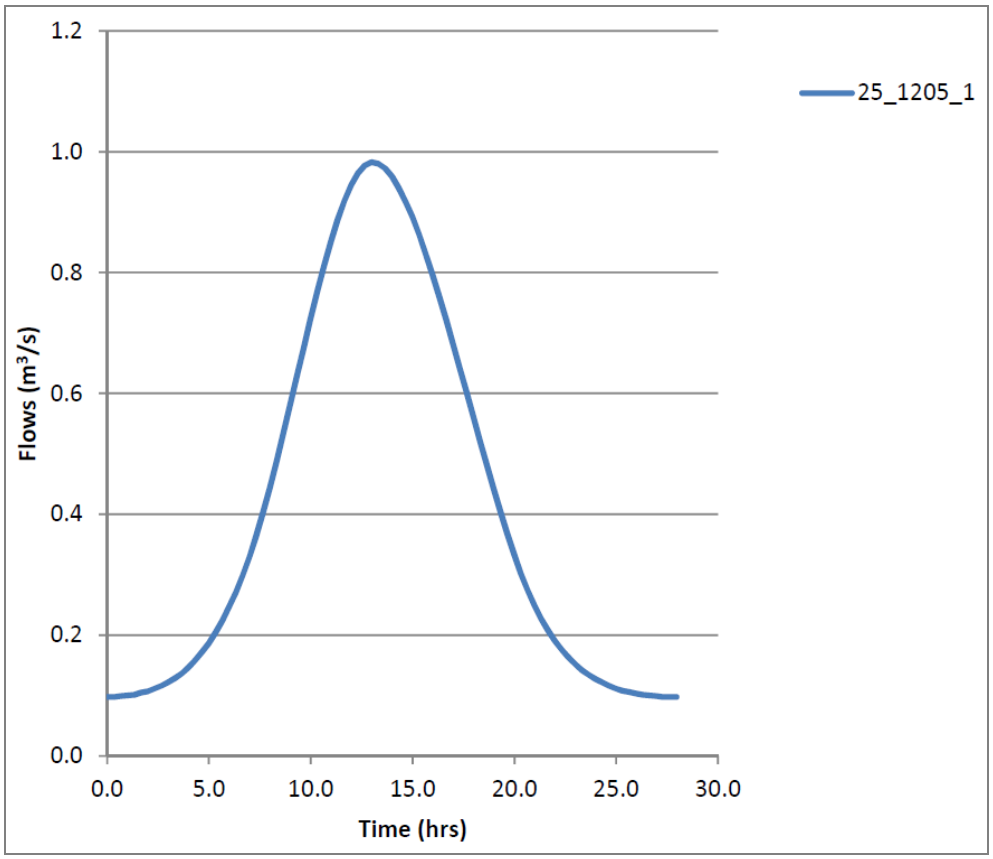


Figure B16.5 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Cappavilla)

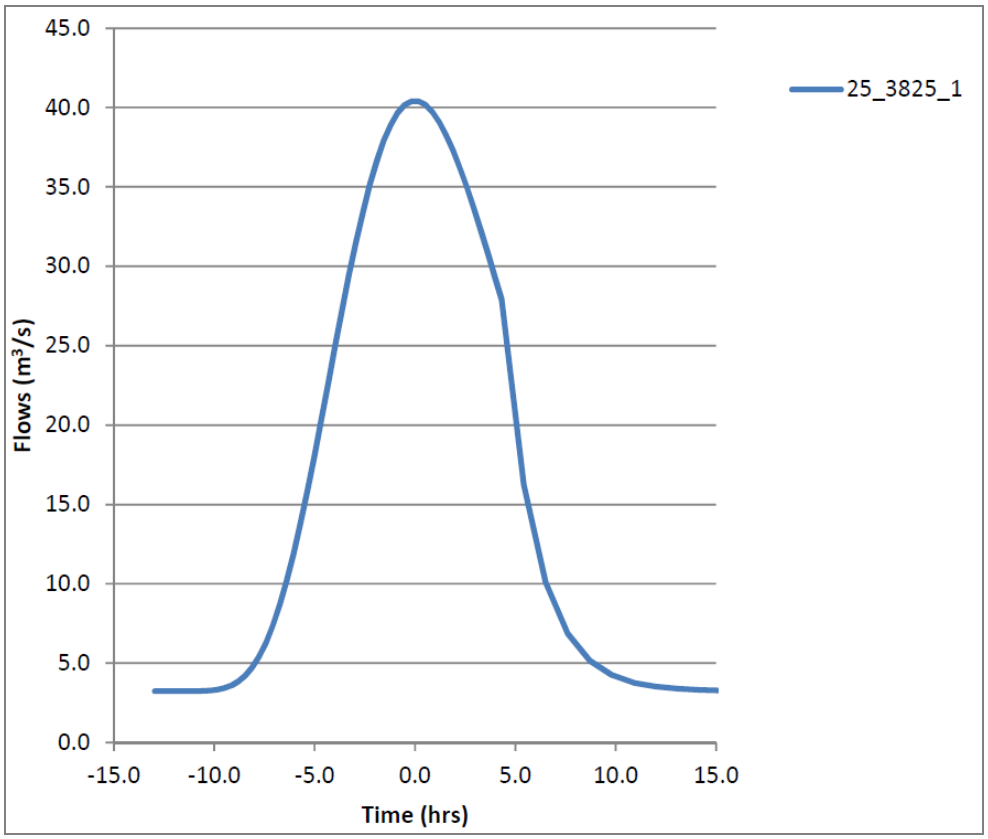


Figure B16.6 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Blackwater)

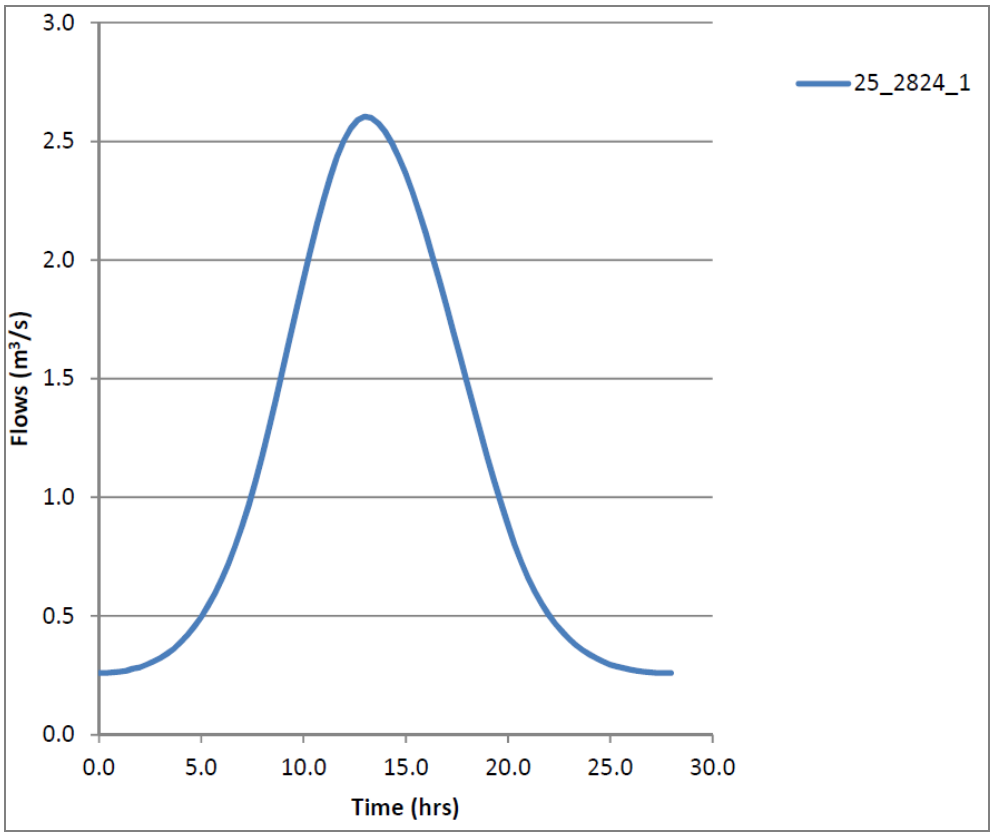


Figure B16.7 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Shannakyle)

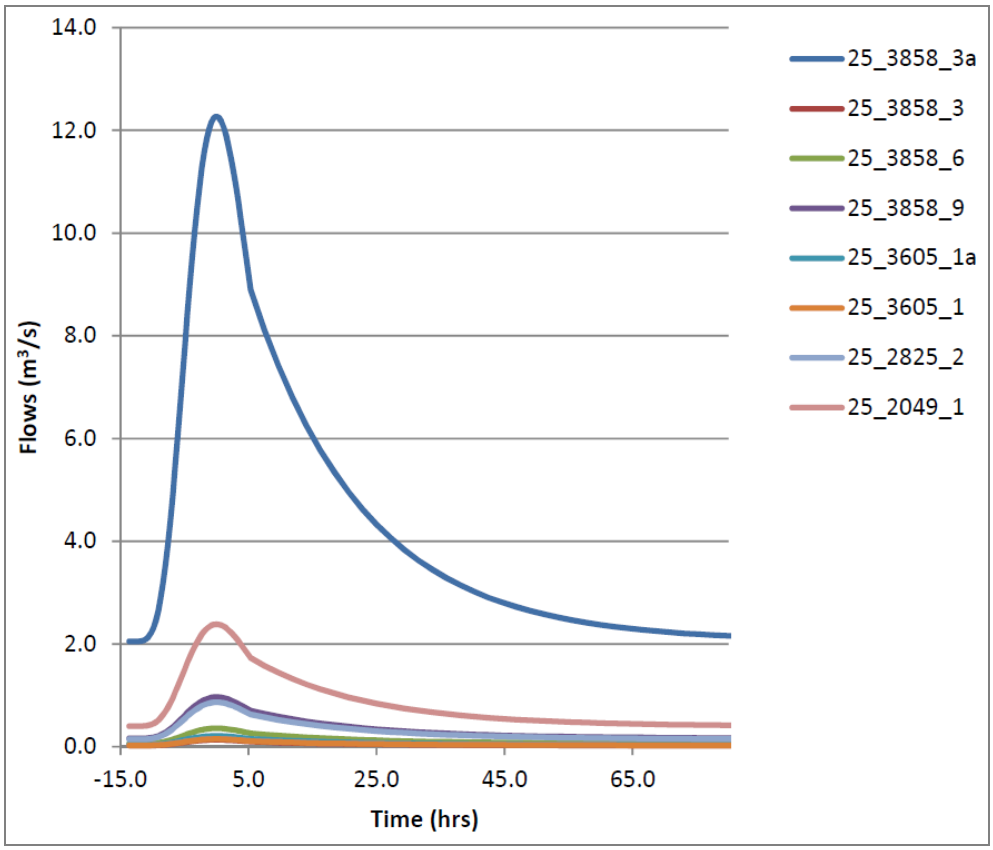


Figure B16.8 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Groody and tributary Towlerten)

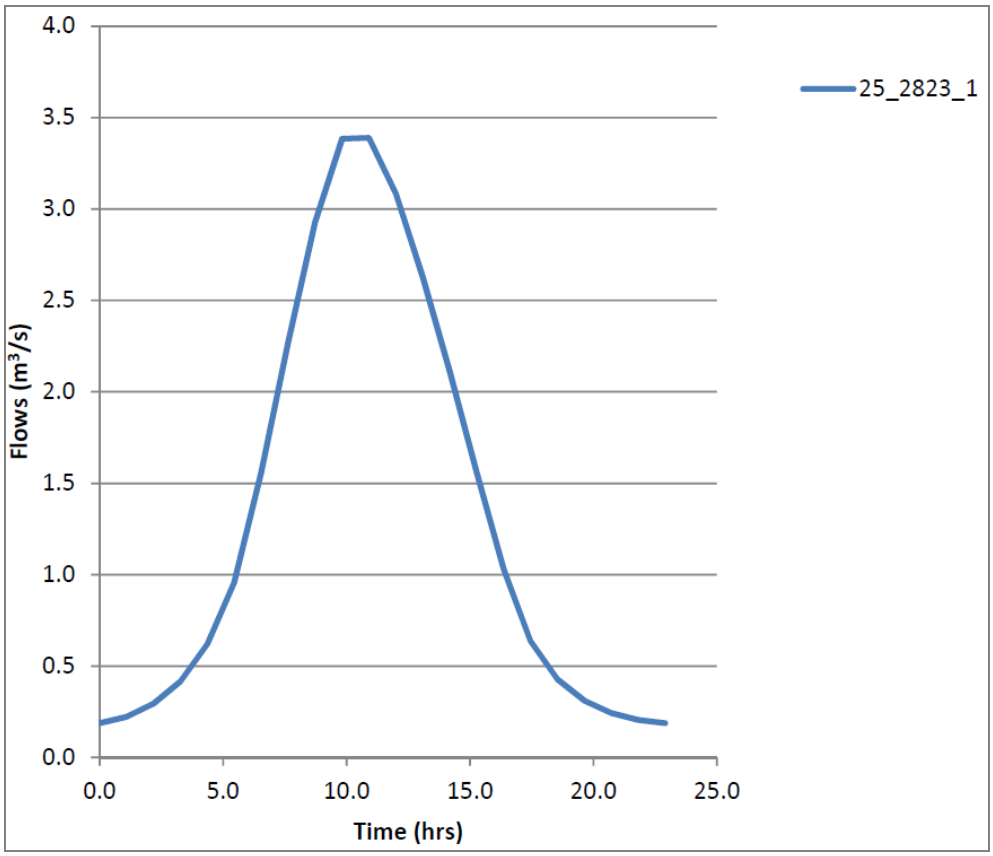


Figure B16.9 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Ballykeelaun)

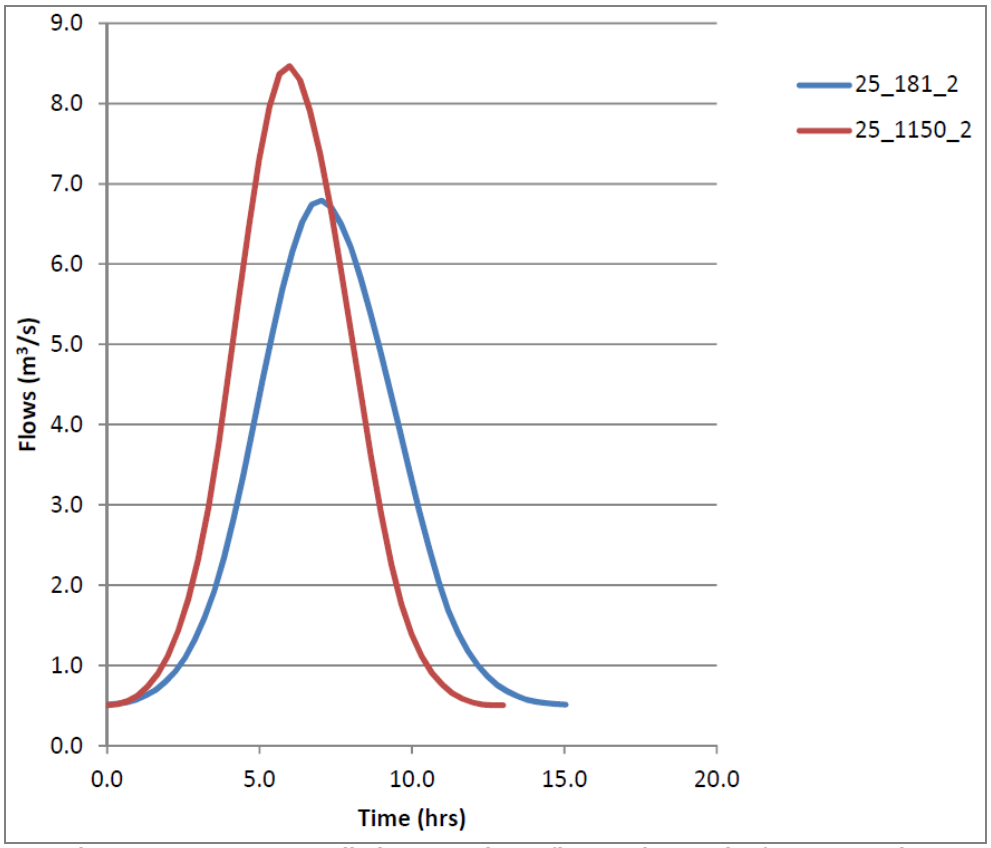


Figure B16.10 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Parteen and Coolnallira)

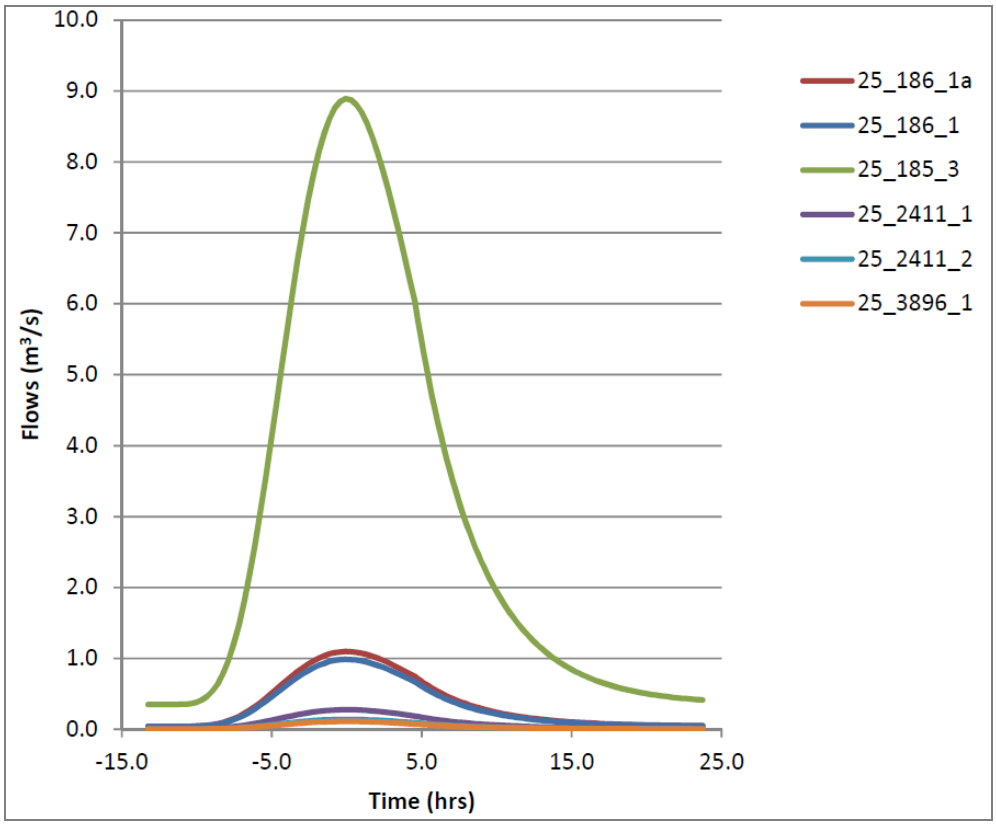


Figure B16.11 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Ballygrennan and Ballycannan)

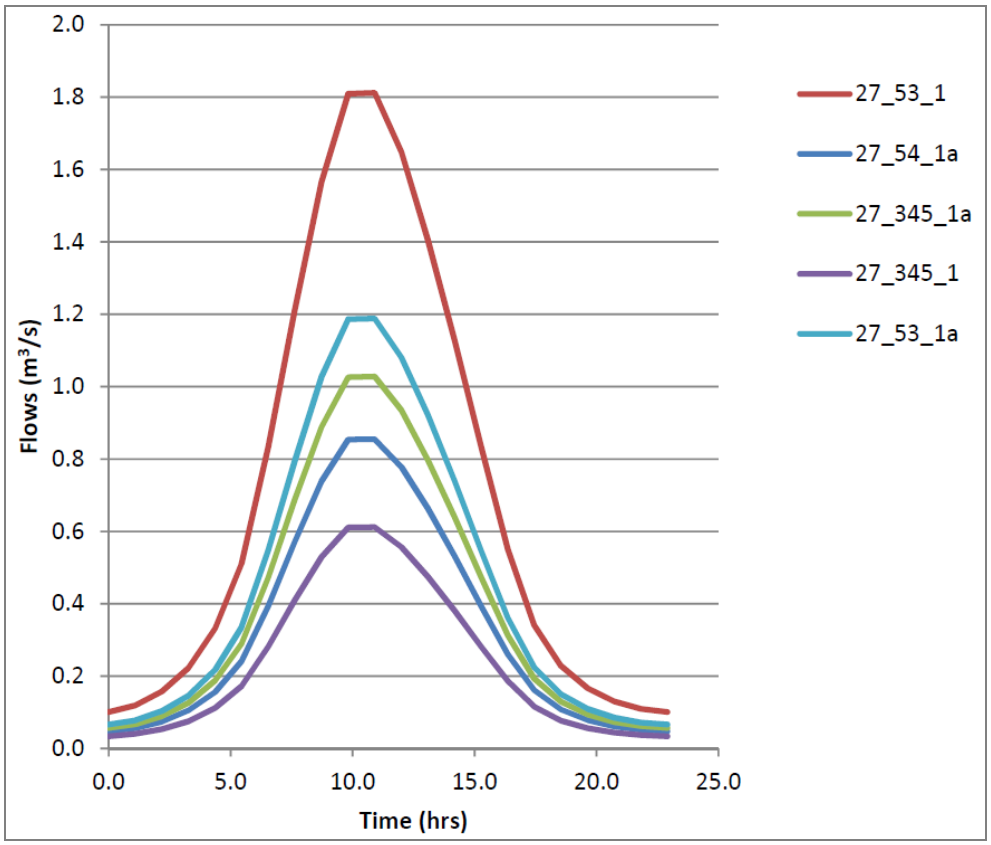


Figure B16.12 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Clonmacken and its tributaries)

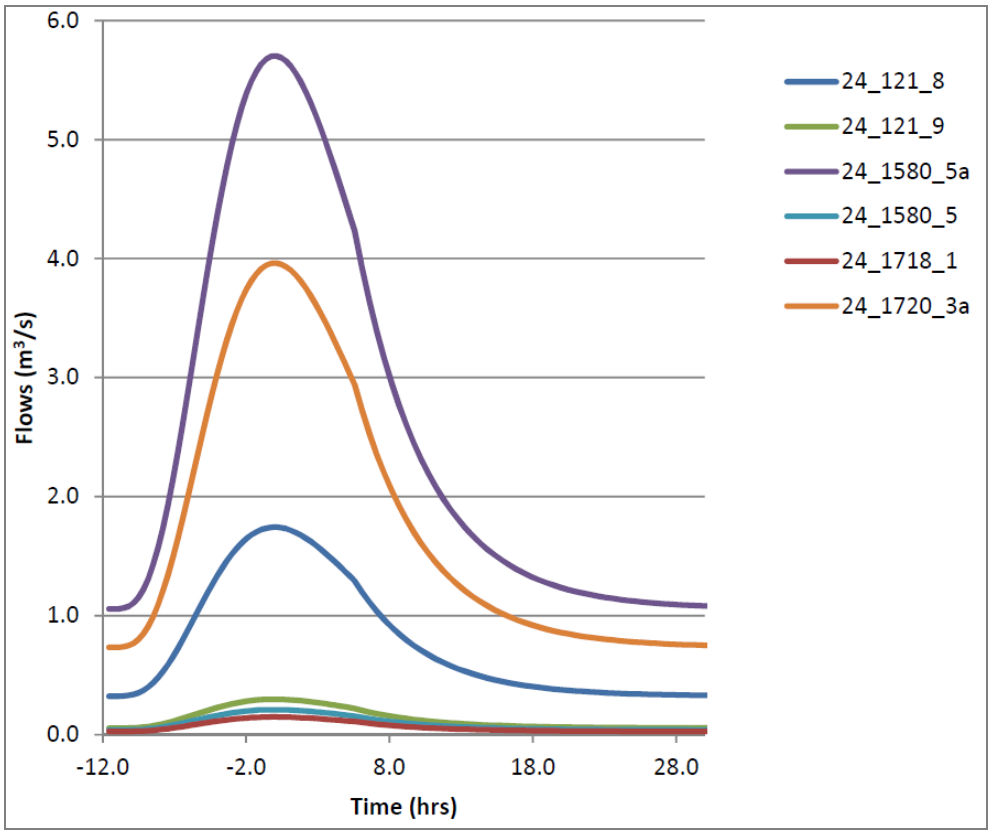


Figure B16.13 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Ballincurra and its tributaries)

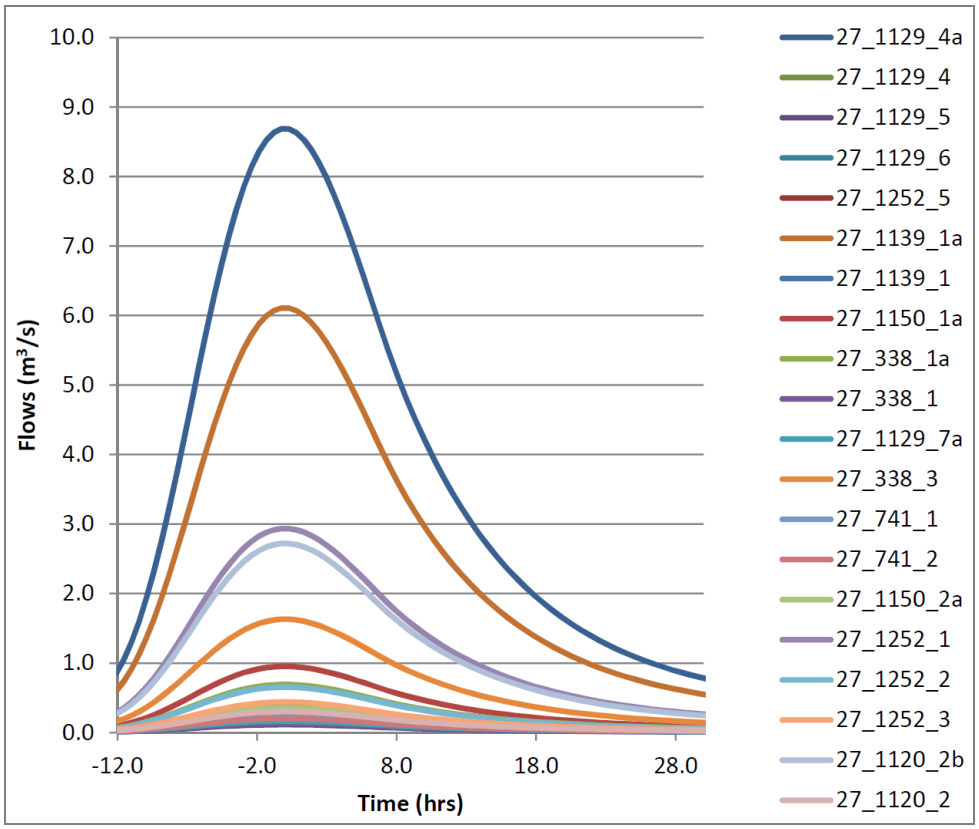


Figure B16.14 N16 Preliminary Design Inflow Hydrographs for 1% AEP (Crompaun)

B16.4 HEP Calibration and Final Design Hydrographs

The hydraulic model uses the preliminary design inflows presented in Tables B16.11 – B16.19 for calibrating the model to the HEP target flows presented in Tables B16.2 – B16.10.

HEP calibration at each HEP was undertaken using the methodology described in Section 2.7.2 of the main hydrology report for UoM 25/26. Hydraulic modelling aspects of the HEP calibration including the results and final design peak flows are presented in the hydraulic modelling report for Model N16.

Appendix C Rating Review Summary Sheets

Table of Content

25001	Annacotty	26001	Ballinamore
25003	Abington	26002	Rookwood
25006	Ferbane	26004	Bookala
25011	Moystown	26005	Derrycahill
25013	Newell's Bridge	26006	Willsbrook
25014	Millbrook	26007	Bellagill
25015	Pollagh	26008	Johnston's Bridge
25016	Rahan	26012	Tinacarra
25017	Banagher	26014	Banada Bridge
25021	Croghan	26016	Ballymurray
25022	Syngefield	26019	Mullagh
25024	New Bridge	26021	Ballymahon
25027	Gourdeen	26022	Kilmore
25029	Clarianna	26108	Boyle Abbey Bridge

The rating review summary sheets in this appendix refer to levels in metres above gauge zero (i.e. local datum), metres above Poolbeg Ordnance Datum (mAOD(P)) and/or metres above Malin Ordnance Datum (mAOD(M)).

The Poolbeg and Malin datums typically differ by approximately 2.7m. For the purpose of the CFRAM model calibration the most recent survey to the Malin datum has been assumed to be accurate.

25001 - Mulkear at Annacotty

Date of data collation: 05/01/2012, completed 04/10/2013

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the left bank, downstream of two bridges. The channel is straight immediately upstream and downstream of the station. There is a weir located upstream of the gauging station where the channel widens. The gauging station was moved a short distance in 1976 due to the construction of a road bridge.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	Office of Public Works
Coordinates	164265, 157679	**Period of Record**	1953 - 2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W <3.7m (139~m^3/s; pre-rating review)

QMED synthetic	146.2 m^3/s
QMED (AMAX, pre rating review)	125.7 m^3/s (57 years)

Gauge Zero (from operator)	10.36mAOD (P)
Gauge Zero (from survey)	7.65mAOD (M)

Revised Rating Equations:

The rating equations at Annacotty have not been revised, as the OPW rating appears to have the best relationship with the check gaugings to date.

Hydraulic Model Details:

Model Name: 25001_Annacotty_ISIS_v3.dat

A one dimensional hydraulic model of the River Mulkear near Annacotty gauging station was built using river survey data collected by Murphy Surveys in August 2012 (survey drawings 4491_25KEAR_A_MULKEAR_A_XS_PLAN, 4491_25KEAR_A_MULKEAR_A_XS_1 to 11, 4491_25KEAR_A_MULKEAR_A _LS_1 and 4491_25KEAR_A_MULKEAR_A _LS_2) and the ISIS one dimensional hydraulic modelling software.

The hydraulic model extends from 1017m upstream of R445 Road Bridge (NGR: 164403.87, 156662.95) on the River Mulkear to 2081m downstream of the structure at the confluence with the River Shannon (NGR: 163172.45 , 158897.18). The gauging station is located on the left bank approximately 38m downstream of the bridge at ISIS node MULK01_2043 in the ISIS model.

There are three hydraulic structures included in the model: the R445 Road Bridge (ISIS node:MULK01_2081), the Annacotty Arch Bridge (MULK01_2111) and the Annacotty weir (MULK01_2205). A disused railway bridge located near the confluence with the River Shannon has been ignored on the basis it would not exert a significant impact on the hydraulics of the river under flood conditions. Both bridges were represented in the model using ISIS USBPR units and spill to allow for bridge overtopping. The Annacotty weir which is compound oblique weir was represented using the ISIS labyrinth weir unit and inline spills.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of gravel/stones and floating vegetation (n=0.045). Near the confluence with the river Shannon the river bed changes to a mix of stones and mud (n=0.043). Banks are often vegetated with varying vegetation type from light scrubs (0.05) to dense trees (0.1) hanging over the channel. Floodplain varies between rural areas where pasture (0.035) and woodland (0.08-0.10) are the dominating land types and urbanised area with buildings (0.1) and roads (0.025).

Estimated roughness values were subsequently modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings.

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The roughness coefficient was adjusted to achieve a reasonable fit to the check gaugings. With bed roughness values adjusted to 0.047 a good agreement was found between the modelled water level at the gauging station and the check gauging levels for flows up to 110 m^3/s. It is acknowledged that the match is not as good for higher flows. A possible contributing factor for this could be that the model cannot represent the obstruction effect, as water level rises, of the tree branches overhanging the river channel along the right bank, downstream of the gauge.

Once calibrated, the hydraulic model has been run with flows ranging from 0.1 to 574 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node MULK01_2043).

Analysis and Results:

A comparison was made between the modelled and the existing OPW rating with all the check gaugings collected at Annacotty gauging station. This indicated that the site experiences significant scatter and there had been a datum change in October 1976. OPW have confirmed that this datum change relates to when the gauging station was temporarily removed during the construction of a road bridge in 1976 and replaced with the gauge zero at a different level. This ties in with the RBD Shannon Data Summary.xls spreadsheet provided by OPW, which has split the station record into pre 1976 and post 1976. Based on the apparent change in stage-discharge relationship associated with moving the site due to construction works, gaugings prior to 1976 have been excluded from this rating review analysis.

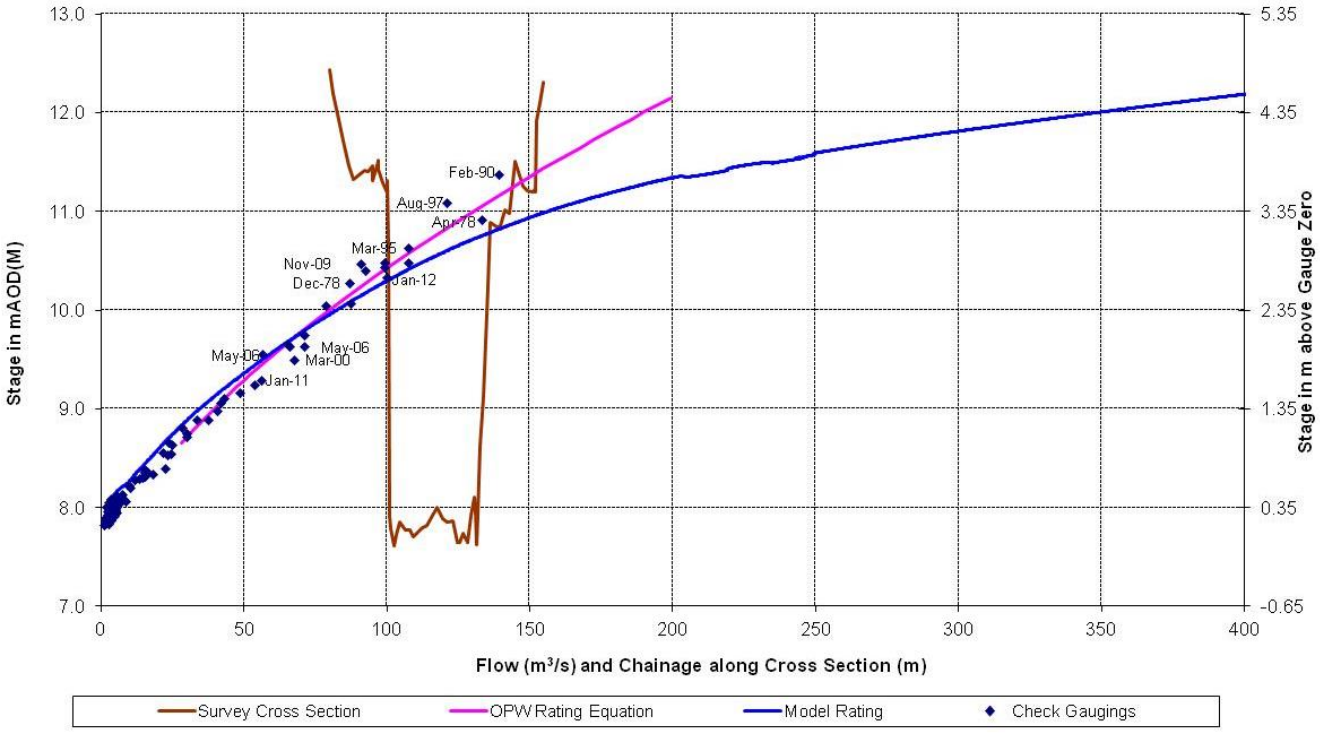
The model rating has a relatively good fit with the check gaugings since 1976 at low to medium flows, although there is considerable scatter in the check gaugings. However, at high flows the check gaugings deviate away from the model rating, although there are very few high flow gaugings, with the last completed in August 1997. The current model rating is the best fit that could be achieved with realistic roughness coefficients, using the model. The check gaugings since 1976 have a good fit with the OPW rating equations, therefore the OPW ratings should continue to be used and it is not recommended to adopt the model rating.

It is noted that the highest gauged flow of 139 m^3/s (February 1990) is above Qmed (1.10xQmed), and that the highest AMAX flow of 155 m^3/s (since 1976) is less than 12% above the highest gauged flow, giving confidence that the use of the OPW ratings on the AMAX series would not involve inappropriate extrapolation beyond the highest gauged flow.

OPW have informed Jacobs that there have been upstream drainage works, relating to the Ballymackeogh Flood Relief Scheme and Cappamore Flood Relief Scheme, which occurred between April 1997 and April 2001. Analysis of the check gauging since 1976 and daily mean flow series suggested that the flood relief works had a very limited effect on the flow regime at Annacotty. Therefore, the existing OPW AMAX series from 1976 to present can be used to estimate QMED and for flood frequency analysis, although it should be used with caution due to the scattered nature of the high flow check gaugings at the site.

Analysis of historic ratings and check gaugings prior to 1976 at the site show that there is a significant amount of scatter and very few of the pre-1976 gaugings have a good relationship with the old ratings, therefore it is recommended that the AMAX series of before 1976 is not used for QMED estimation or for flood frequency analysis. The change in length of AMAX data used for hydrological analysis has increased the estimate of QMED insignificantly from 125.7 m^3/s to 126.4 m^3/s.

It is recommended that regular check gaugings are completed to verify the rating and that check gaugings should be focused on the high flow range, as there have only been three gaugings around QMED since the gauge change in 1976.



Summary, Conclusions and Recommendations:

A stable model was created and calibrated to the available check gaugings from 1976, when the gauge was moved. The model rating had a good fit to the check gaugings at low to medium flows. At high flows however, there is a significant deviation of the model rating from the check gaugings. As the existing OPW rating has a good fit with the check gauging from 1976 across medium and high flows (up to 1.1xQmed), the rating equations and the AMAX series have not been amended for this site. It is recommended that further check gaugings are completed to verify the existing rating for high flows.

The AMAX series has not been revised, but it is recommended that only the AMAX data from 1976 is used for QMED estimation and flood frequency analysis. This results in a QMED of 126.4 m^3/s.

25003 – RIVER MULKEAR AT ABINGTON

Date of data collation: 12/07/2011, completed 04/07/2013

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank downstream of a road bridge and has a natural control. Upstream of the bridge the channel bends to the right and there is some vegetation upstream of the gauging station. The channel is straight downstream of the gauging station with vegetation on the adjacent banks. The channel is flanked on both sides by a narrow floodplain and there are no apparent out-of-bank flow paths which would result in bypassing of the station.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	171538, 153428	**Period of Record**	1954 - 2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 1.8m (60~m^3/s; pre-rating review)

QMED synthetic	93.7 m^3/s
QMED (AMAX, pre rating review)	67.9 m^3/s (56 years)

Gauge Zero (from operator)	37.15mAOD (P)
Gauge Zero (from survey)	34.44mAOD (M)

Revised Rating Equations:

Q = 27.177 (W+0)^1.5744 for the range: 0.599 ≤W<2.150m (above Gauge Zero)
Q = 24.25 (W+0)^1.7232 for the range: 2.150≤W<2.768m (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Name: 25003_Abington_ISIS_v5.dat

A one dimensional hydraulic model of the River Mulkear near Abington gauging station was built using river survey data collected by Murphy Surveys in July 2012 (survey drawings 4491_25KEAR_B_MULKEAR_XS_PLAN, 4491_25KEAR_B_MULKEAR_XS_1 to 5, 4491_25KEAR_B_MULKEAR _LS_1 and 4491_25KEAR_B_MULKEAR _LS_2) and the ISIS one dimensional hydraulic modelling software.

The hydraulic model extends from 1037m upstream of Abington Bridge (NGR: 172585, 151914) on the River Mulkear to 1989m downstream of Abington Bridge (NGR: 169803, 153242). The gauging station is located 15m downstream of Abington Bridge at ISIS node 01MUL01989 in the ISIS model.

Abington Bridge is the only hydraulic structure included in the model (ISIS node 01MUL02009u) and it was schematised using an ISIS Arch Bridge unit and a spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of stones and silt (n= 0.041). Banks are often vegetated with a variety of vegetation types, ranging from light scrubs (0.05) to dense trees (0.1) hanging over the channel. Floodplain is designated as pasture with short to medium grass (0.040).

These estimated roughness values were subsequently modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings.

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as a backwater effect is not expected on the downstream model boundary, and the model extends far enough downstream for the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

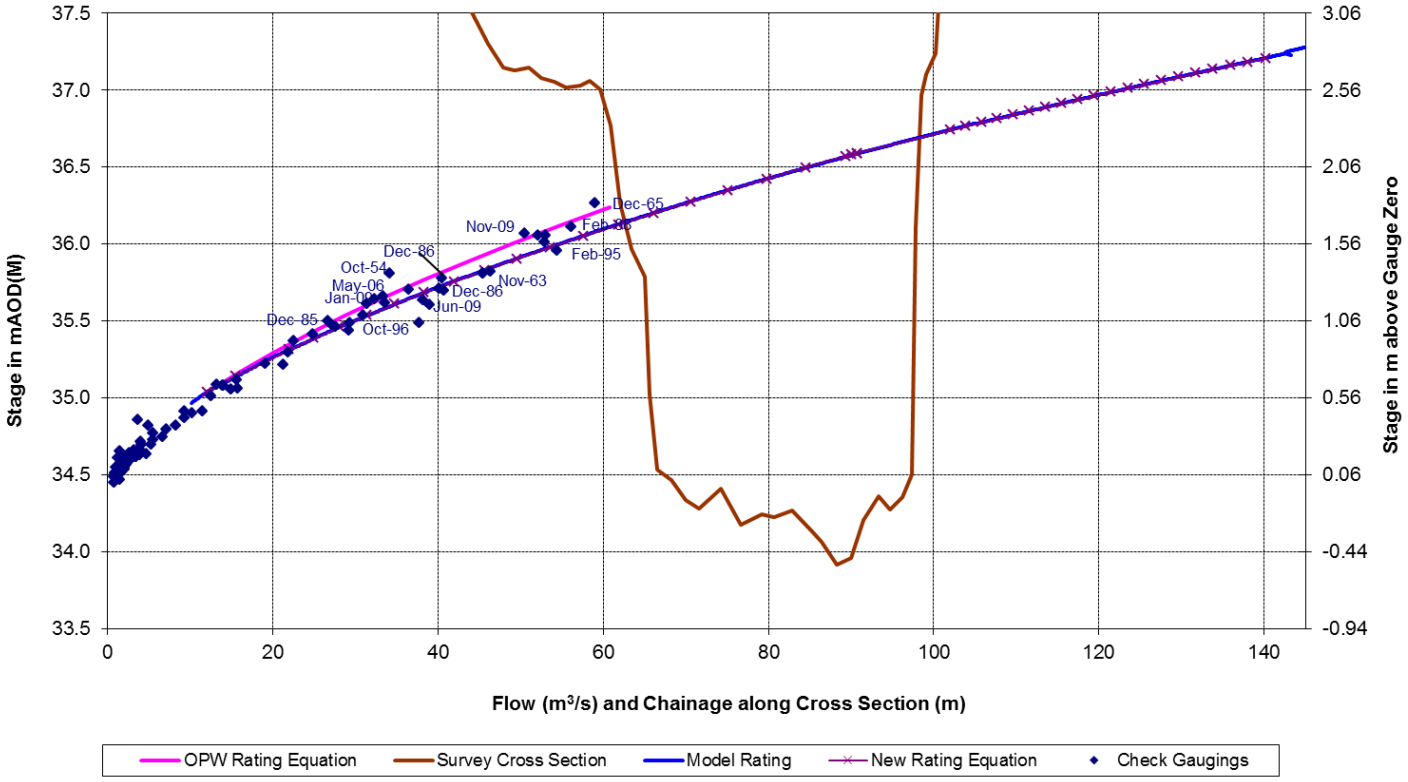
Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The roughness coefficient was adjusted to achieve a reasonable fit to the check gaugings. With the bed roughness values adjusted to 0.046 downstream of the Abington Bridge, a good agreement was found between the modelled water level at the gauging station and the check gauging levels.

Once calibrated, the hydraulic model has been run with flows ranging from 0.1 to 368 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed minor instabilities associated with a trans-critical transition of flows, and a small degree of hysteresis around 150 m^3/s (from about 2.85m above local datum), but these were considered acceptably small and are well above the highest AMAX value recorded. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node 01MUL01989).

Analysis and Results:

Check gaugings have been completed across a range of flows to just below QMED. The model rating shows a good fit with the check gaugings. There is some scatter within the check gaugings, which suggests an instable cross section, or significant variation in weed growth and/or regular channel maintenance local to the gauging station. The chart below shows that the latest OPW rating lies above the modelled rating. Older OPW ratings lie between the latest OPW rating and the modelled rating. The check gaugings do not show a particular trend over the gauged period, and it therefore considered that one rating can be applied to the entire AMAX series.

A new set of rating equations has been derived for high flows following BS ISO 1100-2. The lower limit of the model rating was extended below 0.8xQMED to intersect with the exiting OPW rating at low flows. The model rating shows a kink around 150m^3/s, which is related to a trans-critical transition in the flows. The model rating has been truncated below the kink at approximately 2xQMED. The AMAX flow series lies significantly below this flow. The new set of rating equations is considered an improvement over the existing OPW rating for the range of AMAX values since the start of the AMAX record. Therefore, the whole AMAX series can be used for QMED estimation and flood frequency analysis. The new set of rating equations changes the estimate of QMED from 67.9 m^3/s to 73.7 m^3/s.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section at the gauge. A set of rating equations was established to give a good fit with the modelled rating in the stage interval 0.60<W<2.77.

There is no evidence of a significant catchment change and the model rating has a good fit with the majority of check gaugings from 1954. The new set of rating equations is considered an improvement over the existing OPW rating for the range of AMAX values since the start of the AMAX record. Therefore, the entire AMAX series can be used for QMED estimation and flood frequency analysis.

25006 – BROSNA AT FERBANE

Date of data collation: 05/01/2012, completed 08/08/2012

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the left bank of the River Brosna, upstream of the N62 road bridge at Ferbane. The gauging station channel is clear of vegetation. Flow bypassing the structure is considered unlikely due to the high road embankment at this location.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	211528, 224407	**Period of Record**	1952 - 2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 3.9 m (~120 m^3/s; pre-rating review)

QMED synthetic	89.0 m^3/s
QMED (AMAX, pre rating review)	81.9 m^3/s

Gauge Zero (from operator)	41.20 mAOD (P)
Gauge Zero (from survey)	38.47 mAOD (M)

Revised Rating Equations:

Q= 18*(W-0.56)^1.567	for the range: 2.35<W<3.53m (above Gauge Zero)*
Q = 8.3198 (W+0)^1.9524	for the range: 3.53≤W<4.06m (above Gauge Zero)
Q = 4.7342 (W+0)^2.3543	for the range: 4.06≤W<4.83m (above Gauge Zero)
Q = 0.9207(W+0)^3.3944	for the range: 4.83≤W<5.22m (above Gauge Zero)

**OPW existing high flow rating to continue to be used for stages between 2.35 and 3.53m.*

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Name: 25006_Ferbane_GS_V1.DAT.

A one-dimensional hydraulic model of the River Brosna at Ferbane gauging station was built using river survey data collected by Murphy Surveying in November 2011 (survey drawings 4281_25BSNA_FERBANE_XS_PLAN, 4281_25BSNA_ FERBANE _XS_1 to 5, and 4281_25BSNA_ FERBANE _LS_1, 4281_25BSNA_ FERBANE _LS_2) and ISIS hydraulic modelling software.

The hydraulic model extends from 3070m upstream of the N62 road bridge (NGR: 212819, 222994) on the River Brosna to 1968m downstream of the structure (NGR: 210052, 223516). The gauging station is located upstream of the bridge at node BROS01_1968 in the ISIS model.

In addition to the N62 bridge, another road bridge was included in the ISIS model at node BROS01_2663, which is 700 m upstream of the gauge. Both bridge structures were schematised using ISIS Arch bridge units and spill units to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of sand with cobbles (n=0.033). Bank side and floodplain roughness values range from 0.02 (concrete) to 0.1 (building). However, the majority of the floodplain consists of pasture (0.035) and medium to dense vegetation (0.065).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the available check gaugings. Using the original estimates of the river bed roughness, a good agreement was found between the modelled water level at the gauging station and the check gauging levels. Therefore no further calibration of the model parameters was required.

Once calibrated, the hydraulic model has been run with flows ranging from 0.5 to 343m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station location (ISIS Node: BROS01_1968).

Analysis and Results:

The model rating is in good agreement with the existing OPW rating for medium and high flows and only deviates away from the OPW rating at very high flows. It is recommended that the OPW rating is used for water levels up to 3.53m approximately. Three high flow gaugings lying significantly below the recent ratings date from the 1950s. The deviation from the rating may be linked to reported drainage works from 1948 to 1955. On this basis it is considered that AMAX data from before 1958 is likely to be affected by these drainage works. No check gaugings were undertaken from 1958 to 1969; therefore recorded flows from that period should be used with caution.

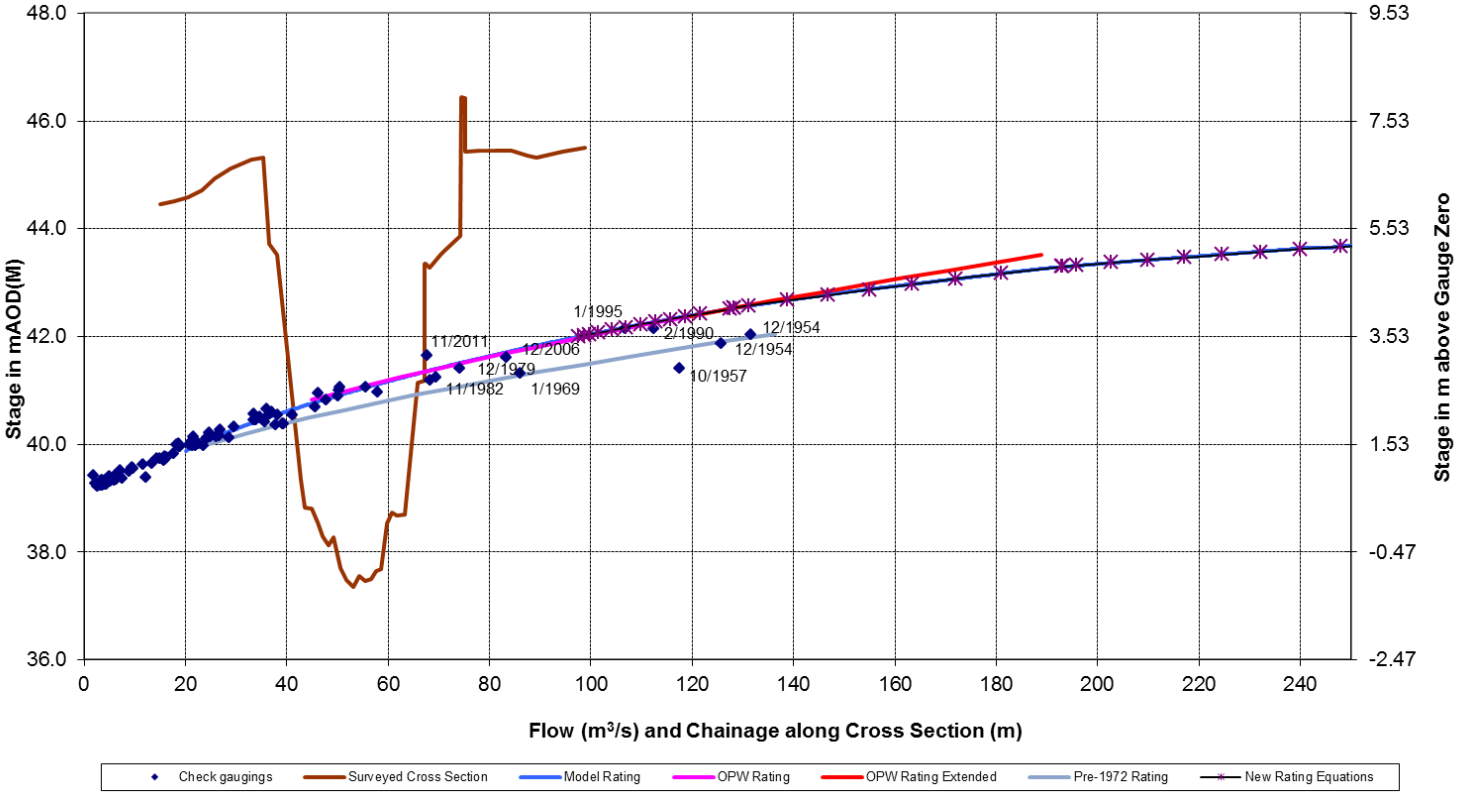
The gauge datum and rating histories show that the gauge was re-surveyed in August 1978, with the gauge datum raised by 0.21m, and re-rated. OPW have confirmed that the gauge board was moved to a new location at that date. On the graph below the check gaugings from before August 1978 have been shifted to relate them to the present gauge board datum. This lined up the older check gaugings with the newer ones in the low flow region, which accords with a gauge board move.

It is recommended that new high flow check gaugings are undertaken at this site.

A new set of rating equations has been derived for high flows in accordance with international standards (ISO 1100-2). The existing OPW ratings can be used up to a stage of 3.53m, above which new rating equations are provided which extend the rating to flows of approximately 250 m^3/s.

There is a step change in the AMAX flow series in 1972 related to a change in the rating. The ratings since 1972 (with corrected stages to the new datum for the period 1972-1978) are all similar in the high flow range and fit well with the most recent check gaugings. The rating before 1972 is shown in the graph below. It fits through two high flow gaugings in Dec 1954 and one gauging in 1969. It is suggested that the recorded flows from 1958 to 1971 should be used with caution.

AMAX flows from 1972 to 1978 can be used unaltered, as the original rating was representative (similar to the latest rating and none of the AMAX stages are higher than 3.53m above the current local datum). The AMAX series from 1978 onwards has been reworked for stages above 3.53m.



Note: Check gaugings preceding the gauge board change in Aug 1978 have been shifted in this graph to relate their stage readings to the new gauge datum.

Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section at the gauge board. The model shows that the existing OPW high flow rating is reliable up to a stage of 3.53m.

A set of rating equations was established for stages above 3.53m, below which the existing OPW rating gives a good fit with the check gaugings. The new equations allow for the estimation of flows up to approximately 250 m^3/s.

As no recent high flow check gaugings are available it is recommended that new high flow gaugings are undertaken at this site.

It is suggested that the recorded flows before 1958 are dismissed due to drainage works. AMAX flows from 1958 to 1971 should be used with caution, using the original OPW rating derived for that period (i.e. unaltered).

AMAX flows from 1972 to 1978 can be used unaltered, as the original rating was representative (similar to the latest rating and none of the AMAX stages are higher than 3.53m above the current local datum). The AMAX series from 1978 onwards has been reworked for stages above 3.53m.

The AMAX series from 1978 onwards has been reworked for stages above 3.53m.

25011 – BROSNA AT MOYSTOWN

Date of data collation: 11/01/2012, completed 24/09/2012.

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located downstream of Moystown Bridge on the River Brosna. The gaugeboard and stilling well are located on the left bank of the river. The gauging station has a nature control and the channel is clear of vegetation. Flow bypassing the structure is considered unlikely due to high road embankment.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	204601, 220861	**Period of Record**	1954 to 2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.6 m (~ 112 m^3/s; pre-rating review)

QMED synthetic	88.7 m^3/s
QMED (AMAX, pre rating review)	82.8 m^3/s (56 years)

Gauge Zero (from operator)	35.78 mAOD (P)
Gauge Zero (from survey)	32.95 mAOD (M)

Revised Rating Equations:

Q = 22.025 (W+0)^1.6139	for the range: 1.08<W<2.40 (above Gauge Zero)
Q 11.098 (W+0)^2.3952	for the range: 2.40≤W<2.85 (above Gauge Zero)
Q = 1.3515 (W+0)^4.4073	for the range: 2.85≤W<2.99 (above Gauge Zero)
Q = 0.0079 (W+0)^9.0987	for the range: 2.99≤W<3.05 (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Details: 25011_Moystown_GS_V6_C1.dat.

A one-dimensional hydraulic model of the River Brosna at Moystown gauging station was built using river survey data collected by Murphy Surveying in November 2011 (survey drawings 4281_25BSNA_MOYSTOWN_XS_PLAN, 4281_25BSNA_MOYSTOWN_XS_1 to 7, and 4281_25BSNA_MOYSTOWN_LS_1) and ISIS one-dimensional hydraulic modelling software.

The hydraulic model extends from 1766m upstream of Moystown Bridge (NGR: 206348, 221464) on the River Brosna to 2129m downstream of the bridge (NGR: 203227, 219663). The gauging station is located approximately 70m downstream of the bridge at node BSNA01_1942 in the ISIS model.

Moystown Bridge is the unique structure included in the hydraulic model. It was schematised using an ISIS Arch bridge unit and a spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were originally estimated using site visit and survey information. The river bed consists mainly of silt, stones and gravel (n= 0.040). Bank side and floodplain roughness values range from 0.02 (road) to 0.1 (Building). However the majority of the roughness values used in the floodplain are split between pasture (0.035) and medium to dense vegetation (0.065).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate. A normal depth boundary unit was used as the downstream boundary condition.

Hydraulic Model Calibration:

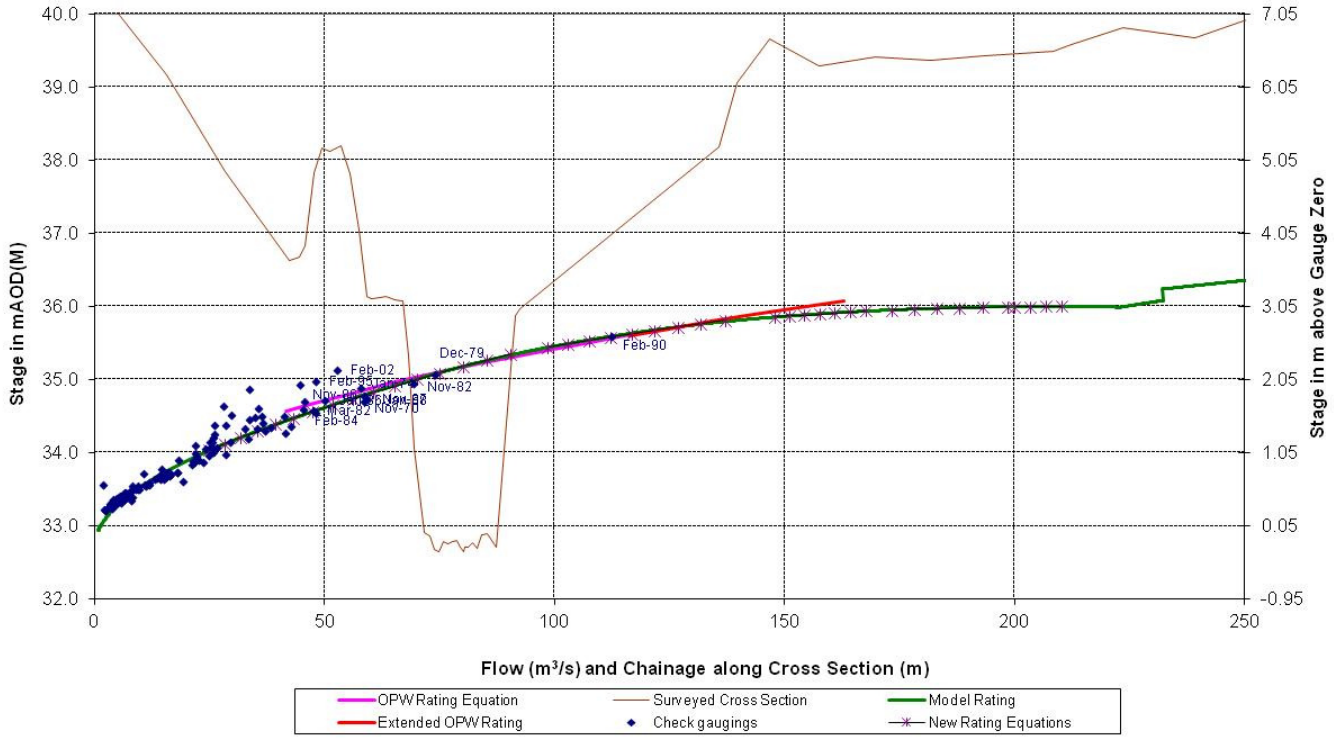
Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The bed roughness coefficient in the hydraulic model was gradually varied from its original value of 0.040 to 0.045 where a good agreement was found between the modelled water level and the highest check gaugings.

Once calibrated, the hydraulic model has been run with flows ranging from 1 to 342 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities, but slight hysteresis at flows above 210 m^3/s. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS node BSNA01_1942).

Analysis and Results:

There is some notable scatter in the check gaugings in the mid-flow range, giving concern that the dearth of high flow gaugings may hide scatter in the high-flow range. Due to the scatter this station should be used with caution. The scatter may be due to backwater effects from the River Shannon. Nevertheless, the model rating has a good relationship with the majority of check gaugings throughout the full range of gaugings. The model rating and existing OPW rating have similar flow-level relationships around QMED, but the existing rating deviates at the lower and upper limits. Therefore, a new set of rating equations has been derived for high flows following BS ISO 1100-2 and applied to the AMAX levels from 1971, when there was a rating change and a slight adjustment in datum. This shows that the original rating is acceptable around QMED, but that AMAX values significantly lower and higher have changed. The rating equations have been extended up to about 210 m^3/s, which equates to 2.5xQMED approximately. Above this flow the model shows some slight hysteresis which affects the ability to derive a reliable rating. Although the upper limit of the derived rating equations is somewhat short of the normal 3xQMED applied at most other gauging stations, the 2.5xQMED limit is of the order of a typical Q1000 flow, and is therefore considered an acceptable upper limit. The shorter recalculated AMAX series results in a small change in QMED from 82.8 m^3/s to 81.9 m^3/s

As drainage works occurred in 1948-1955, it is recommended that only AMAX values from 1956 are used for QMED estimation or flood frequency analysis.



**Gaugings prior to 1972 have been shifted to incorporate changes in datum.*

Summary, Conclusions and Recommendations:

Due to scatter in the check gaugings this station should be used with caution.

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section at the gauge board. A set of rating equations was established to give a good fit with the modelled rating in the stage interval 1.08<W<3.05m. The resulting rating equation is slightly different from the OPW rating equation at the lower and upper limits. We have reworked the AMAX series from 1971 to improve flood frequency analysis at this site.

As drainage works occurred in 1948-1955, it is recommended that only AMAX values from 1956 are used for QMED estimation or flood frequency analysis.

25013 – BROSNA AT NEWELL'S BRIDGE

Date of data collation: 11/01/12, completed 10/12/2013.

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located 9m downstream of the Newell's road bridge on the left bank of the Brosna River. The gauging station has a natural channel control and the channel is clear of vegetation. Flow bypassing the structure is considered unlikely due to the high road embankment.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	238334, 242315	**Period of Record**	1973-2009
Existing Rating Curve	No	**Validity / Upper Limit**	N/A - No existing rating but highest gauging at W < 1.6 m (~12 m^3/s)

QMED synthetic	11.5 m^3/s
QMED (AMAX, pre rating review)	No Rating

Gauge Zero (from operator)	80.38 mAOD (P)
Gauge Zero (from survey)	77.67 mAOD (M)

Revised Rating Equations:

Q = 5.6974 (W+0)^1.3412	for the range: 0.89<W<1.53 (above Gauge Zero)
Q = 4.4278 (W+0)^1.9327	for the range: 1.53≤W<1.92 (above Gauge Zero)
Q = 2.6359 (W+0)^2.7287	for the range: 1.92≤W<2.43 (above Gauge Zero)
Q = 0.2864 (W+0)^5.2657	for the range: 2.43≤W<2.57 (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Name: NewellsBr_25013_ISIS_v7_cali5.DAT, NewellsBr_25013_ISIS_v7_cali6.DAT

A one-dimensional hydraulic model of the River Brosna at Newell's Bridge was built using river survey data collected by Murphy Surveying in November 2011 (survey drawings 4281_25BSNA_NEWELLS BRIDGE_XS_PLAN, 4281_25BSNA_NEWELLS BRIDGE_XS_1 to 4, and 4281_25BSNA_NEWELLS BRIDGE_LS_1) and ISIS one-dimensional hydraulic modelling software developed by Halcrow.

The hydraulic model extends from 1525m upstream of Newell's Bridge (NGR: 238157, 243790) on the River Brosna to 1828m downstream of this structure (NGR: 238305, 240739). The gauging station is located 9m downstream of the Newell's road bridge on the left bank of the Brosna River at ISIS node BROS01_1820 in the ISIS model.

Newell's Bridge was schematised using an ISIS arch bridge unit and a spill unit to allow for bridge overtopping. There is also a weir located 940m upstream of Newell's bridge (ISIS node BROS01_2768u) which has been modelled using inline spill units to represent the weir crest profile and the adjacent floodplain.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of silt, stones and gravel (n=0.039). Bank side and floodplain roughness values range from 0.020 (roads) to 0.1 (Building). However the majority of the floodplain was given roughness values of 0.035 (pasture) and 0.080 (dense vegetation).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as the model extends far enough downstream of the gauging station to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The calibration coefficient at the bridge section had no significant effect on the rating curve as the available gaugings are within the low to medium flow range for which the structure barely affects the hydraulics in the river. The river bed roughness coefficient and the "user defined" bed slope were gradually varied to achieve a reasonable fit to the gaugings. The final model coefficients retained are 0.050 for the roughness and a bed slope of 1m/11km at the downstream boundary. It is acknowledged that with these coefficients the model rating lies at the lower end of the wide range of check gaugings, but the model rating accords well with the highest gauged flows. Further modification of the calibration parameters (outside reasonable limits) is not considered appropriate.

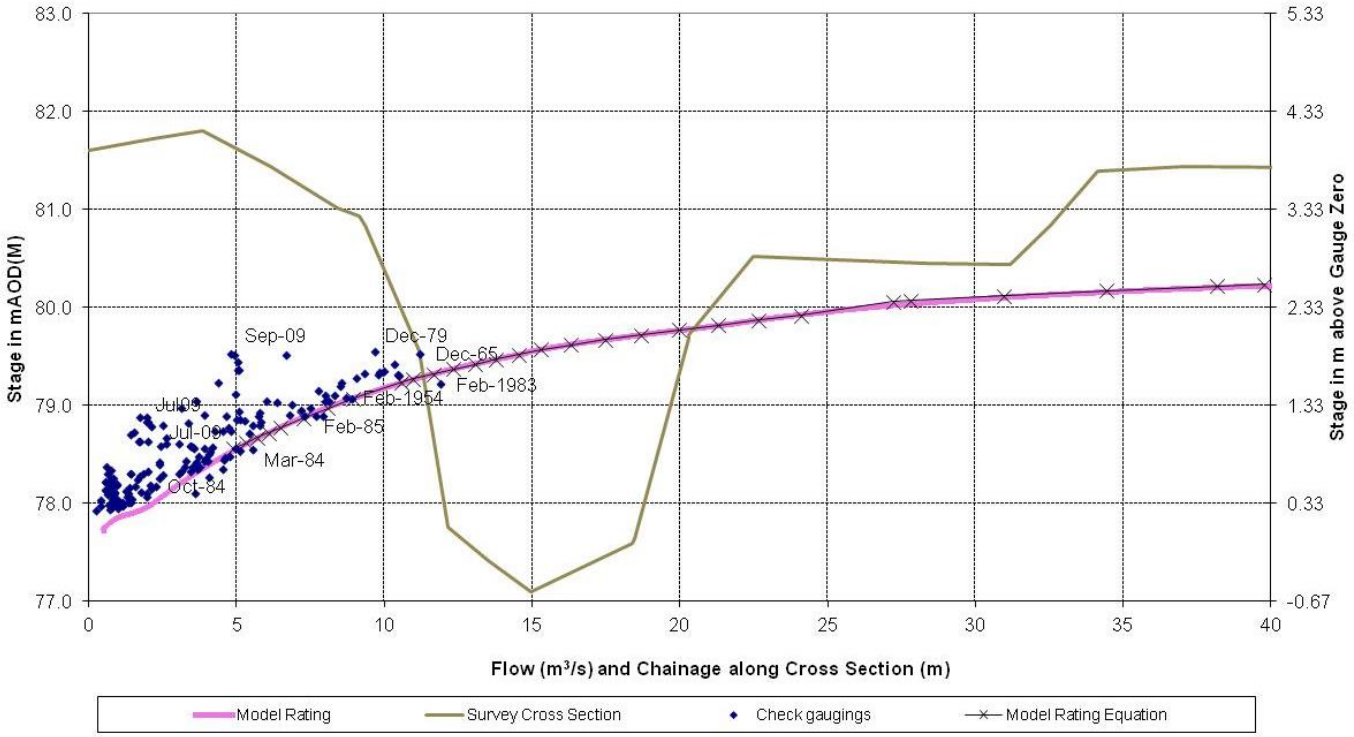
Once calibrated, the hydraulic model has been run with flows up to 43m^3/s using the unsteady state solver in ISIS in a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS node BROS01_1820).

Analysis and Results:

There is no existing OPW rating and (therefore) no AMAX flow series for this site.

The check gaugings are highly scattered. This may be related to the maintenance regime in the channel. OPW have informed us that drainage works were carried out in the 1950s, followed by clearing silt and weed from the channel on a 4-5 yearly cycle. This causes the flow-level relationship to change every time this maintenance work is carried out at or immediately downstream of the gauge. In addition, the site is reported to experience significant weed growth and variable siltation which affects the reliability of the flow measurements. Due to the reported poor nature of this flow monitoring site, it is recommended that this site is not used for flood estimation purposes. There is a weir upstream of the gauge, but due to the variable control (sluice) and feedback from OPW stating that the site is not suitable for flow monitoring, this site cannot currently be considered as an alternative flow monitoring site.

The model rating shows a reasonable fit with the highest gauged flows, and a new set of rating equations has been derived for high flows following international standards (ISO 1100-2).



Conclusions:

A stable model was created, calibrated to the highest observed flows and run to provide the flow-level relationship (rating) at the gauge. A set of rating equations was established to give a good fit with the modelled rating in the stage interval 0.89<W<2.57m. There was no historic rating that the modelled rating could be compared to.

Due to the reported poor nature of this flow monitoring site, evident in the scatter in the check gaugings, it is recommended that this site is not used for flood estimation purposes. It is recommended that the gauge be moved to a geomorphologically stable section and that a formal control be used to reduce the scatter in the check gaugings.

25014 – SILVER AT MILLBROOK

Date of data collation: 01/01/2012, completed 24/09/2012

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the left bank on the upstream face of the bridge. The gauging section, control and channel are clear of vegetation and the bed is relatively stable. Flow bypassing the structure is considered unlikely due to the high road embankment.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	213540, 218796	**Period of Record**	1951-2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.4 m (~26.4 m^3/s; pre-rating review)

QMED synthetic	26.5 m^3/s
QMED (AMAX, pre rating review)	17.2 m^3/s (59 years)

Gauge Zero (from operator)	47.17 mAOD (P)
Gauge Zero (from survey)	44.41 mAOD (M)

Revised Rating Equations:

Q = 5.3869 (W+0)^1.8512	for the range: 1.390<W<2.480 (above Gauge Zero)
Q = 7.2514 (W+0)^1.5241	for the range: 2.480≤W<2.990 (above Gauge Zero)
Q = 2.3547 (W+0)^2.5508	for the range: 2.990≤W<3.243 (above Gauge Zero)
Q = 0.5238 (W+0)^3.8282	for the range: 3.243≤W<3.470 (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Hydraulic Model Name: 5014_Millbrook SILV_GS_V5_C1.dat

A one dimensional hydraulic model of the River Silver (and its tributary the River Island) was built using river survey data collected by Murphy Surveying in December 2011 (survey drawings 4281_25SILV_MILLBROOK_XS_PLAN, 4281_25SILV_MILLBROOK _XS_1 to 9, 4281_25SILV_MILLBROOK _LS_1, 4281_25ISLD_MILLBROOK_XS_PLAN, 4281_25ISLD_MILLBROOK_XS_1 to 4 and 4281_25ISLD_MILLBROOK_LS_1) and the ISIS one-dimensional hydraulic modelling software developed by Halcrow.

The hydraulic model extends from 1712m upstream of Millbrook Bridge (NGR: 212662, 217531) to 2218m downstream of the bridge (NGR: 214013, 220538) on the River Silver. The model also includes a 2000m long reach of the River Island which runs parallel to the River Silver on its right hand side. The Millbrook gauging station is located on the upstream face of the Millbrook Bridge at ISIS node SILV01_2218u in the ISIS model.

Millbrook Bridge was schematised using an ISIS arch bridge unit and a spill unit to allow for bridge overtopping. Five other bridge structures crossing the River Silver were included in the model using the same approach at ISIS nodes SILV01_1277u, SILV01_1270u, SILV01_0930u, SILV01_0830u and SILV01_0510u. On the River Island, two circular culvert structures were schematised using ISIS orifice units and spill units for overtopping at ISIS nodes ISLD01_0520u and ISLD01_0497u.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of silt, stones and gravel (n=0.037). Bank side and floodplain roughness values range from 0.020 (road), 0.035 (pasture) to 0.090 (forest).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate. Where the River Silver and the River Island share the same floodplain, connections have been set up between the cross-sections of each river reach using lateral spills.

A normal depth boundary unit was used as the downstream boundary condition on the River Silver reach. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gaugings provided by OPW. With the roughness coefficients and calibration coefficient at the bridge originally set in the ISIS model a good agreement was found between the modelled water level at the gauging station and the check gauging levels, therefore no further calibration of the model was deemed necessary.

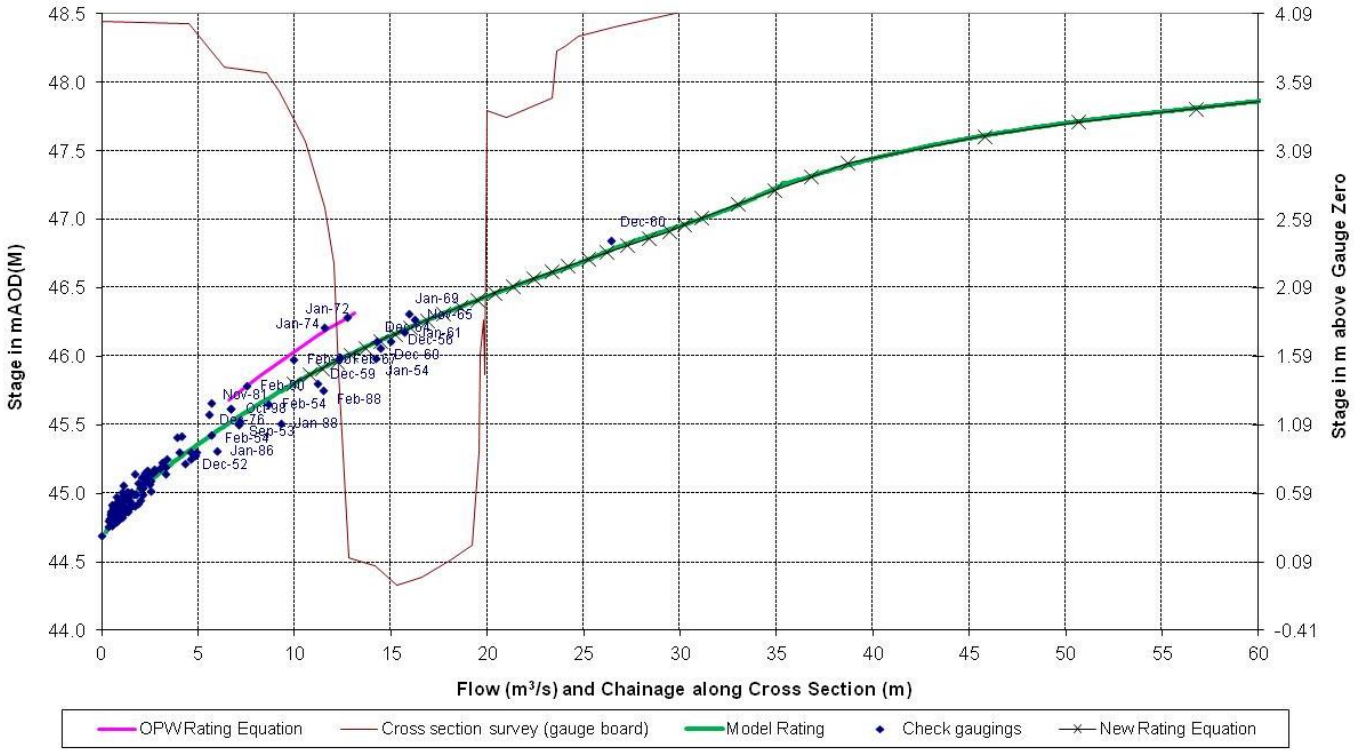
Once calibrated, the hydraulic model has been run with flows ranging from 0.2 to 105 m^3/s using the unsteady state solver in ISIS in a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (SILV01_2218u).

Analysis and Results:

The model rating has a relatively good relationship with the majority of the check gaugings. There is some scatter but this seems to be situated evenly around the rating. The existing OPW rating lies significantly above the majority of the check gaugings. A high flow gauging was completed in December 1960, which lies close to the model rating. However, due to its age this gauging may not be representative of the current condition.

Only two gaugings have been completed since 2000, and no high flow gaugings since the 1960s. It is therefore recommended that high flow gaugings are undertaken to identify the most appropriate rating for the site.

A new set of rating equations has been derived for high flows following international standard ISO 1100-2. The revised rating has been applied to the AMAX series from 1952, which is the first year after the completion of drainage works in 1951, as there is no evidence of a significant change within the catchment since that year. The revised AMAX series shows that the previous estimate of QMED (17.2 m^3/s) can be expected to be an underestimate.



Conclusions:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section at the gauge board. A set of rating equations was established to give a good fit with the modelled rating in the stage interval 1.39<W<3.47m. This rating cannot be verified against recent high flow gaugings, as there have been no high flow gaugings since the 1960s. It is therefore recommended that high flow gaugings are undertaken to confirm the rating. Despite this issue, it would seem a reasonable conclusion that the original rating equations were not suitable for high flows. The revised rating has been applied to the AMAX series dating back to the completion of drainage works (1952) as there is no evidence of a significant change within the catchment since that year.

25015 – BROSNA AT POLLAGH

Date of data collation: 11/01/2012, completed 20/05/2014.

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

Recorded located on right bank downstream of Pollagh Bridge. No formal control or weir structure. Good straight section upstream and downstream of the gauging station. Notes from Jacobs site visit indicates that flow may go out of bank due to gaps in embankment both downstream and upstream of the gauge.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	219000, 225693	**Period of Record**	1972 -2010 (level only)
Existing Rating Curve	No Existing Rating	**Validity / Upper Limit**	W < 2.65 m (~51.2 m^3/s; pre-rating review)

QMED synthetic	61.7 m^3/s
QMED (AMAX, pre rating review)	N/A (No existing rating)

Gauge Zero (from operator)	43.63 mAOD (P)
Gauge Zero (from survey)	40.97 mAOD (M)

Hydraulic Model Details:

Model name: 25015_POLLAGH_GS_V11.DAT.

A one-dimensional hydraulic model of the River Brosna at Pollagh gauging station was built using river survey data collected by Murphy in 2011 (survey drawings 4281_25BSNA_POLLAGH_XS_PLAN, 4281_25BSNA_POLLAGH_XS_1 to 6 and 4281_25BSNA_POLLAGH_LS1) and ISIS one-dimensional hydraulic modelling software developed by Halcrow.

The hydraulic model extends from 2000m upstream of Pollagh Bridge (NGR: 221076, 226405) on the River Brosna to 1836m downstream of this structure (NGR: 217579, 224737). The gauging station is located on the downstream face of the Pollagh Bridge at ISIS node BSNA01_1829u in the ISIS model.

Pollagh Bridge was schematised using an ISIS Arch bridge unit and a spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of silt and mud (n=0.033). Bank side and floodplain roughness values range from 0.020 (roads) to 0.1 (Building) however the majority of the roughness values used in the floodplain split between pasture (0.035) and dense vegetation (0.080).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition.

Hydraulic Model Calibration:

An attempt to calibrate the hydraulic model has been carried out by comparing model results against available check gaugings. The Manning's n values used in the model were adjusted within an acceptable range to try and fit the modelled rating curve to the check gaugings.

However a good fit was not obtained and further adjustment to the Manning's n values was considered and the use of unrealistic downstream boundary conditions, neither of these improve the fit of the model rating to the check gaugings. The comparison of check gaugings and model rating was poor. The calibration of the hydraulic model has been abandoned and Manning's n values originally estimated were kept in the model.

The hydraulic model has then been run with flows ranging from 2.5 to 240 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS node BSNA01_1829u)

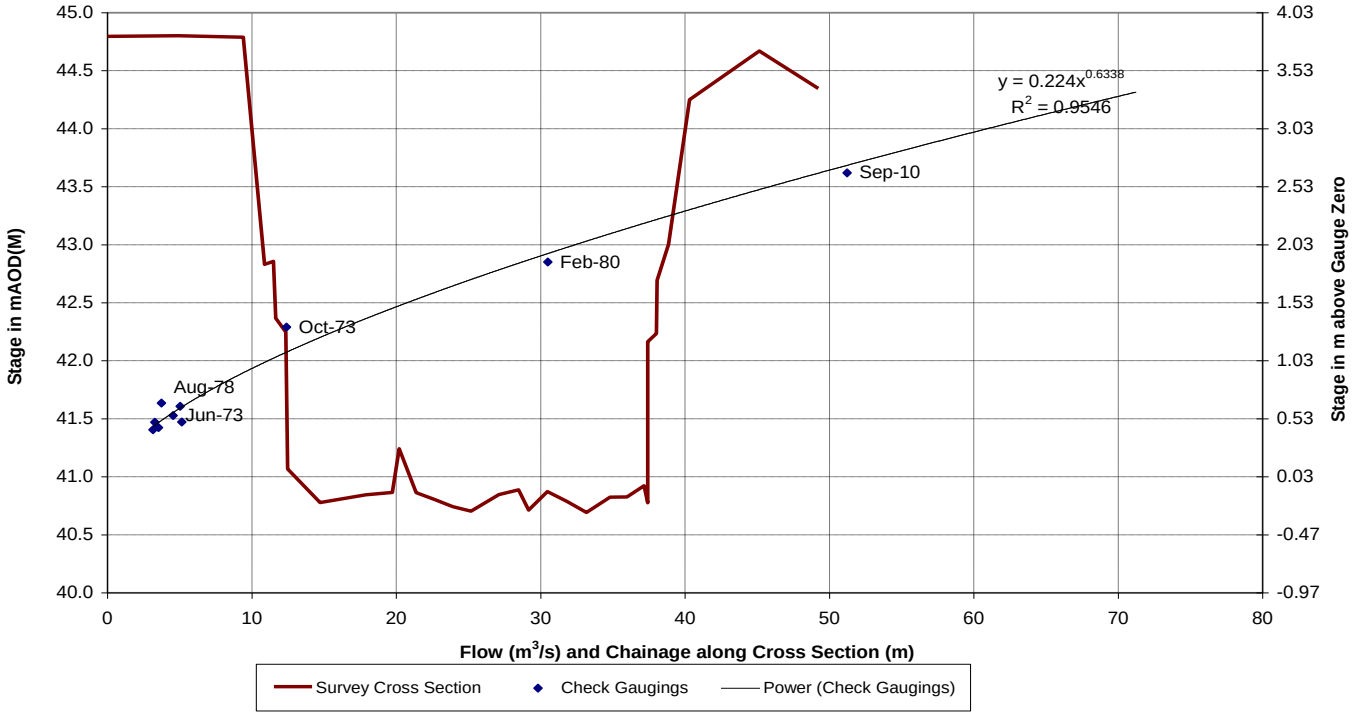
Analysis and Results:

The model rating for Pollagh compares poorly with the check gaugings at this station. The topographic survey, model, check gaugings and site information were investigated but did not reveal obvious errors. OPW supplied us with a high flow gauging in September 2010, which did not tie in with the model rating, but fitted in with the general trend of the existing check gaugings.

It is noted that the check gaugings suggest a rating curve that gives an estimate of QMED of 62 m^3/s (based on the median of AMAX levels of 43.97 mAOD[M] and a preliminary rating as described below) , which broadly agrees with the synthetic estimate of QMED.

OPW confirmed that the drainage maintenance technicians in the area were aware of channel maintenance carried out upstream and downstream of this station since 1980. Therefore the check gaugings of 1980 and before may not provide good calibration data for the model. There is only one gauging since 1980, which is of September 2010, and it is not realistic to verify the accuracy of any rating based on one gauging. Furthermore, Kenneth Freehill from OPW confirmed in an email of 20/09/2012 that OPW's hydrometric technician considered the site unsuitable for flow measurement due to slow velocities, peat build-up and vegetation creating high uncertainties in the gauging.

Due to the lack of recent, representative check gaugings, the poor fit between gauged and modelled data, the varying nature of the channel and the reported unsuitability for flow monitoring we have not created a rating equation for this station. Any rating created here would have a very limited reliability. A power law equation has been created through the existing check gaugings as a very preliminary rating ($Q=0.224\ (H+0)^{0.6338}$). However, if essential, OPW could build on the preliminary rating by undertaking additional gaugings.



Conclusions and Recommendations:

A stable model was created and run to provide the flow-level relationship (rating) at the gauge board. It was not possible to establish a good fit between the check gaugings and the model rating, without using unrealistic calibration parameters.

Analysis of the available data suggests issues with the reliability of some of the check gaugings. Since all of the gaugings except one where completed prior to channel alterations it was not considered appropriate to validate any rating on one gauging. In addition, OPW technicians identified that the site was not suitable for flow gauging due to slow velocities, peat build-up and vegetation.

It is recommended that a rating equation is not derived for this site and that the site is not used for flow estimation. We recommend that either another site is found which is more suitable for flow monitoring, or that a formal flow monitoring structure is installed, such as a weir built to international standards. Both these options would require the collection of check gaugings before a high flow rating can be developed.

25016 – CLODIAGH AT RAHAN

Date of data collation: 22/05/2012, completed 16/10/2013.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank, upstream of the Rahan Bridge on the River Clodiagh. The gauging station has no formal control and the channel is clear of vegetation. The downstream bridge may act as a control during some flow conditions. Flow bypassing the structure is considered unlikely due to high road embankment.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	225669, 225645	**Period of Record**	1952 to 2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.5 m (~23 m^3/s; pre-rating review)

QMED synthetic	40.2 m^3/s		**Gauge Zero (from operator)**	47.87 mAOD (P)
QMED (AMAX, pre rating review)	23.4 m^3/s (56 years)		**Gauge Zero (from survey)**	45.14 mAOD (M)

Revised Rating Equations:

Q = 5.42*(W-0.10)^1.649	for the range: 1.07≤W<2.86m (above Gauge Zero)*
Q = 3.4222*(W+0)^2.0307	for the range: 2.86≤W<3.25m (above Gauge Zero)
Q = 1.6521*(W+0)^2.6534	for the range: 3.25≤W<3.77m (above Gauge Zero)
Q = 7.1928*(W+0)^1.545	for the range: 3.77≤W≤4.36 m (above Gauge Zero)

* *Existing OPW rating (rating 9)*

Hydraulic Model Details:

Model name: N07_QXXXX_Flu_C_1D2D_BldV2.DAT

A dynamically linked one-dimensional and two-dimensional ISIS-TUFLOW hydraulic model of the River Clodiagh was built using river survey data collected by Murphy Surveying in November 2011 (survey drawings 4281_25CLOD_RAHAN_XS_PLAN, 4281_25CLOD_RAHAN_XS_1 to 8, and 4281_25CLOD_RAHAN_LS_1).

The 1D hydraulic model extends from 1.3km upstream of the R422 Road Bridge, Clonaslee (NGR: 230988, 210148) on the River Clodiagh to 2.1km downstream of Rahan Bridge (NGR: 224408, 227092). The gauging station is located just upstream of Rahan Bridge at ISIS node 02CLD02397u in the ISIS model.

The two-dimensional model domain extends 0.5km upstream of Rahan Bridge and 1km downstream of the Rahan Bridge. The two-dimensional model used 10m cells and the topography was based on 2m resolution LiDAR data.
In addition to Rahan Bridge, all other hydraulic structures along the watercourse were modelled in ISIS. The dimensions of each structure were taken from the survey drawings. Spill units were attached to appropriate structures to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were originally estimated using site visit and survey information. The river bed consist mainly of silt, stones and gravel (n=0.040). Bank side and floodplain roughness values range from roads (0.020) to building (0.1). However, the majority of the floodplain is designated as pasture (0.035) or dense vegetation (0.080). Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings.

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the available check gaugings provided by OPW. The calibration coefficient at bridge sections was modified but no significant effect on the rating curve was observed. The bed roughness from downstream of the confluence with the River Clodiagh and the River Tullamore was increased from 0.040 to 0.048, which provided a good agreement between the modelled water level and the check gauging levels at the gauging station.

Once calibrated, the hydraulic model has been run with flows ranging up to 89m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node 02CLD02397u).

Analysis and Results:

The RBD Shannon Data Summary.xls spreadsheet reported that drainage works were carried out in the period 1948-1955. There is a gap in the AMAX series from 1955 to 1957, presumably related to the drainage works. Data from before 1958 should not be used for flood frequency analysis at this site.

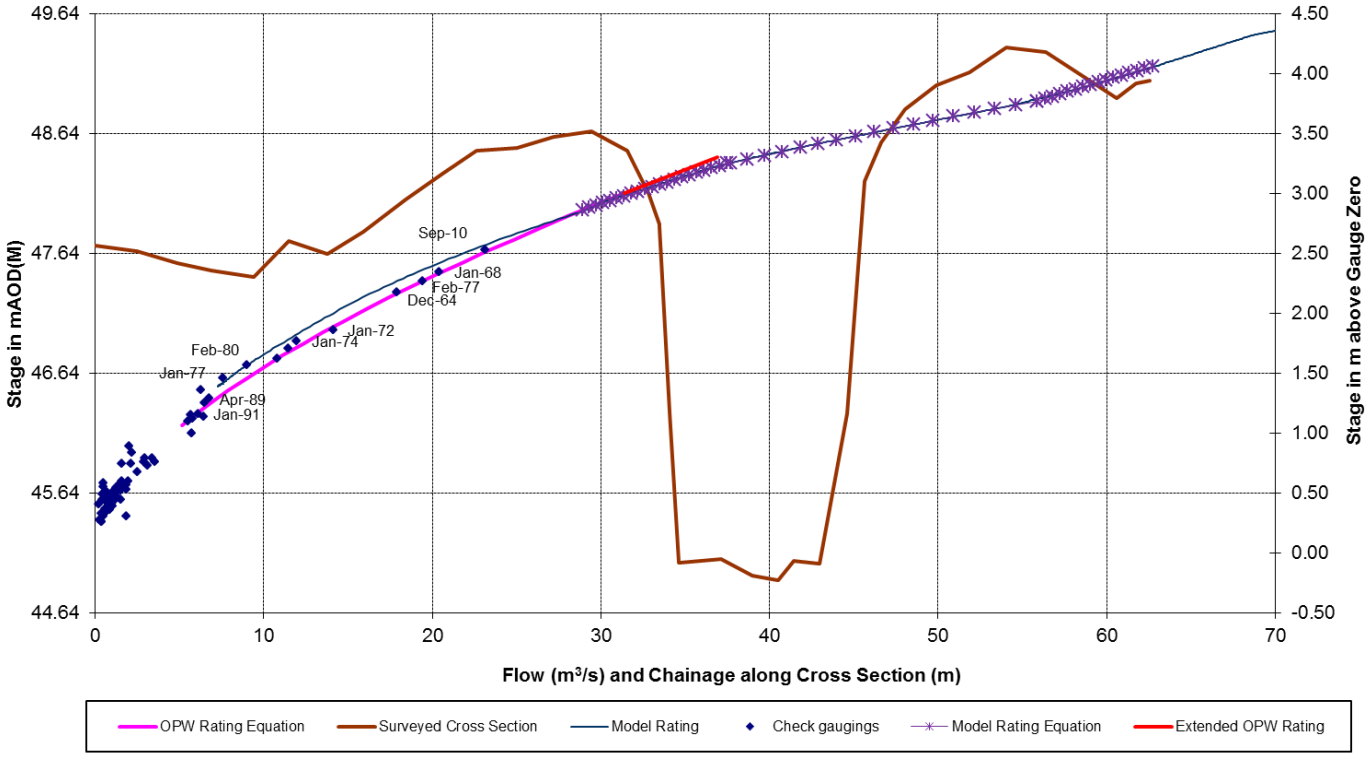
The historic OPW ratings and the modelled rating have been compared to the check gaugings in the mid- and high-flow range. It was found that the OPW rating from 1955 to 1962 (post drainage works) shows a poor fit with the check gaugings for that period. A plot of all the check gaugings also shows a shift in flow regime around 1963. This is reflected in OPW's change in the rating equations in January 1963. A request for more information to OPW on the apparent step change in 1963 did not yield any further information. It is recommended that the AMAX data prior to 1963 is not used for QMED estimation or flood frequency analysis.

The modelled rating has a good fit with the most recent high flow gauging of September 2010. This gives confidence that the modelled rating is reliable for high flows. Close inspection of the ten historic sets of OPW rating equations shows that the existing rating number 9 (which is the same as rating number 3 and was originally used in the period 1963-1973 and 1979-1989) has a particular good fit with the eight highest check gauging since 1963. The majority of these gaugings are from the late 1960's and 1970's, but they show little scatter and line up well with the 2010 observation. OPW rating 9 is therefore preferred in the mid-flow range.

As the confidence in OPW rating 9 is high for water levels up to the highest check gauging (Sep 2010, stage of 2.53m), it is suggested that that rating can be used up to the intersection of the OPW rating with the modelled rating (stage of 2.86m). The modelled rating is more realistic for levels considerably above the highest check gauging, as it encompasses a representation of the physical reality instead of simply extrapolating a power function, and shows a good fit with the highest check gauging.

The new set of rating equations has been derived for high flows above a stage of 2.86m in accordance with BS ISO 1100-2. Below that stage, the existing OPW rating (rating 9) should be applied. The resulting set of rating equations should be applied to the entire AMAX series from 1963 as the check gaugings in the AMAX range (from 1.81m to 3.26m) show very little scatter. The estimate of QMED remains unchanged.

It is recommended that more medium and high flow gaugings are completed to further verify the adopted rating, as there are currently only four gaugings around QMED since 1963 and only one since 1980, and none for flows above QMED.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section at the stilling well. A new set of rating equations was established, to give a good fit with the modelled rating in the stage interval 2.86≤W<4.36m. The existing OPW rating number 9 can be used for stages below 2.86m.

The AMAX series from 1963 has been revised based on the new set of rating equations. It is recommended that for QMED estimation and flood frequency analysis the AMAX data from 1963 is used.

25017 – Shannon at Banagher

Date of data collation: 05/01/2012, completed 24/05/2014

Introduction:

High flow rating reviews have been undertaken for 42 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The recorder is situated on the right bank upstream of the bridge over the Shannon at Banagher. The river has a stable sand/silt bed with negligible weed growth. A multi-arch bridge just upstream will act as a barrier to flows and the bypass flow path around that bridge is not evident. The river is on a long right bend as it passes the station. The channel has a constant width upstream and downstream of the station.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	200506, 215829	**Period of Record**	1950-2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 3.9 m

QMED synthetic	322 m^3/s
QMED (AMAX, pre rating review)	426 m^3/s (60 years)

Gauge Zero (from operator)	33.19 mAOD (P)
Gauge Zero (from survey)	30.49 mAOD (M)

Revised Rating Equations:

Q = 60 (W–1.00)^2.030 for the range: 2.15<W<5.00m (above Gauge Zero)*

* OPW rating retained

The rating review modelling and hydrological analysis are summarised below.

Hydraulic Model:

The N10 model, which covers the Banagher gauging station, was used to represent the River Shannon at Banagher. Details of this model are provided in Appendix B of the UoM25/26 Hydraulic Report.

Hydraulic roughness (Manning's n) values used in the model were originally estimated using site visit and survey information. Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings (see next page).

Floodplain areas were represented in the model using extended cross sections and reservoir units as appropriate.

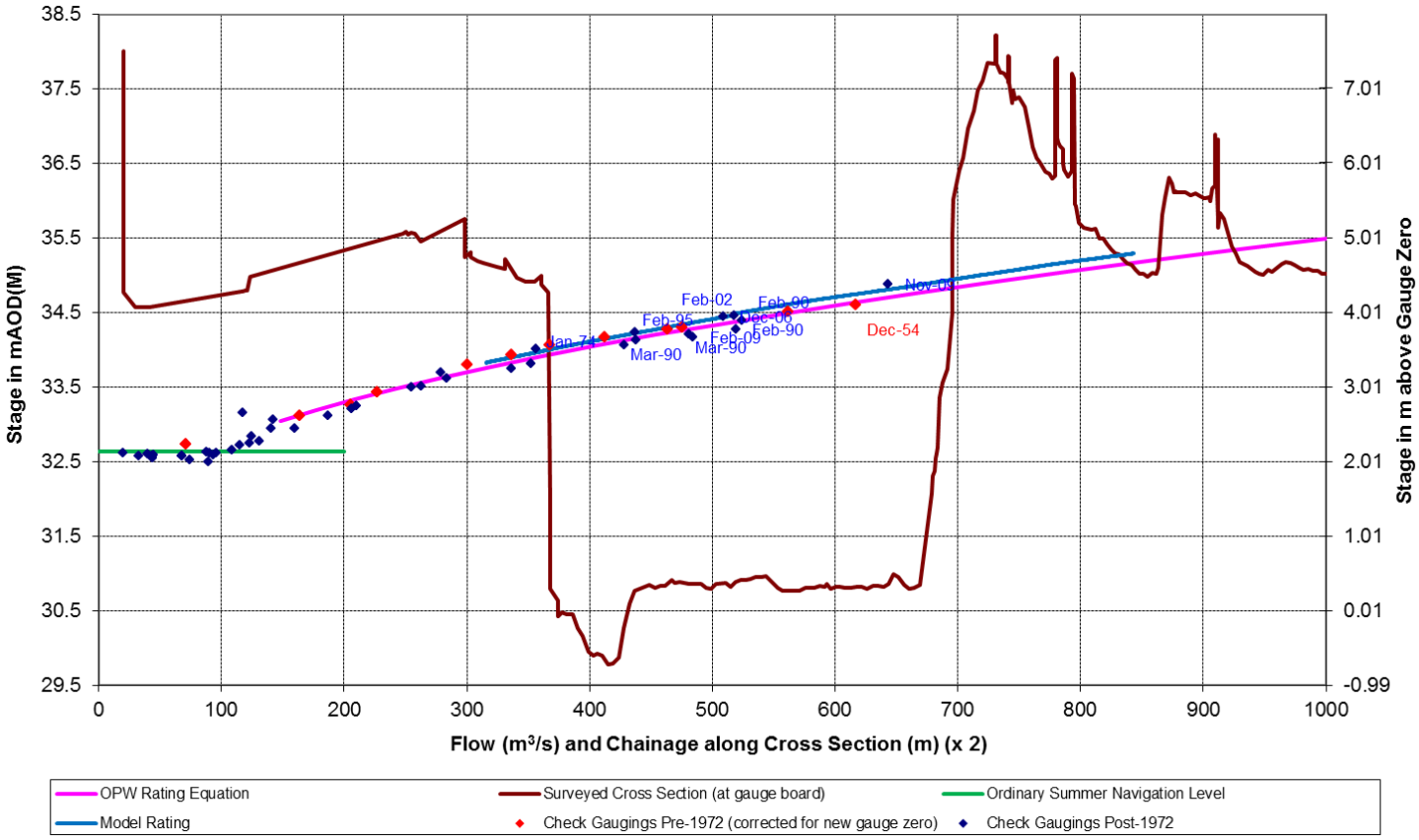
Analysis and Results:

There are check gaugings available from December 1954. In February 1972 the gauge was re-rated to allow for a datum shift of 1.6m. Apart from this datum shift the rating was not changed. This suggests that the gauge board and stilling well were re-sited to a new datum. When the check gaugings are corrected (moved up) by 1.6m they fall in line with the check gaugings taken after 1972 confirming that there are no other significant changes at the gauge in that year.

Analysis of the available check gaugings and OPW rating showed that the existing rating is reliable and suitable for use.

The OPW rating has a good fit with the check gaugings, confirming the rating up to 643 m^3/s. The model rating confirms that the OPW rating can be used for flows up to approximately 850 m^3/s, or 2xQMED. This is well above the highest AMAX recording and about the estimate of the 1000-year peak flow at this station.

There is little scatter in the check gaugings from the 1950s once the datum shift mentioned above has been taken account of. However there is a slight gradual upward trend in the AMAX series (levels and flows) from 1950 at Banagher. This suggests that flood flows at this station may be affected by drainage works carried out on various rivers in the Shannon catchment. As the trend is relatively mild it is considered appropriate to use the entire AMAX series from 1950 for flood estimation, but the older records should be used with some caution.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at the gauge board. The model rating shows a good fit with the check gaugings and the OPW ratings available from 1950. The OPW rating can be retained for the entire AMAX series from 1950.

it is considered appropriate to use the entire AMAX series from 1950 for flood estimation. The older records should be used with some caution due to a slight upward trend in the AMAX levels and flows from 1950.

25021 – LITTLE BROSNA AT CROGHAN

Date of data collation: 11/01/2012, completed 24/04/2013.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

This is a velocity area gauging station installed in 1956 and automated in 1961. The station is located on the right bank immediately downstream of a three arch bridge, north of Birr. Sedimentation is thought to be a problem and during the site visit it was noted that debris was collecting on the upstream face of the road bridge. Flood flows are likely to be contained within the channel and bypass is unlikely.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	205365, 205654	**Period of Record**	1961-2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 1.49 m (~30.0 m^3/s)

QMED synthetic (urban)	49.2 m^3/s
QMED (AMAX, pre rating review)	28.6 m^3/s (49 years)

Gauge Zero (from operator)	41.75 mAOD (P)
Gauge Zero (from survey)	39.08 mAOD (M)

Revised Rating Equations:

Q = 9.0069 (W+0)^2.5268	for the range: 1.269 < W < 1.574 (above Gauge Zero)
Q = 5.5214 (W+0)^3.6052	for the range: 1.574 ≤ W < 1.790 (above Gauge Zero)
Q = 3.4279 (W+0)^4.4236	for the range: 1.790 ≤ W < 2.450 (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Name: 25021_Croghan_GS_V10.DAT

A one-dimensional hydraulic model of the River Little Brosna near Croghan Bridge gauging station was built using river survey data collected by CCS Surveying in June 2012 (survey drawings P606-CR-XS-001 to 012 Rev2, P606-CR-LS-013 to 014 REV2, P606-CR-LP-015 to 016 REV2 and P606-CR-BL-017 to 018 REV1) and the ISIS hydraulic modelling software.

The hydraulic model extends from 2069m upstream of Croghan Bridge (NGR: 205313.77, 204102.42) on the River Little Brosna to 2058m downstream of the structure (NGR: 204170, 206932). The gauging station is located on the right bank approximately 3m downstream of the bridge at ISIS node LBSN01_2051 in the ISIS model.

There are three hydraulic structures included in the model: Croghan Bridge (ISIS node: LBSN01_2058), Ivy Bridge (LBSN01_2236) and an access bridge (LBSN01_2341). All bridges were represented in the model using ISIS Arch bridge units and spills to allow for bridge overtopping. Two other accommodation bridges at ISIS node LBSN01_3264 and LBSN01_1078 were not included in the model build as early model runs demonstrated they do not exert a significant impact on the hydraulics of the river under flood conditions.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of light gravel and mud with a large proportion of wooden debris leading in some places to a partial obstruction of the river channel. Therefore, the bed roughness ranges from n= 0.045 to 0.070. Banks are often vegetated with varying vegetation type from light scrub (0.05) to dense trees (0.1) over-hanging the channel. The floodplain is essentially rural where rough pasture (0.045) and wood land (0.08-0.10) are the dominating land types. Estimated roughness values were subsequently modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings (see next section).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by the OPW. The roughness coefficient was the only parameter that was adjusted to achieve a reasonable model fit to the check gaugings. With bed roughness values adjusted to 0.050 a good agreement was found between the modelled water level at the gauging station and the check gauging levels.

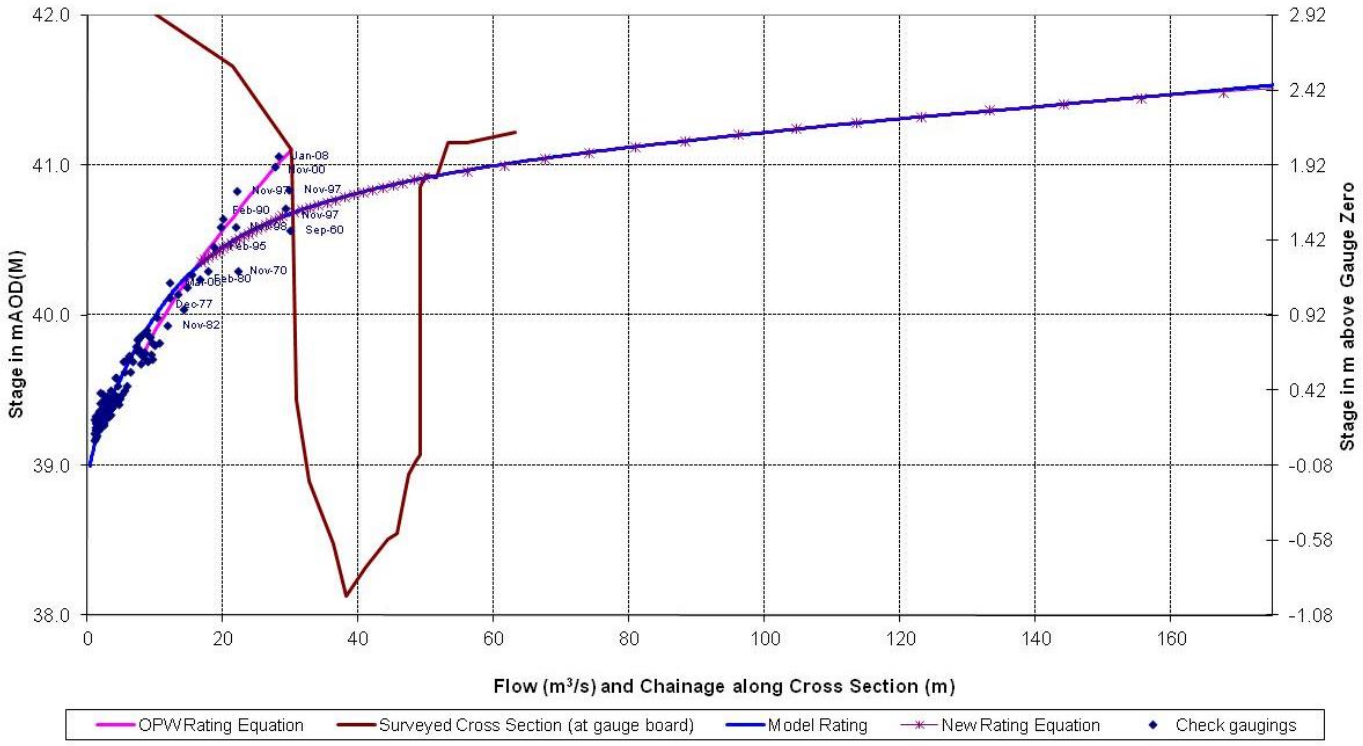
Once calibrated, the hydraulic model has been run with flows ranging from 0.5 to 191 m^3/s using the unsteady state solver in ISIS and a triangular-shaped hydrograph. The model showed no instabilities. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node LBSN01_2051).

Analysis and Results:

The check gaugings at Croghan are scattered around both the OPW existing rating and the model rating. There is no evidence of a change in datum at this site. However, there is evidence from the site visit and from OPW that the banks have over-hanging vegetation which affects river flows and the site suffers from debris build-up and sedimentation which results in blockages. There is no obvious seasonal pattern in the check gaugings. The rating equation at this site has frequently been reviewed and revised due to sedimentation, which suggested that the gauging section is unstable

The model rating fits well with check gaugings at low to medium flows (up to approximately 20 m^3/s). However, at high flows the check gaugings are increasingly scattered around the model rating. Check gaugings completed on 9th November 2000 and 22nd January 2008 do not fit well with the model rating, and it is possible that they were completed when there was a downstream blockage leading to a raised stage for the given flow at the gauging location. The OPW rating appears to have been created with the upper limit based on the November 2000 and January 2008 gauging and therefore deviates significantly from the model rating.

A new set of rating equations have been derived for high flows in compliance with BS ISO 1100-2 and should be used to derive flows from 2001 onwards. It was not deemed appropriate to revise the rating prior to 2001 due to numerous ratings applied in this period, reflecting continuous changes in the flow-level relationship at this site. It is therefore recommended that the existing OPW AMAX series prior to 2001 (excluding the 1996 and 2000 AMAX) and the revised AMAX series post- 2001 is used to estimate QMED at this site. However, it is not recommended that this data be used for flood frequency analysis.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) for a cross-section at the stilling well. A set of rating equations have been established based on the results from the model and indicate a good fit with the modelled rating in the stage interval 1.269<W<2.450 m.

The model rating fits well with the check gauging up to medium flows, but there is significant scatter to the check gaugings at high flows. Due to the instable nature of the site the existing OPW AMAX series prior to 2001 (excluding the 1996 and 2000 AMAX) and the revised AMAX series post- 2001 can be used to estimate QMED at this site. This site should not be used for flood frequency analysis.

The high flow rating has been developed based on the current geomorphology of the site and can be apply to the site at present but not past.

It is suggested that the rating at this site is frequently reviewed and altered as necessary. It is also recommended that further high flow check gaugings are completed to verify the upper limit of the model rating and help to reduce any uncertainty in the high flow model rating.

25022 – CAMCOR AT SYNGEFIELD

Date of data collation: 11/01/2012, completed 26/02/2014

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

Syngefield gauging station is located on the right bank of the River Camcor about 27m downstream of Springfield Bridge. The gauging station was installed in 1953, but the site was moved downstream in 1975. There is a pumping station upstream of Springfield Bridge taking negligibly small rates of flow out of the river. The gauging station has a natural channel control. There is negligible weed growth at this site. Site observations confirmed the channel to be deeper than on other locations along the river.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	207996, 204655	**Period of Record**	1953-2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 1.2 m (~10 m^3/s; pre-rating review)

QMED synthetic	25.5 m^3/s
QMED (AMAX, pre rating review)	26.3 m^3/s (57 years)

Gauge Zero (from operator)	58.30 mAOD (P)
Gauge Zero (from survey)	55.56 mAOD (M)

Revised Rating Equations:

Q = 7 (W-0.05)^1.804	for the range: 0.050 ≤ W < 0.569 (above Gauge Zero)*
Q = 9.0307 (W+0)^2.42	for the range: 0.569 ≤ W < 0.754 (above Gauge Zero)
Q = 8.4874 (W+0)^2.2006	for the range: 0.754 ≤ W < 1.110 (above Gauge Zero)
Q = 8.7418 (W+0)^1.9174	for the range: 1.110 ≤ W < 1.789 (above Gauge Zero)
Q = 5.2091 (W+0)^2.8061	for the range: 1.789 ≤ W < 1.906 (above Gauge Zero)
Q = 9.2245 (W+0)^1.9199	for the range: 1.906 ≤ W < 2.620 (above Gauge Zero)

The derivation of these equations is detailed below.

* *Existing OPW low-flow rating, slightly extended upwards to intersect with the model rating.*

Hydraulic Model Details:

Model name: 25022_SYNGEFIELD_GS_v9.dat

A one-dimensional hydraulic model of the River Camcor at Syngefield gauging station was built using river survey data collected by CCS Surveying in May 2012 (survey drawings P606-SF-LS-010 to 011 REV1.dwg, P606-SF-XS-001 to 009 REV1.dwg) and ISIS hydraulic modelling software.

The hydraulic model extends from 1728m upstream of Springfield Bridge on the River Camcor (NGR: 209666, 204227) to 1167m downstream of this structure (NGR: 207351, 205397). The gauging station is located 27m downstream of the bridge at ISIS node CMCR01_1125 in the ISIS model.

Springfield Bridge is a 15m long structure which was modelled using ISIS sprung arch and rectangular culvert units between ISIS node CMCR01_1167 and CMCR01_1152. An accommodation bridge was also included in the model at ISIS node CMCR01_0510u using an ISIS Arch bridge unit and a spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of silt, sand with cobbles and stones (n= 0.036). Bank side and floodplain roughness values range from 0.02 (road) to 0.09 (forest) with the majority of the land type being pasture/open land (0.035-0.040).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effect is expected, and the model extends far enough downstream of the gauge to be insensitive to the downstream boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. Initially, model results at the gauging station were slightly under-predicting levels in comparison to the check gauging levels. The bed roughness value was increased to a value of 0.038 following which a good agreement was found between the modelled water level and the check gauging levels.

Once calibrated, the hydraulic model has been run with flows ranging from 0.5 to 104m^3/s using the unsteady state solver in ISIS with a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS node CMCR01_1125).

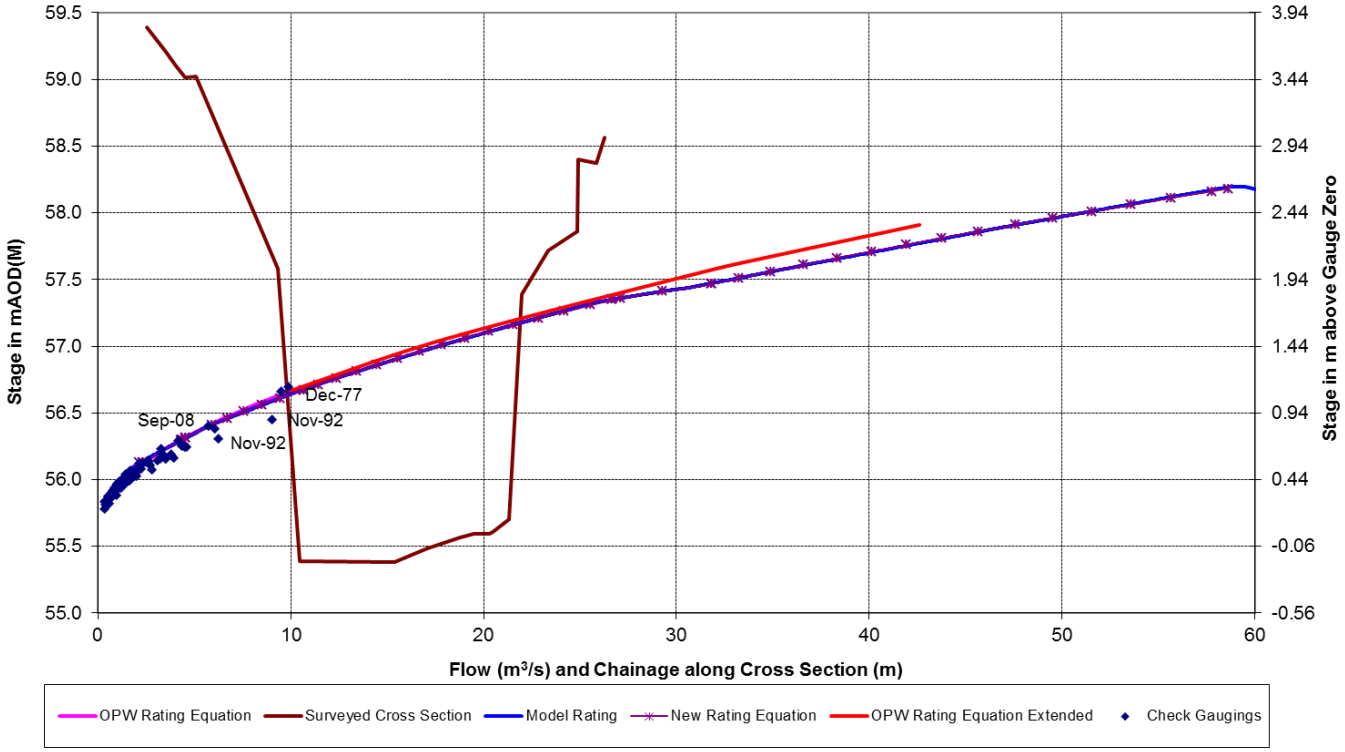
Analysis and Results:

The model rating demonstrates a good relationship with both the check gaugings and OPW's existing rating at low to medium flows. The model rating starts to deviate from the existing extended OPW rating at flows above 27m^3/s (around QMED), but there are no check gaugings to confirm the rating at this point. There is a kink in the model rating at a flow of approximately 59 m^3/s. The model rating equation has been truncated just below this point at 2.62m (57 m^3/s), as there is disproportional uncertainty in the stage-discharge relationship above this level as a consequence of the trans-critical flow. The maximum reliable modelled flow corresponds to 2.4xQMED. A new set of rating equations has been derived for high flows (stage 0.569 to 2.620m) following BS ISO 1100-2, based on the model rating. Although the model rating and the original OPW rating are very similar across the low flow and medium flow range, the model rating does not intersect with the OPW rating at any point, so to avoid jumps in the transition from the low flow (OPW) rating to the high flow (model) rating the model rating was extended downwards until it meets with a slightly extended version of OPW's lowest rating at 0.569m.

The gauging station was moved downstream in 1975 and this resulted in a change in rating and gauge datum. During the period since 1975, the gauge datum has stayed consistent and there have only been minor changes in the rating equation datum shift constant (difference between the stage zero and the cease-to-flow level), which are likely to be related to minor variations in the bed overtime. This suggests that the site has stayed relatively stable since 1975. The model rating can be applied to the AMAX series since the station moved in 1975.

Using the OPW ratings only, there was an apparent drop in the AMAX flow series in 1975 when the gauge was moved. Application of the revised model rating reduces the step change, suggesting that the drop is at least in part due to a poor re-rating for high flows following the move of the gauge. This poor rating would have been caused by the lack of high flow gaugings carried out since the move. OPW and Offally County Council where contacted to investigate whether they knew of any catchment change that could have contributed to the drop in flood peaks. Both sources had no evidence of such catchment change. It is concluded that the AMAX series of before 1975 (using the original OPW ratings) can be retained for QMED estimation and flood frequency analysis.

It is recommended that additional high flow check gaugings are completed to verify the rating for this station.



Conclusions:

A stable model was created, calibrated to observed check gaugings, and run to provide the flow-level relationship (rating) at the stilling well. A rating equation was established, which fits well with the modelled rating in the stage interval 0.569<W<2.620m. Due to the occurrence of a kink in the rating above a flow of 58 m^3/s the model rating equations have only been established up to this point (approximately 2.4xQMED). The resulting rating equation should be used to revise the AMAX series from 1975 to present. As there is no evidence of significant catchment change the whole AMAX series (existing OPW AMAX 1953 to 1974 and revised AMAX series 1975 to 2009) can be used for QMED estimation and flood frequency analysis.

It is recommended that further medium and high flow check gaugings are completed to verify the rating at this station.

25024 – LITTLE BROSNA AT NEW BRIDGE

Date of data collation: 11/01/2012, completed 09/05/2014

Introduction:

High flow rating reviews have been undertaken for 42 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The recorder is located just upstream of a five arch road bridge on the R438. The river flows around a sharp right bend upstream of the gauge. The channel downstream of the gauge is straight. The Jacobs site visit notes report some vegetation at and downstream of the gauge. The site visit also highlighted the risk of bypassing as there could be some potential for flood flow paths to take water away from the gauging station.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	201702, 209007	**Period of Record**	1973-2010
Existing Rating Curve	No	**Validity / Upper Limit**	N/A

QMED synthetic	50.1 m^3/s
QMED (AMAX, pre rating review)	N/A

Gauge Zero (from operator)	34.83 mAOD (P)
Gauge Zero (from survey)	32.05 mAOD (M)

Revised Rating Equations:

N/A, as described below

Hydraulic Model Details:

The N10 model, which covers the New Bridge gauging station, was used to represent the Little Brosna at the station and produce a flow-stage relationship at New Bridge Gauging Station. Details of the N10 model can be found in Appendix B of the UoM25/26 Hydraulic report.

Hydraulic roughness (Manning's n) values used in the model were originally estimated using site visit and survey information. Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings (see next page).

Floodplain areas were represented in the model using extended cross sections and reservoir units as appropriate.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been attempted using the available check gaugings. However the model rating could not be fit to the medium to high flow check gaugings using realistic calibration parameters.

The uncalibrated hydraulic model has been run using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-stage relationship (rating) has been extracted from the model results at the relevant section.

Analysis and Results:

The model rating could not be calibrated to fit the medium to high flow check gaugings using realistic calibration parameters. It is noted that there have not been any medium to high flow check gaugings since 1955, i.e. for nearly 60 years. Over such time scales it can be expected that the local channel geometry has changed, making it less appropriate to put much trust in the old check gaugings.

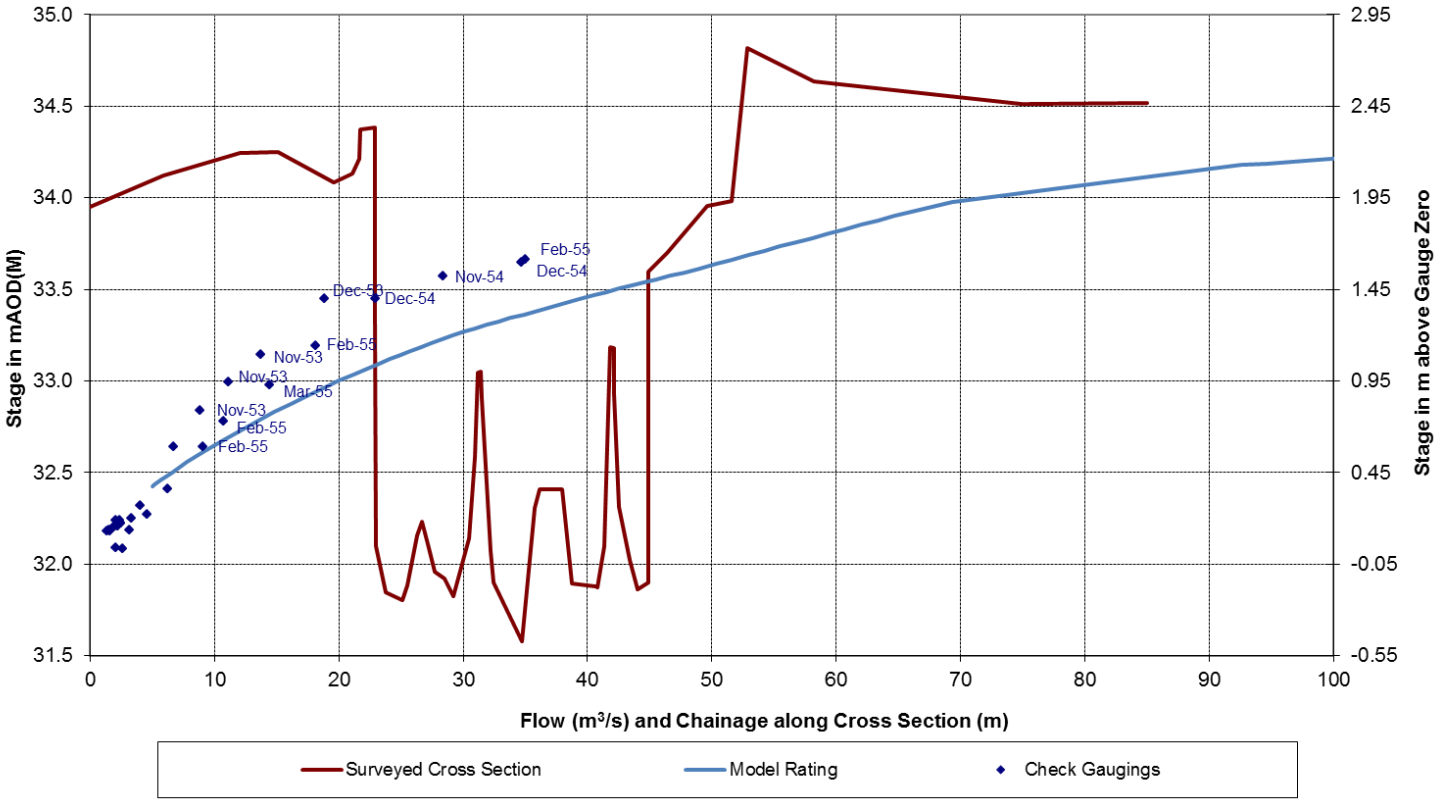
Without recent check gaugings the model rating remains uncalibrated. It is not recommended that the uncalibrated model rating is used for flood flow estimation until some high flow check gaugings have been undertaken.

AMAX levels are only available from 1973 onwards, which is 18 years after the last medium/high flow gaugings were taken. Neither OPW nor Offaly CC could provide information on changes to the gauging station or upstream catchment (e.g. drainage works) from the 1950s, but given the considerable time passed between the check gaugings and the AMAX record it is not recommended that a rating is derived from the check gaugings and applied to any of the AMAX level data.

The Jacobs site visit notes highlighted the risk of bypassing as there could be some potential for flood flow paths to take water away from the gauging station. This could be a contributing factor to the discrepancy between the check gaugings and the model rating as flow measurements taken during floods may not accurately account for floodplain and bypassed flows, whilst the 1D-2D combined model would account for these.

Given the absence of check gaugings over the full period of AMAX records and the discrepancy between the historic check gaugings of nearly 60 years ago and the uncalibrated model rating, it is not considered appropriate to use this station for flood flow estimation.

Additional high flow check gaugings will be required to confirm the rating at this station.



Summary, Conclusions and Recommendations:

A stable model was created and run to provide the flow-level relationship (rating) at a cross section at the gauge. It was not possible to calibrate the model to the available check gaugings using realistic calibration parameters.

As the medium to high flow check gaugings available are nearly 60 years old it is not considered appropriate to use them to establish a rating that represents the condition during the period of AMAX record (1973-present).

Given the absence of check gaugings over the full period of AMAX records and the discrepancy between the historic check gaugings of nearly 60 years ago and the uncalibrated model rating, it is not considered appropriate to use this station for flood flow estimation.

It is recommended that high flow check gaugings are completed to confirm the rating at this station.

25027 – RIVER OLLATRIM AT GOURDEEN

Date of data collation: 20/12/2012 completed 09/10/2013

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the left bank of the River Ollatrim, 5 m upstream of Gourdeen Bridge. The gauging station has a natural channel control and the channel is clear of vegetation. Flow bypassing of the gauging station is considered unlikely due to Gourdeen Road embankment, which is 3 m higher than bank full.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	188689, 179703	**Period of Record**	1962-2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W <1.86m (~22 m^3/s; pre-rating review)

QMED synthetic	20.4 m^3/s (Urban)
QMED (AMAX, pre rating review)	22.4 m^3/s (48 years)

Gauge Zero (from operator)	53.13 mAOD (P)
Gauge Zero (from survey)	50.47 mAOD (M)

Revised Rating Equations:

Q = 7.6732(x+0)^1.6925	for the range: 1.21≤x<1.79 m (above Gauge Zero)
Q = 8.470 (x+0)^1.5187	for the range: 1.79≤x<2.55 m (above Gauge Zero)
Q = 6.7846(x+0)^1.7602	for the range: 2.55≤x<2.97 m (above Gauge Zero)
Q = 15.344(x+0)^1.0117	for the range: 2.97≤x<3.22 m (above Gauge Zero)
Q = 3.987(x+0)^2.1622	for the range: 3.22≤x<3.49 m (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Hydraulic Model Name: Ollatrim_ISIS_V5_cali1.DAT

A one-dimensional hydraulic model of the River Ollatrim near Gourdeen Gauging Station was built using river survey data collected by Murphy Surveys in November 2012 (Survey drawings 4491_25OLLA_OLLATRIM_XS_PLAN, 4491_25OLLA_OLLATRIM_XS_1 to 12, 4491_25OLLA_OLLATRIM__LS_1 to 3) and the ISIS hydraulic modelling software.

The hydraulic model extends from 805 m upstream of the R491-Gourdeen Bridge on the River Ollatrim to 1645 m downstream of the final modelled structure. The gauging station is located 5 m upstream of R491-Gourdeen bridge at ISIS node OLTM01_1640u (Surveyed cross section 25OLLA00172D).

There are a total of three hydraulic structures, including the R491-Gourdeen Bridge, within the model and these were schematised using ISIS arch bridge units and spill units to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of sand, gravel and cobbles (n=0.036 and 0.041). Bank side and floodplain roughness values vary widely from road (0.020) to dense woodland (0.1). However, the majority of the floodplain is designated as pasture (0.035). Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gauging. Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The roughness coefficient was the only parameter that was adjusted to achieve a reasonable fit to the check gaugings. For flows above 10 m^3/s, and with bed roughness values adjusted to 0.042 and 0.046, a reasonable agreement between the modelled water level at the gauging station and the check gaugings was found.

Once calibrated, the hydraulic model has been run with flows ranging from 0.1 to 89 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the rating section (ISIS Node: OLTM01_1640u).

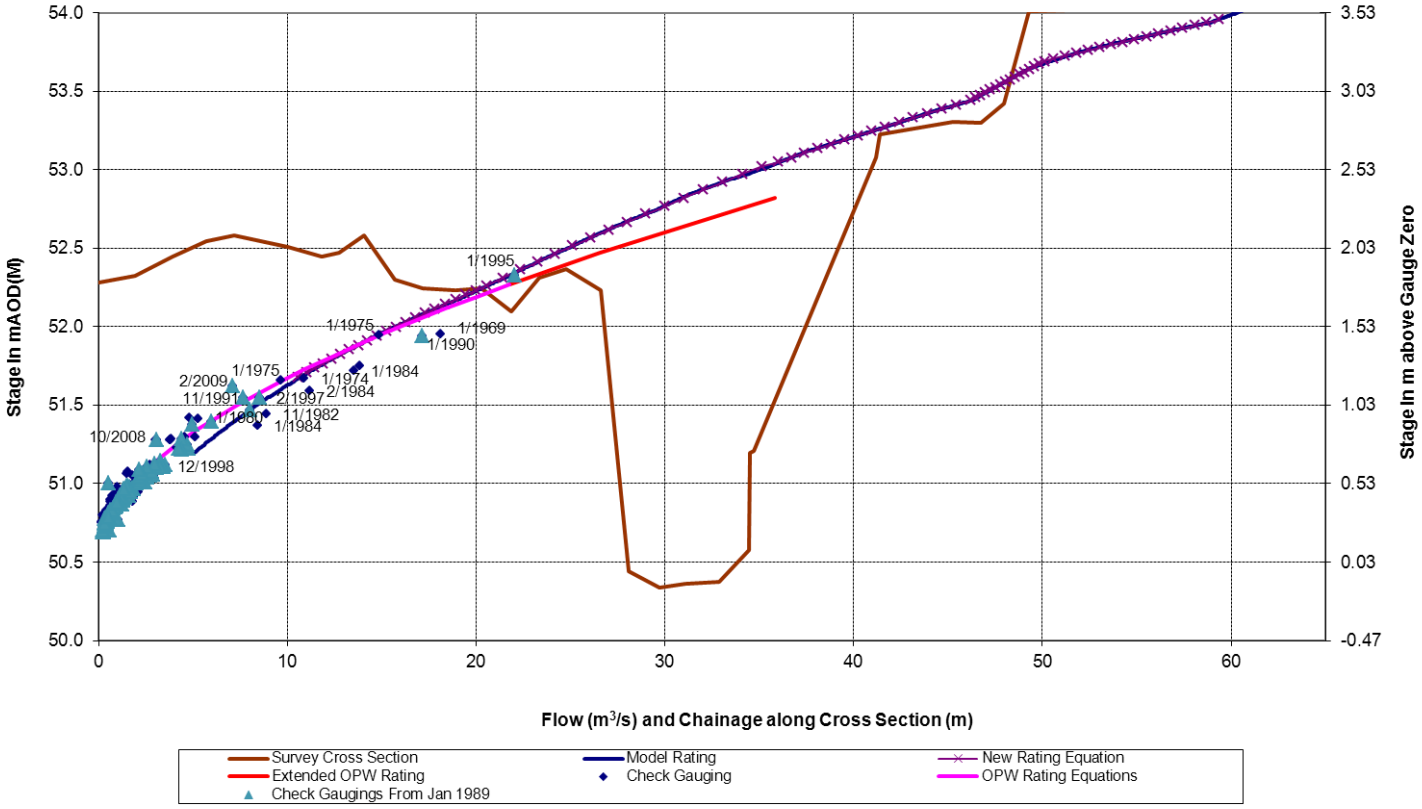
Analysis and Results:

The modelled rating is supported by a good fit with the highest check gauging completed in January 1995. It is noted however that there is considerable scatter in the check gaugings, which suggests an unstable channel or backwater effects, at least for medium flows. There are limited recent high flow check gaugings at Gourdeen, with only the gauging of Jan 1995 near QMED. The considerable scatter for medium flows may be due to local channel changes, as the majority of these were not gauged recently (second highest check gauging recorded in January 1969). Such in-bank changes may not have a large effect on high flows. The model rating deviates from the OPW rating for high flows above QMED. In the high flow range the original OPW rating may overestimate flows for a given stage, with the variance increasing with stage.

The site experienced drainage works from 1955 to 1965. It is thought that the drainage works may have resulted in a catchment change as the ARTDRAIN2 parameter (the percentage of the river network in a catchment that is affected by drainage works) is 48%. Therefore it is recommended that the AMAX flow data from 1962 to 1965 is not used for QMED estimation or flood frequency analysis.

There has been a large number of rating adjustments since the drainage works, in response to the variation in check gaugings. Therefore, it is suggested that the new rating equations that has been derived for high flows following BS ISO 1100-2, should only be applied to the AMAX series from 1989, when the penultimate rating adjustment was completed, which is similar to the last rating of 2001.

It is recommended that the existing OPW AMAX series from 1966 (end of the drainage works) to 1988 and the revised AMAX series from 1989 is used for QMED estimation and flood frequency analysis. The revised estimate of QMED (22.2 m^3/s) differs insignificantly from the original OPW estimate of QMED. However the revised rating has a significant effect on AMAX flow estimates above QMED.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section at the stilling well. A set of rating equations was established to give a good fit with the modelled rating in the stage interval 1.21<W<3.49 m.

It is recommended that the existing OPW AMAX series from 1966 (end of drainage works) to 1988 and the revised AMAX series from 1989 is used for QMED estimation and flood frequency analysis. The revised estimate of QMED (22.2 m^3/s) differs insignificantly from the original OPW estimate of QMED. However the revised rating has a significant effect on AMAX flow estimates above QMED.

As there is only one check gauging within the range of QMED, and none higher, it is recommended that further high flow check gaugings are undertaken to confirm the rating in that range.

25029 – NENAGH AT CLARIANNA

Date of data collation: 12/04/2013, completed 31/05/2013

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank of the River Nenagh, 28 m downstream of the Clarianna Road Bridge. The gauging station is an automated velocity-area station installed in 1957, with a natural channel control. The channel in the vicinity of the gauge is subject to weed growth. There is potential for out-of-bank flows during very high flows events.

Gauging Station Details:

Station Type	Recorder
Coordinates	187234, 180436
Existing Rating Curve	Yes

Gauging Authority	OPW
Period of Record	1972-2008
Validity / Upper Limit	W < 2.3 m (~16 m^3/s; pre-rating review)

QMED synthetic	59.2 m^3/s
QMED (AMAX, pre rating review)	56.5 m^3/s (37 years)

Gauge Zero (from operator)	44.54 mAOD (P)
Gauge Zero (from survey)	41.92 mAOD (M)

Revised Rating Equations:

Q = 17.642 (W+0)^1.61 for the range: 1.43≤W<2.19 m (above Gauge Zero)
Q = 1.1284 (W+0)^5.079 for the range: 2.19≤W<2.74 m (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Name: 25029_Clarianna_ISIS_V7.DAT

A one-dimensional hydraulic model of the River Nenagh near Clarianna Gauging Station was built using river survey data collected by Murphy Surveys in July 2012 (Survey drawings 4491_25NENA_B_NENAGH_B_XS_PLAN, 4491_25NENA_B_NENAGH_B_XS_1 to 9, 4491_25NENA_B_NENAGH_B_1 to 2) and ISIS hydraulic modelling software.

The hydraulic model extends from 2448 m upstream of the Clarianna Bridge on the River Nenagh (NGR: 187234 180436) to 2321 m downstream of the structure (NGR: 184314 182778). The gauging station is located approximately 28 m downstream of Clarianna Bridge at ISIS node NENA01_2269.

There are a total of three hydraulic structures included in the model: Clarianna Bridge, Nenagh Bridge and N52 Bridge. These were schematised using ISIS Arch Bridge units and spill units to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using survey and site visit information. The river bed consists mainly of natural sand with cobbles and large stones (n=0.041). Bank side and floodplain roughness values vary widely as the main river runs across different types of land. Typical roughness coefficient ranges from 0.02 (road), 0.035 (pasture, short grass), 0.06-0.08 (medium-dense vegetation) to 0.10 (buildings, wooded land).

Floodplain areas were represented in the model using mostly extended cross sections as deemed appropriate.

A parallel channel is provided between ISIS nodes NENA01_4204 and NENA01_3586 to model a potential flood route on the right bank floodplain by-passing both the N52 and Nenagh Bridges.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gaugings provided by OPW. The original roughness and spill unit coefficients indicated an acceptable agreement between the modelled water level at the gauging station and the check gauging level.

Once calibrated, the hydraulic model has been run with flows ranging from 1 to 230 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed minor instabilities and a small degree of hysteresis around 65 m^3/s but these were deemed acceptable. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node NENA01_2269).

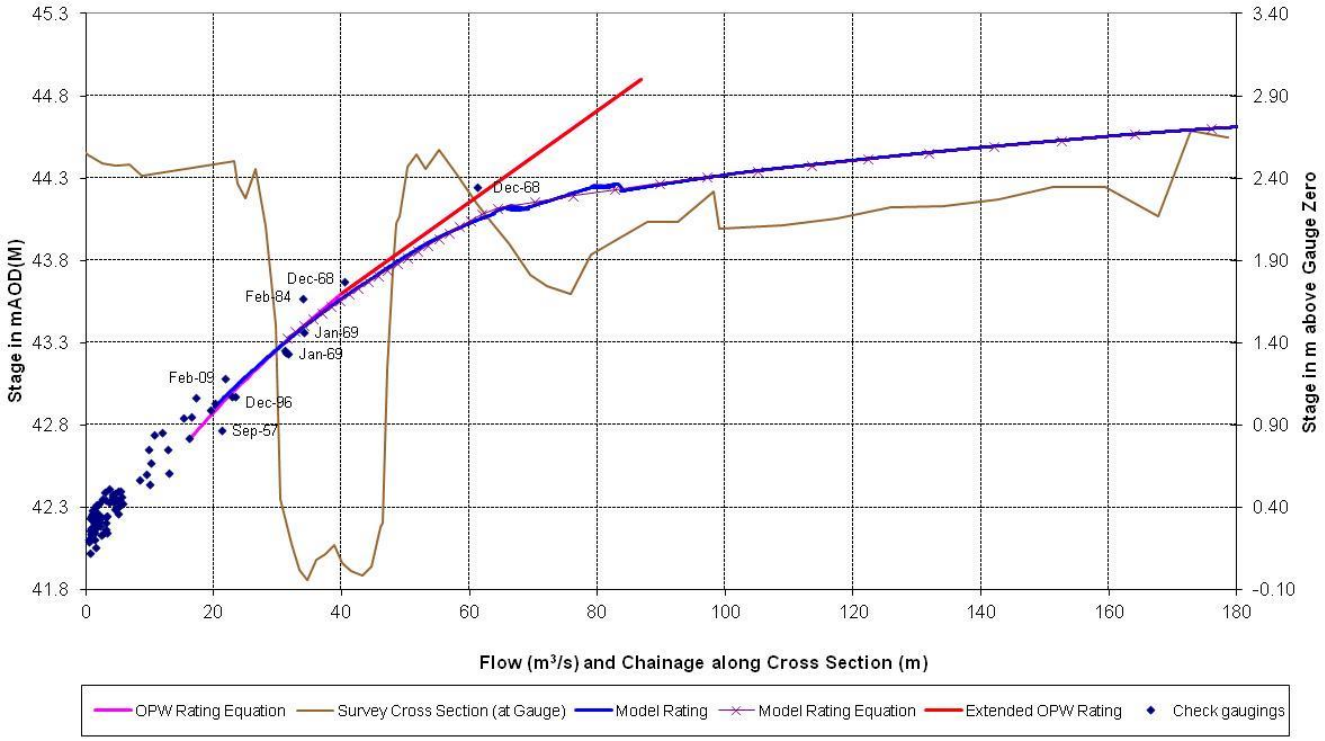
Analysis and Results:

The model rating has a good fit with the check gaugings across the medium flow range up to 40-50 m^3/s, although the check gaugings show some scatter. The gauging with the highest deviation is the high flow gauging of December 1968. It would appear that this check gauging was undertaken while the site experienced shallow floodplain flooding. It is possible that the flow calculation does not include or underestimates the flow through the floodplain, which is a common problem. Blockages at the downstream bridge and/or potential level measurement difficulties during high flows may also have occurred. However, there is no evidence to confirm any of these suggestions.

A new set of rating equations have been derived for high flows following international standards (ISO 1100-2). It should be noted that the existing OPW rating was only derived up to a stage of 1.5 m.

It is not proposed that the model rating is adopted at this stage because the only high flow gauging of Dec 1968 supports the original OPW rating and not the model rating. It is recommended that the original AMAX series is retained. QMED therefore remains unchanged.

Further high flow check gaugings will be required to confirm the rating.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) for a cross section at the stilling well. A set of rating equations was established following BS ISO 1100-2 and reflect a good fit with the modelled rating in the stage interval 1.43<W<2.74 m. The revised model rating differs considerably from the original OPW rating at high flows.

It is not proposed that the model rating is adopted at this stage because the only high flow gauging available (of Dec 1968) supports the original OPW rating and not the model rating. The AMAX series and the estimate of QMED therefore remain unchanged.

Further high flow check gaugings will be required to confirm the rating.

26001 – SHIVEN AT BALLINAMORE

Date of data collation: 13/01/2012 **completed:** 26/09/2012.

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

Gauging station is located off the road R363 on the left bank of the river Shiven, approximately 0.3 km upstream of the R363 road bridge. The gauging station is natural channel controlled and is clear of vegetation. Flow bypassing is considered unlikely due to the high road embankment.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	175752, 248877	**Period of Record**	1946-2006 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.4 m (40 m^3/s)

QMED synthetic	30.4 m^3/s
QMED (AMAX, pre rating review)	36.4 m^3/s

Gauge Zero (from operator)	47.10 mAOD(P)
Gauge Zero (from survey)	44.48 mAOD(M)

Revised Rating Equations:

Q =4.3351(W+0)^2.7906 for the range: 1.82<x<3.12m
Q =1.0089(W+0)^4.0788 for the range: 3.12≤x<3.37m

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Name: 26001_BALLINAMORE_GS_C7.DAT.

A one-dimensional hydraulic model of the River Shiven at Ballinamore gauging station was built using river survey data collected by Murphy Surveys in December 2011 (survey drawings 4281_26SHRI_BALLINAMORE_XS_PLAN, 4281_26SHRI_BALLINAMORE_XS_1, 4281_26SHRI_BALLINAMORE_XS_2, 4281_26SHRI_BALLINAMORE_XS_3, 4281_26SHRI_BALLINAMORE_XS_4, 4281_26SHRI_BALLINAMORE_XS_5, and 4281_26SHRI_BALLINAMORE_LS_1) and ISIS one-dimensional hydraulic modelling software developed by Halcrow.

The hydraulic model extends from 2025m upstream of the R363 Road Bridge (NGR: 174153, 248967) on River Shiven to 2175m downstream of the structure (NGR: 177708, 248679). The gauging station is located approximately 250m upstream of the bridge at cross section SHVN01_2423 in the ISIS model.

The R363 Road Bridge was schematised using an ISIS USPBR bridge unit and a spill unit to allow for bridge overtopping. Farmers Bridge and Ballina Lass Bridge located downstream of the former structure were modelled using ISIS Arch bridge units and spill units to allow for bridge overtopping

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of sand, gravel and cobbles (n=0.036). Bank side and floodplain roughness values range from 0.035 (grass) to 0.060 (dense vegetation).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

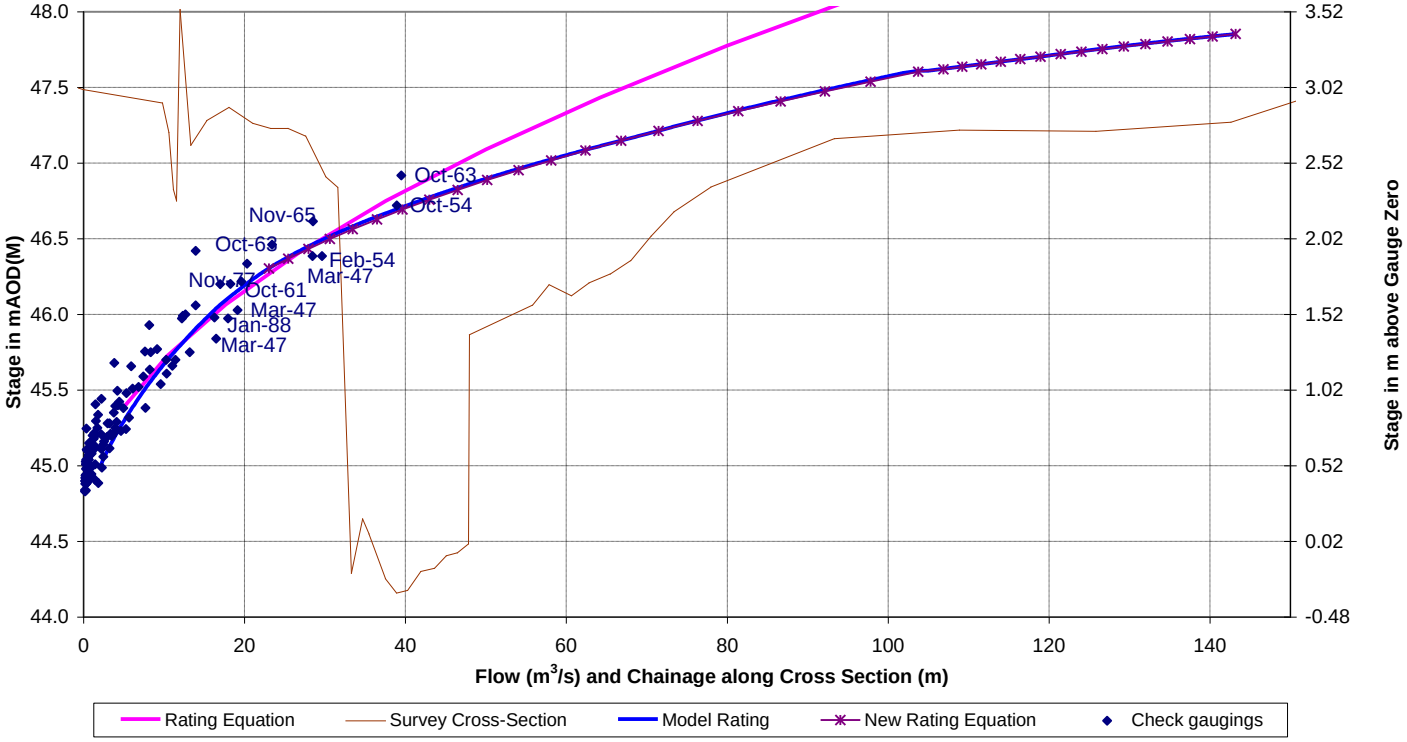
Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The gauging station is natural channel controlled so the bed roughness coefficient was increased from 0.036 to 0.045 and a good agreement was found between the modelled water level at the gauging station and the check gauging levels.

Once calibrated, the hydraulic model was run with flows ranging from 0.5 to 144 m^3/s using the unsteady state solver in ISIS and triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating) has been extracted from the model results at the gaugeboard (ISIS node: SHVN01_2423).

Analysis and Results:

The check gaugings show considerable scatter which raises doubts about the reliability of any rating at this station. The model rating shows a good fit through the cloud of check gaugings, although there is a need for more high flow gaugings as the latest available mid/high flow check gaugings are from the 1950s and 60s. The model rating and the latest OPW rating experience a similar trend up to a flow of 30 m^3/s approx., above which the two ratings deviate significantly. Where the cross section widens the OPW rating appears to be too steep with little change in the slope of the curve. A new set of rating equations has been derived for high flows based on BS ISO 1100-2.

The AMAX level series shows a step change (and 2 year gap) in the values around 1970, suggesting a local change. This step change is not reflected in the rating history. It is therefore recommended that AMAX data from before 1970 is not used or used with great care. Based on the revised rating and AMAX data from 1972 (the first year after the gap in the data) only, QMED increases to 51 m^3/s (compared with 36 m^3/s based on the latest and historic OPW ratings).



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section very close to the gauge board. A set of rating equations was established to give a good fit with the modelled rating in the stage interval 1.82<W<3.37 m.

The AMAX level series shows a step change (and 2 year gap) in the values before and after 1970, suggesting a local change. This step change is not reflected in the rating history. It is therefore recommended that AMAX data of before 1970 is not used or used with great care. Based on the revised rating and on AMAX data from 1972 (the first year after the gap in the data) only, QMED increases from 36 to 51 m^3/s.

It is recommended that OPW carry out check gaugings during high flows to validate the new rating, as there have not been any high flow gaugings since the 1960s.

26002 – SUCK AT ROOKWOOD

Date of data collation: 13/01/2012, completed 21/10/2013.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank of the River Suck. Downstream and upstream of the gauging station, the channel is bifurcated, but acts as one channel during high flows. The channel has some vegetation, particularly upstream of the gauging station, which is overgrown.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	180656, 257075	**Period of Record**	1952 – 2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W< 2.5 m (~88 m^3/s; pre-rating review)

QMED synthetic	59.8 m^3/s
QMED (AMAX, pre-rating review)	56.6 m^3/s (58 years)

Gauge Zero (from operator)	47.98mAOD(P)
Gauge Zero (from survey)	45.20mAOD(M)

Revised Rating Equations:

Q = 8.685 (W+0)^0.4175	for the range: 0.07≤W<0.30m (above Gauge Zero)
Q = 16.788 (W+0)^0.9565	for the range: 0.30≤W<0.57m (above Gauge Zero)
Q = 22.568 (W+0)^1.4655	for the range: 0.57≤W<1.37m (above Gauge Zero)
Q = 19.559 (W+0)^1.9386	for the range: 1.37≤W<1.87m (above Gauge Zero)
Q = 13.407 (W+0)^2.5515	for the range: 1.87≤W<2.78m (above Gauge Zero)

The derivation of these equations is shown below.

Hydraulic Model Details:

Model Name: 26002_ROOKWOOD_GS_V8.DAT

A one-dimensional hydraulic model of the River Suck near Rookwood gauging station was built using river survey data collected by Murphy Surveys in May 2012 (survey drawings (4281_26SUCK_ROOKWOOD_XS_PLAN, 4281_26SUCK_ROOKWOOD_XS_1 to 6, 4281_26SUCK_ROOKWOOD_LS_1 and 4281_26SUCK_ROOKWOOD_LS_2) and the ISIS hydraulic modelling software.

The hydraulic model extends from 2045m upstream of Rookwood Bridge (NGR: 179869, 258892) on the River Suck to 4977m downstream of Rookwood Bridge (NGR: 180406, 255310). The gauging station is located approximately 450m downstream of the bridge at node SUCK01_3526 in the ISIS model. Rookwood Bridge is the only hydraulic structure included in the model (ISIS node SUCK01_4977u) and was schematised using ISIS arch bridge unit and spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consist mainly of silt, gravel and cobbles (n= 0.039). Bank side and floodplain roughness values vary widely from 0.02 (road) to 0.1 (dense woodland). However, the majority of the floodplain is designated as bog (0.030), pasture (0.035) or dense woodland (0.1). Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings.

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effect is expected, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The gauging station has a natural channel control so the roughness coefficient was the only parameter that was adjusted to achieve a reasonable fit to the check gaugings. With bed and bank roughness values ranging from 0.039 to 0.10 (very dense vegetation near the stilling well) a good agreement was found between the modelled water level at the gauging station and the check gauging levels.

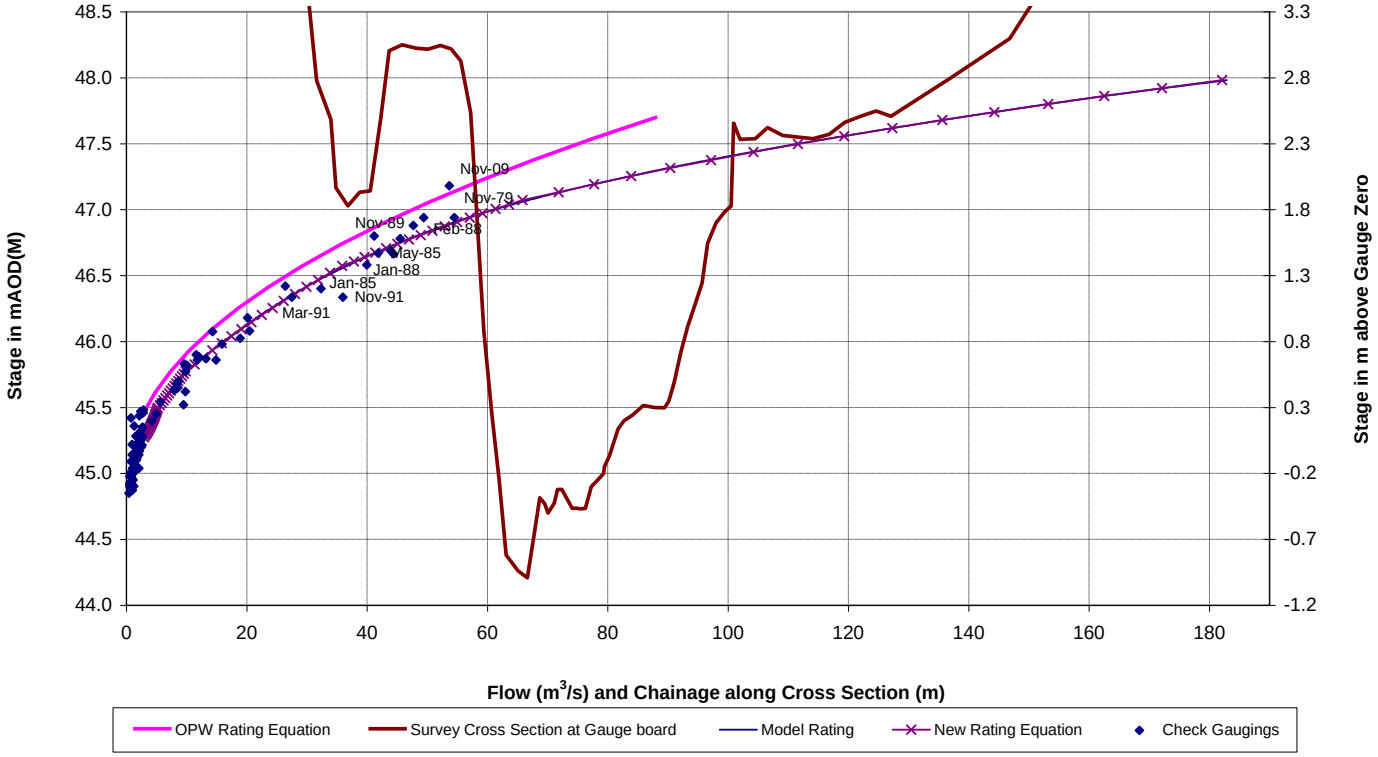
Once calibrated, the hydraulic model has been run with flows ranging from 0.6 to 237 m3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node: SUCK01_3526).

Analysis and Results:

Check gaugings undertaken before 28th July 1976 have been excluded from the plot below as OPW's RBD Shannon Data Summary.xls spreadsheet indicated that dredging work was completed in July 1976 and the station data set was split with one series before the dredging and one series after. The aforementioned spreadsheet indicates that no drainage works were carried out in the upstream catchment, and the FSU catchment descriptor ARTDRAIN2 to the station is 0 (zero), suggesting that the dredging work of 1976 was local instead of relevant on a catchment scale. Check gaugings recorded since the dredging (post July 1976), represent a relatively good fit around the model rating. There is some scatter in the check gaugings, which could be linked to the comment in the RBD Shannon Data Summary.xls spreadsheet that the site can be difficult to gauge. It is noted that the check gauging recorded in November 2009 lies well above the model rating. OPW were consulted on this check gauging and confirmed that the gauging was not suspect in their view. OPW did however explain that they were not able to visit the site for this check gauging as the station was not accessible during the flood. The gauging was completed by measuring the flow from a bridge at Athleague and the water level was taken from the telemetry data. The bridge at Athleague is approximately 8 km upstream of the gauging station and as a consequence, there could be a discrepancy between the flow at the bridge and the flow at the gauging station at the time of the gauging. As the station was not visited, it was not possible to identify the influence of any downstream conditions such as backwater effects or any instrument drift. These factors could explain or contribute to the deviation of the Nov 2009 check gauging from the model rating. Another contributing factor could be hysteresis. This mechanism is most prominent in watercourses with a shallow gradient, and the Suck at this station has a very shallow gradient (the catchment slope descriptor S1085 is approximately 0.6 m/km, and locally the gradient may be much lower).

The historic ratings at the site have been analysed. The latest OPW rating appears to have been fitted to the potentially suspect November 2009 gauging and not through the majority of the check gauging, unlike the older ratings at this station. The model rating has a good relationship with the check gaugings and the OPW rating derived for the period 1978-1988. The only changes in the ratings between 1976 and present have been slight adjustments of the datum shift constant, with the adjustment more significant for the rating from 1996 to present. The changes in the datum shift constant may be a result of local erosion and deposition, the effects of which would diminish with higher flows.

A new set of rating equations, based on the model rating, have been derived for high flows following BS ISO 1100-2. As the rating at the site has stayed relatively consistent from 1976 to 1996, and the larger rating change in 1996 was only to fit the model rating to the potentially incorrect gauging in Nov 2009, it is concluded that the revised rating can be applied to all AMAX values since 1976. As there is no evidence of significant catchment change, the whole AMAX series (using the OPW existing AMAX values from 1952 to 1976 and the revised rating from 1976) can be used for QMED estimation and flood frequency analysis.



Conclusions:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) for a cross section at the stilling well. A set of rating equations have been established based on the results from the model and indicate a good fit with the modelled rating in the stage interval 0.07<W<2.78m. The revised rating differs from the latest OPW rating, but is similar to OPW ratings adopted from 1976 to 1996. The AMAX series since the dredging in 1976 has been revised. The existing OPW AMAX flows from 1952 to 1975 and the revised AMAX flows from 1976 can be used for QMED estimation and for flood frequency analysis.

It is recommended that more high flow check gaugings are conducted to confirm the rating.

26004 – ISLAND AT BOOKALA

Date of data collation: 13/01/2012, completed 14/11/2012.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the upstream face of the road bridge at Bookala on the left bank. The gauging station has a natural control. The channel is very wide (approx. 30 m) and therefore the natural control would be insensitive to low flows. There was little weed growth in the channel upstream and downstream during the site visit in July 1011, but images from Google streetview indicate that weed growth is a issue downstream of the bridge during the summer months. Flow bypassing of the structure is considered unlikely due to the high road embankment. It was not possible to survey the gaugeboard during the initial survey as the bridge was under-reconstruction, but the surveyor returned to survey the gaugeboard in December 2012. It is believed that the alterations to the bridge have been minor and have not altered positioning of the piers within the water course.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	166254, 272967	**Period of Record**	1972 -2009 (level only)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.0m (~31 m^3/s; pre-rating review)

QMED synthetic	18.9 m^3/s
QMED (AMAX, pre-rating review)	No flow AMAX series*

*based on the existing OPW rating the Qmed is approx. 14.8 m^3/s

Gauge Zero (from operator)	62.65mAOD(P)
Gauge Zero (from survey)	59.76mAOD(M)

Revised Rating Equation:

Q=11.336 (W+0)^1.5265	for the range: 0.94<W<1.34m (above Gauge Zero)
Q=8.9921 (W+0)^2.3508	for the range: 1.34<W<1.63m (above Gauge Zero)
Q=7.5122 (W+0)^2.7355	for the range: 1.63<W<2.32m (above Gauge Zero)

The derivation of these equations is detailed below:

Hydraulic Model Details:

Model Name: 26004_Bookala_GS_C2.dat

A one-dimensional hydraulic model of the River Island at Bookala gauging station was built using river survey data collected by Murphy Surveying in November 2011 (survey drawings 4281_26ISLE_BOOKALA_XS_PLAN, 4281_26ISLE_ BOOKALA _XS_1 to 4281_26ISLE_ BOOKALA _XS_5, and 4281_26ISLE_ BOOKALA _LS_1) and ISIS hydraulic modelling software.

The hydraulic model extends from 407m upstream of Bookala Bridge (NGR 166146, 272686) on the River Island to 1890m downstream of the bridge (NGR: 167990, 272541). The gauging station is located on the upstream face of the bridge at model node ISLD01_1890u in the ISIS model.

Bookala Bridge and another bridge structure were schematised using ISIS Arch bridge units, at model nodes ISLD01_1890 and ISLD01_1180, respectively. Spill units were used in parallel to the bridge units to allow for overtopping of the structure at very high flows.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of sand, cobbles, gravel and stones (n=0.040). Bank side and floodplain roughness values vary according to the land type: 0.020 for roads, 0.035 for pasture and 0.1 for buildings. Roughness values were then modified at calibration stage, within acceptable limits, to achieve a best fit to the available check gaugings (see next page).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effect is expected, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

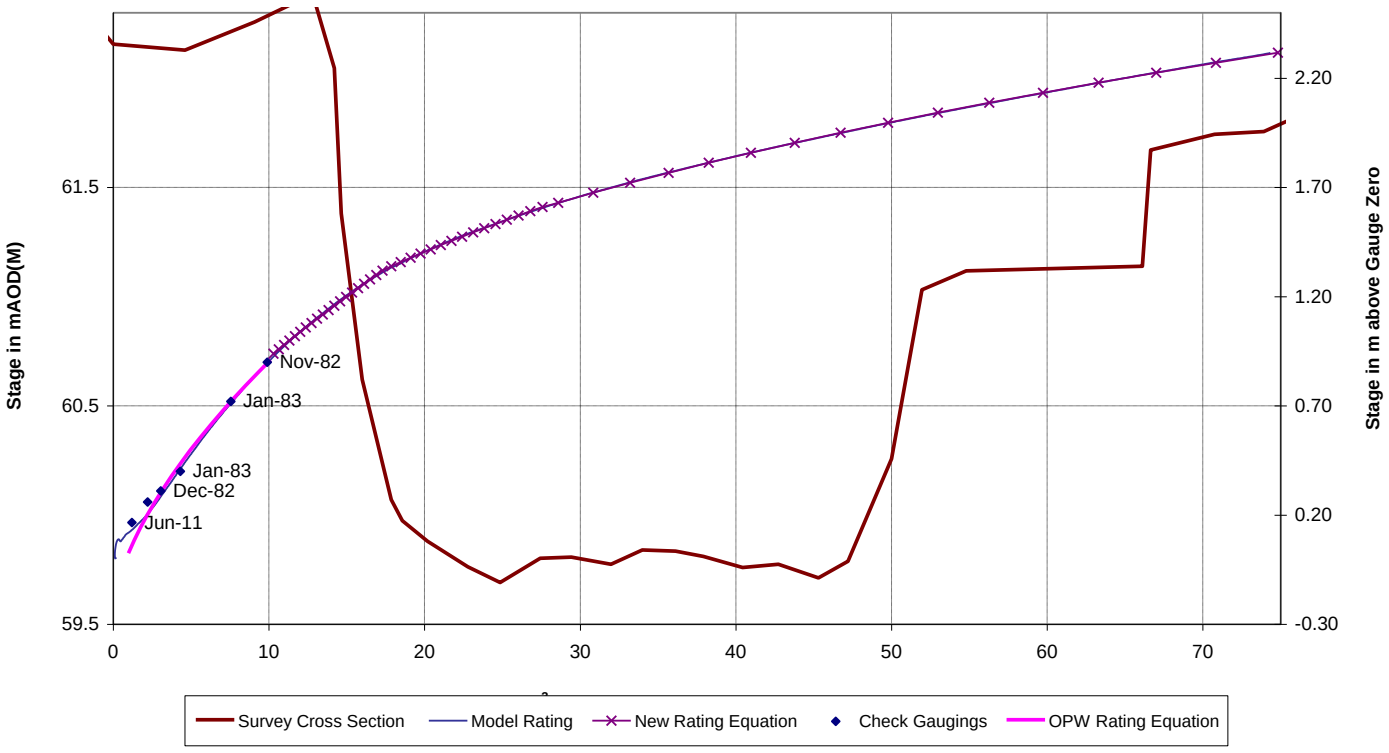
Calibration of the hydraulic model has been carried out using the available check gaugings, however there are only seven check gaugings that can be used (since drainage works) and they are not greater than the Qmin, which has implication on the certainty of the rating. The bed roughness coefficient (0.040) has been gradually varied to achieve a best fit (0.048) between the modelled water level and the check gaugings.

Once calibrated, the hydraulic model has been run with flows ranging from 0.2 to 75.0 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating) has been extracted from the model results at the gauging station location (model node ISLD01_1890).

Analysis and Results:

The check gaugings provided by OPW reveal a clear datum shift around 1982 which can primarily be attributed to drainage works. Therefore check gaugings and level AMAX values collected prior to 1982 have been excluded. Check gaugings collected since 1982 have been recorded during relatively low flows and are of little use for flood estimation purposes.

A new set of rating equations has been derived for high flows following BS ISO 1100-2 There is no existing rating and AMAX flow series at this site.



Conclusions and recommendations:

A stable model was created, calibrated to observed check gaugings (at lower flows only) and run to provide the flow-level relationship (rating) at a cross section at the gauge. A set of rating equations were developed which have a good fit with the modelled rating in the stage interval 0.91<W<2.3m. As there are only low flow check gaugings the accuracy of the model rating cannot be verified for high flows. There is no existing rating and AMAX flow series at this site.

It is recommended that high flow check gaugings are completed to verify the accuracy of the model rating.

26005 – SUCK AT DERRYCAHILL

Date of data collation: 16/01/2012, Completed 11/02/2013.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the left bank of River Suck on the upstream face of Derrycahill Bridge (located at surveyed cross section 26SUCK03396D). The channel is heavily vegetated, however there is still good capacity in the channel. The potential for flow bypassing the station is high. The station is in the floodplain and it is not possible to identify if all flood flows would be picked up by the gauge.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	182557, 242372	**Period of Record**	1954 - 2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.45m (104 m^3/s; pre-rating review)

QMED synthetic	98.8 m^3/s
QMED (AMAX, pre-rating review)	88 m^3/s (56 years)

Gauge Zero (from operator)	42.66mAOD(P)
Gauge Zero (from survey)	39.87 mAOD (M)

Revised Rating Equations:

Q = 4.80 (W+0.55)^2.7 for the range: 1.66<W<3.90m (above Gauge Zero)*

*Existing OPW Rating
The derivation of these equations is shown below.

Hydraulic Model Details:

Model Name: Derrycahill_SUCK_ISIS_V10.DAT

A one dimensional hydraulic model of the River Suck at Derrycahill gauging station was built using river survey data collected by Murphy Surveys in May 2012 (survey drawings 4281_26SUCK_DERRYCAHILL_XS_PLAN, 4281_26SUCK_DERRYCAHILL_XS_1 to 4, 4281_26SUCK_DERRYCAHILL_LS_1 and 4281_26SUCK_DERRYCAHILL_LS_2) and the ISIS one dimensional hydraulic modelling software.

The hydraulic model extends from 2267m upstream of Derrycahill Bridge (NGR: 184050, 243314) on the River Suck to 1868m downstream of Derrycahill Bridge (NGR: 182904, 240760). The gauging station is located just downstream of the bridge at ISIS node SUCK01_1868d in the ISIS model.

Derrycahill Bridge is the only hydraulic structure included in the model (ISIS node SUCK01_1868u) and it was schematised using ISIS Arch Bridge unit and a spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consist mainly of Sand, silt, gravel with peat (n= 0.035), at some locations channel consists of reeds growing in the channel (n=0.06). Bank side and floodplain roughness values vary widely from 0.02 (Road) to 0.1 (Dense woodland). However, the majority of the floodplain is designated as bog (0.030), pasture (0.035) or dense wood land (0.1). Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings (see next page).

Floodplain areas were represented in the model using extended cross sections and parallel channels as deemed appropriate.

A normal depth boundary unit with user defined bed slope was used as the downstream boundary condition. Bed slope was originally derived using available survey downstream of the model and then adjusted during the calibration process.

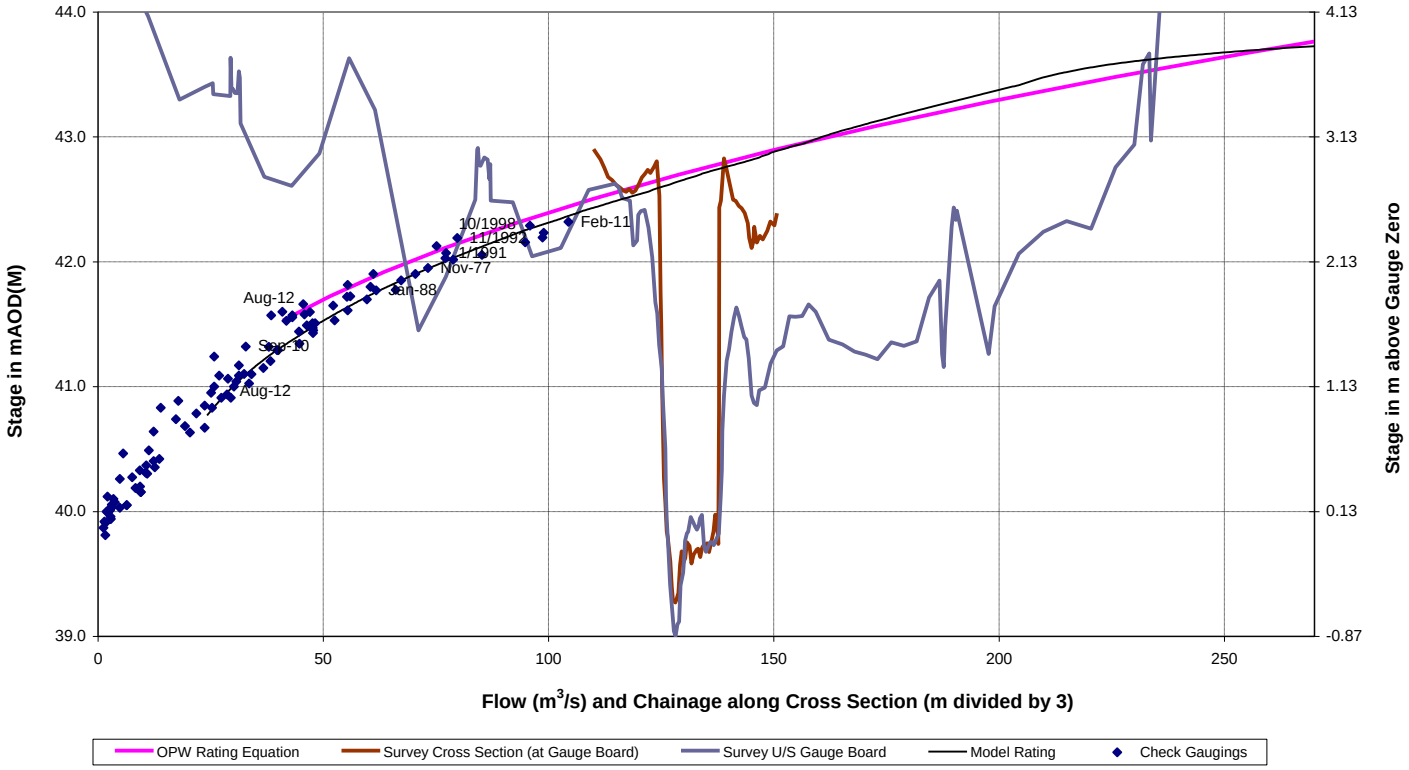
Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the spot gaugings provided by OPW. The roughness coefficient and bed slope at the downstream boundary (due to the flatness of the local river bed) were the parameters adjusted to achieve a reasonable fit to the spot gaugings. With bed and bank side roughness values ranging from 0.035 to 0.10 a good agreement was found between the modelled water level at the gauging station and the spot gauging levels.

Once calibrated, the hydraulic model has been run with flows ranging from 1 to 391 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node SUCK01_1868d).

Analysis and Results:

The model and existing OPW rating are very similar and the check gaugings were scattered around both of the ratings, with more recent gauging in good agreement with the OPW rating. Therefore the OPW rating will continue to be used. A new rating has not been derived and the AMAX series, flood frequency curves, gauging station summary sheets will not be altered.



Conclusions:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section at the gauge board. However, the OPW rating showed a good agreement with the model rating for high flows, and with more recent check gaugings. It is therefore not considered necessary to revise the AMAX flow series.

26006 – SUCK AT WILLSBROOK

Date of data collation: 16/01/2012, Completed 18/10/2012.

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

At Old Castlerea Road Bridge over the River Suck. Gauging station is located on the left bank of the river, just upstream of the two road bridges. The gauging station is structure controlled and the channel is clear of vegetation. Flow bypassing the structure is considered unlikely due to the high road embankment.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	169281, 275594	**Period of Record**	1952-2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 3.0 m (~59 m^3/s; pre-rating review)

QMED synthetic	25.3 m^3/s
QMED (AMAX, pre-rating review)	26.8 m^3/s (58 years)

Gauge Zero (from operator)	61.40mAOD(P)
Gauge Zero (from survey)	58.61m AOD (M)

OPW Rating (retained):

Q=3.7*(w+0.12)^1.95	for the range: 1.72<W<2.05m (above Gauge Zero)
Q=4.7*(w+-0.45)^2.71	for the range: 2.05<W<3.29m (above Gauge Zero)

Hydraulic Model Details:

Model Name: 26006_Willsbrook_GS_C1.dat.

A one-dimensional hydraulic model of the River Suck near Willsbrook was built using river survey data collected by Murphy Surveys in February 2012. Refer to survey drawings (4281_26SUCK_WILLSBROOK_XS_PLAN, 4281_26SUCK_WILLSBROOK_XS_1,4281_26SUCK_WILLSBROOK_XS_2,4281_26SUCK_WILLSBROOK_XS_3, 4281_26SUCK_WILLSBROOK_XS_4 and 4281_26SUCK_WILLSBROOK_LS_1) and the ISIS hydraulic modelling software.

The hydraulic model extends south from Castlerea to about 4000m downstream (NGR: 170457, 274265). The gauging station is located at chainage SUCK01_1980u in the hydraulic model. The rating curve was extracted from the model at the closest surveyed section (chainage 1980m) in the hydraulic model. The structures at chainage SUCK01_1954 & SUCK01_1980 are schematised using Arch Bridge units and spill units to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consist mainly of silt, gravel and cobbles (n=0.042). Bank side and floodplain roughness values range from 0.035 (grass/pasture) to 0.080 (woodland dense).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

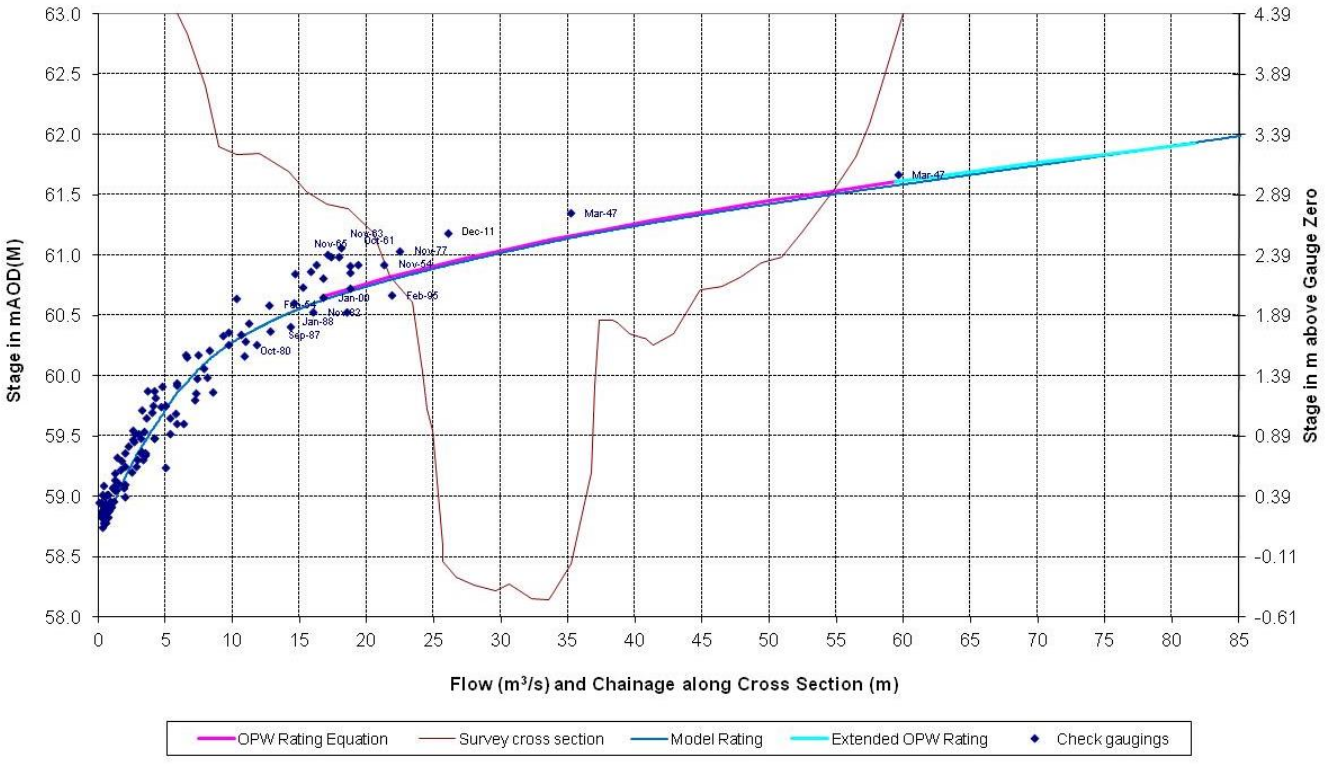
Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The gauging station has a natural channel control so the bed roughness coefficient was gradually varied from 0.042 to 0.045 and a good agreement was found between the modelled water level at the gauging station and the check gauging levels. The check gaugings show considerable scatter in the low and mid-flow range. If this scatter is due to local changes in the river bed and weed growth than it can be expected to reduce for higher flows. Nevertheless, the highest check gauging was taken in 1947 and the high flow rating needs to be confirmed with new check gaugings.

Once calibrated, the hydraulic model has been run with flows ranging from 0.2 to 106 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating) has been extracted from the model results at the rating section (chainage 1980m).

Analysis and Results:

The model rating was compared to the existing OPW rating, which indicated that the two rating are very similar with a difference in flow of less than 1%. The two ratings also have a good relationship with the gaugings throughout the full flow range. We therefore recommend that the existing OPW rating is used and have extended it to a flow of 80 m^3/s (approximately 3xQMED). The AMAX series does not need to be amended for this station.

With the two highest check gaugings originating from 1947 new high flow gaugings are required to confirm the rating. It is noted that there is considerable scatter in the mid-flow range which may affect the accuracy of flow estimates at this station.



Conclusions:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at the gauge board. It was confirmed that the model rating and the existing OPW rating are very similar from 0.8xQMED to 3xQMED, and the OPW rating can be used to an extended upper limit of the local water level of 3.29m (approximately 80 m^3/s). Therefore the AMAX series does not need to be amended for this station.

With the two highest check gaugings originating from 1947 new high flow gaugings are required to confirm the rating. It is noted that there is considerable scatter in the mid-flow range which may affect the accuracy of flow estimates at this station.

26007 – SUCK AT BELLAGILL

Date of data collation: 16/01/2012

Introduction:
For 42 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:
The station is located on the right bank downstream of the road bridge. The bridge has 5 in-channel arches and 4 floodplain arches. The river is straight upstream and downstream of the gauge. The channel has reeds and grass growing in it. In extreme flood events flooding upstream of the road bridge could come out of bank and move through the floodplain and bypass the station, especially on the right bank.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	184175, 234570	**Period of Record**	1952 - 2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.81m (148 m^3/s; pre-rating review)

QMED synthetic	92.5 m^3/s
QMED (AMAX, pre-rating review)	88.2 m^3/s (58 years)

Gauge Zero (from operator)	40.12 mAOD(P)
Gauge Zero (from survey)	37.41 mAOD(M)

Revised Rating Equations:

Q = 16 (W+0.5)^1.726	1.14<W<1.77m*
Q = 12 (W+0.5)^2.205	1.77≤W<2.42m*
Q = 17.5 (W-0.6)^2.70	2.42≤W<3.10m*

* OPW rating retained.

Hydraulic Model Details:

Model Name: 26007_BELLAGILL_GS_C5.DAT

A one dimensional hydraulic model of the River Suck near Bellagill gauging station was built using river survey data collected by Murphy Surveys in May 2012 (survey drawing 4281_26SUCK_Bellagill_V0) and the ISIS one dimensional hydraulic modelling software.

The hydraulic model extends from 2202m upstream of Bellagill Bridge (NGR: 184064, 236378) on the River Suck to 2737m downstream of Bellagill Bridge (NGR: 183774, 232834). The gauging station is located just downstream of the bridge at ISIS node SUCK01_2709d in the ISIS model.

Bellagill Bridge is the only hydraulic structure included in the model (ISIS node SUCK01_2737u) and it was schematised using an ISIS Arch Bridge unit and a spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consist mainly of sand, silt and gravel with peat (n=0.035). At some locations the river has reeds growing in the channel (n=0.06). Bank and floodplain roughness values vary widely from 0.02 (road) to 0.10 (dense woodland). However, the majority of the floodplain is designated as bog (0.030), pasture (0.035) or dense woodland (0.10). Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings (see next page).

Floodplain areas were represented in the model using extended cross sections and parallel channels.

A normal depth boundary unit with user defined bed slope was used as the downstream boundary condition. Bed slope was derived using available survey downstream of the model.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the spot gauging data provided by OPW. Roughness coefficient was adjusted in an attempt to achieve a reasonable fit to the spot gaugings. Even with bed and bank side roughness values increased the model could not produce a good agreement with the check gaugings. Once Model N09 had been constructed the model rating showed a better agreement with the check gaugings, and this model could then be calibrated to optimise the fit with n=… for …, n=… for … and n=… for ….

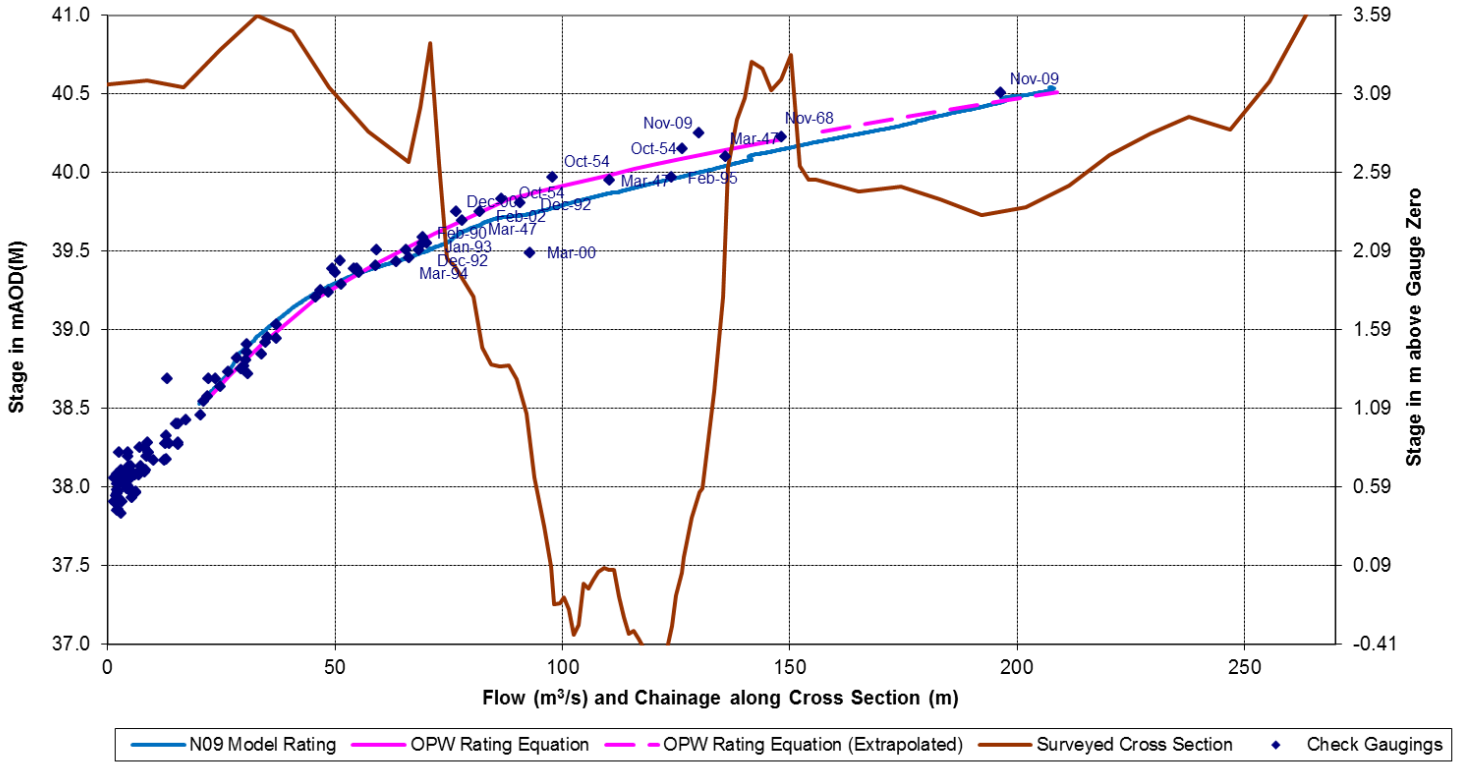
Analysis and Results:

The original hydraulic model produced for Bellagill GS did not show a particularly good fit with the check gaugings. However, when the N09 model was complete (with the detailed gauging station model incorporated in it) this could be adjusted with realistic calibration parameters to show a good fit with the low and medium flow gaugings and the highest check gauging of Nov 2009. The original OPW rating and the model rating have up to approximately 20% difference in flow around QMED. It seems appropriate to retain the original OPW rating for flood estimation given its good fit to a larger range of check gaugings.

Check gaugings have been undertaken up to 196 m^3/s (2.2 x QMED) on 23rd November 2009. The OPW rating was created before the November 2009 event, but shows a good fit with the highest check gauging. This provides considerable confidence in the existing OPW rating up to that flow. It is recommended that the OPW ratings are retained and that the entire AMAX series from 1952 is used for flood estimation. The use of the existing AMAX series means no change in the QMED estimate of 88 m^3/s.

The plot below shows that a check gauging in March 2000 lies below the model and OPW ratings with a considerable margin, which hints at an error in the flow estimate or level reading.

A site visit highlighted that there is some potential for flow bypassing the gauge completely for high flows, and this may have affected the accuracy of the high flow gaugings.



Conclusions:

The hydraulic model produced for Bellagill GS does not show a good fit with the check gaugings. However, the N09 model (which incorporates the Bellagill GS model features) could be calibrated to show a good agreement with the check gaugings, especially in the low/medium flow range and for the highest gauged flow. In the flow range around QMED the original OPW rating shows a better fit with the check gaugings than the model rating. The OPW rating is therefore considered sufficiently reliable to be used for flows up to the highest check gauging (2.2 x QMED). The use of the existing AMAX series (applied to the entire AMAX series from 1952) means no change in the QMED estimate of 88 m^3/s.

Flows have the potential to bypass the gauging station during floods. Bypass flows should be considered when high flow check gaugings are undertaken.

26008 – RINN AT JOHNSTON'S BRIDGE

Date of data collation: 16/01/2012, Completed 22/02/2013.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank of River Rinn on the upstream face of Johnston's Bridge. At this location, the river is generally clear of vegetation and has a good conveyance capacity. Flow bypassing the structure is considered unlikely due to a high road embankment.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	209006, 286138	**Period of Record**	1955 – 2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.7 m (~35 m^3/s; pre-rating review)

QMED synthetic	24.8 m^3/s
QMED (AMAX, pre-rating review)	22.9 m^3/s (55 years)

Gauge Zero (from operator)	39.92mAOD (P)
Gauge Zero (from survey)	37.24 (mAOD) (M)

Hydraulic Model Details:

Model Name: 26008_JOHNSTONS BRIDGE_GS_V8_3.DAT

A one-dimensional hydraulic model of the River Rinn near Johnston's Bridge gauging station was built using river survey data collected by Murphy Surveys (4281_26RINN_JOHNSTONS BRIDGE_XS_PLAN, 4281_26RINN_JOHNSTONS BRIDGE _XS_1 to 4, 4281_26RINN_JOHNSTONS BRIDGE_LS_1) and ISIS hydraulic modelling software.

The hydraulic model extends from 1579m upstream of Johnston's Bridge (NGR: 210203, 287431) on the River Rinn to 2422m downstream of Johnston's Bridge (NGR: 208901, 284225). The gauging station is located on the upstream face of the bridge at node RINN01_2422u in the ISIS model.

There are two structures included in the hydraulic model at ISIS nodes RINN01_2422u and RINN01_0180u. These were schematised using Arch Bridge and USBPR Bridge units respectively and spill units to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of silt, gravel and cobbles (n= 0.039), bank side and floodplain roughness values range from 0.02 (Road) to 0.1 (Forest). However, the majority of the floodplain is designated as open land/pasture (0.045).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit with user defined slope was used as the downstream boundary condition. The slope was determined using recorded water level between RINN01_0501 and RINN01_0157 during the survey (normal conditions). Normal depth boundary condition is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

An attempt to calibrate the hydraulic model was carried out by comparing model results against available check gaugings. The Manning's n values used in the model were adjusted to within acceptable range (up to 0.044 on the river bed, 0.10 for the densely vegetated banks) in an attempt to fit the modelled rating curve to the check gaugings. However a good fit was not obtained and further adjustment to the Manning's n values has been considered inappropriate. Calibration of the hydraulic model was therefore abandoned.

The hydraulic model has been run with flows ranging from 0.5 to 98 m3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node: RINN01_2422u).

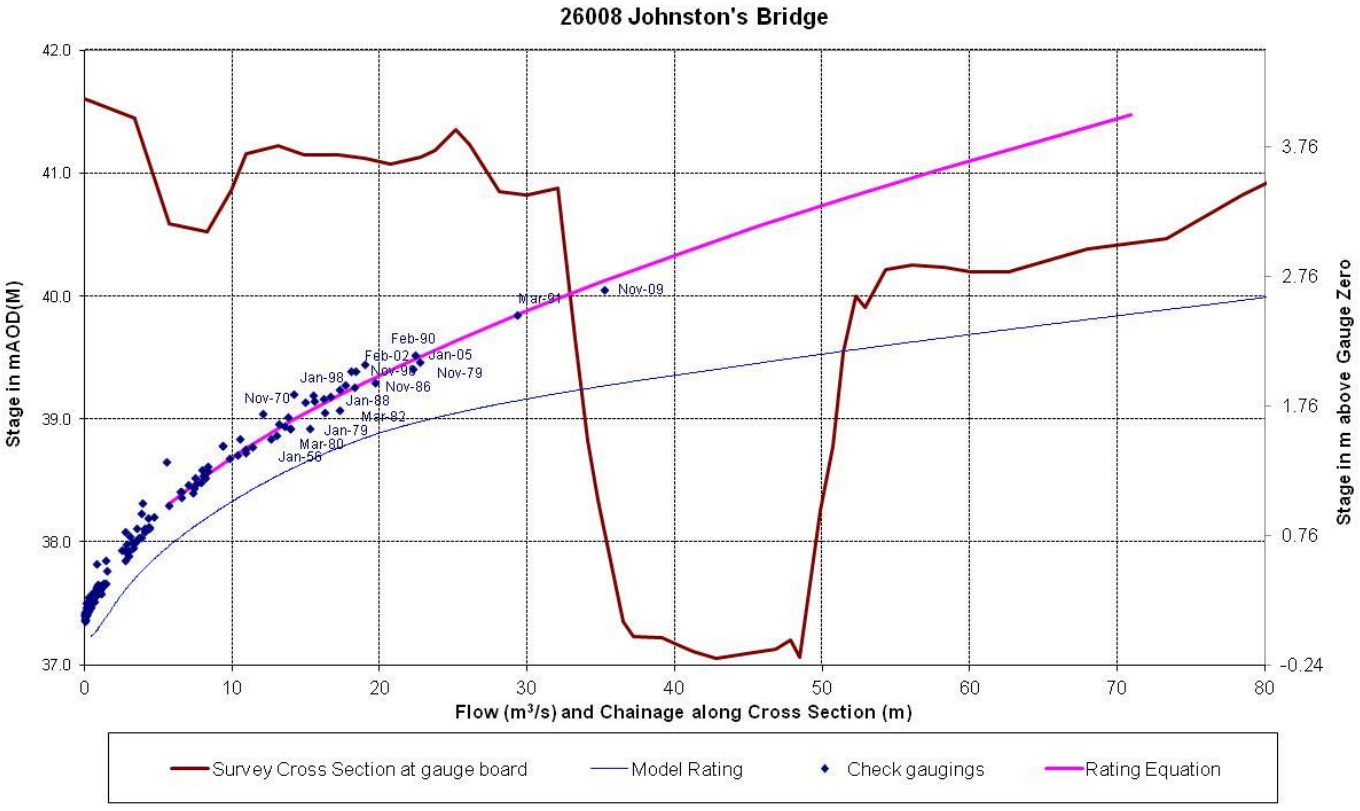
Analysis and Results:

A new set of rating equations have not been derived at this location as a good fit between the model rating curve and the check gaugings could not be achieved. The survey data and model were scrutinised but it has not been possible to identify any problems with either, which suggests that the topographic survey has failed to capture a local control.

In the absence of an acceptable model fit, the continued use of the existing OPW rating is recommended. This rating appears reliable up to 1.5 x QMED (approximately 35 m^3/s) due to the good fit with the November 2009 check gauging. The existing AMAX series has only two recorded values that are higher than the OPW verified rating equation limit (i.e. highest check gauging).

There is a slight gradual upward trend in the AMAX flow and level series from 1955, the cause of which is unknown. There is no evidence of drainage works in the catchment or any other obvious explanation for the trend.

QMED estimated from the entire flow series (1955 to 2009) is 22.9 m^3/s, compared to a QMED estimate of 24.3 m^3/s derived from a reduced-length dataset of 1992 to 2009 (post latest rating change). This is a small difference and may be entirely attributed to record bias. The check gaugings fit reasonably well to the OPW rating with minimal scatter for the full period of AMAX records. It is therefore considered appropriate that the entire AMAX dataset is used for flood frequency analysis.



Conclusions:

A stable model was created and attempts made to calibrate the flow-level relationship (rating) at the gauge board cross-section to check gaugings. However, despite significant model parameter adjustments, the model rating continues to significantly overestimate flows across the whole stage range.

In the absence of an appropriate model rating it is recommended that the existing OPW rating (verified up to 1.5 x QMED) is used. The existing OPW rating fits well with the rating for the full record period from 1955. It is considered appropriate that the entire AMAX series from 1955 is used for flood frequency analysis. Use of the existing OPW ratings will not change the AMAX series for this site.

26012 – Boyle at Tinacarra

Date of data collation: 16/01/2012, completed 05/03/2014

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the left bank of the River Boyle within farmland. It has a natural channel control and the channel is clear of vegetation. Flow bypassing the gauging station is considered unlikely due to very steep banks on both sides.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	177054, 301854	**Period of Record**	1957-2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2m (~38m^3/s; pre-rating review)

QMED synthetic	49 m^3/s
QMED (AMAX, pre rating review)	41.0 m^3/s (53 years)

Gauge Zero (from operator)	64.38 mAOD (P)
Gauge Zero (from survey)	61.79 mAOD (M)

Revised Rating Equations:

Q = 11.27 (W+0.09)^1.947 for the range: 0 < W < 3.5 (above Gauge Zero)*

*This equation is the OPW existing rating equation, see below for more details.

Hydraulic Model Details:

Hydraulic Model Name: **Model name is 26012_Tinacarra_GS_V6.DAT**

A one-dimensional hydraulic model of the River Boyle at Tinacarra Gauging Station was built using river survey data collected by Murphy Surveys in May 2012 (survey drawings 4281_26BOYL_TINACARRA_XS_PLAN, 4281_26BOYL_TINACARRA_XS_1 to 6, 4281_26BOYL_TINACARRA _LS_1 and 4281_26BOYL_TINACARRA _LS_2) and ISIS hydraulic modelling software.

The hydraulic model extends from Lough Gara Lower (NGR: 175178, 301607) to approximately 5 km downstream of the lake (NGR: 178282, 301937). The gauging station is located approximately 2 km downstream of Lough Gara Lower at ISIS Node BOYL01_2762 in the ISIS model.

Two bridges were included in the model at ISIS nodes BOYL01_0895u & BOYL01_0538u and both structures were schematised using ISIS Arch Bridge units with spill units to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of mud (n=0.026) in Lough Gara and stone/rocks (n=0.036) in the river channel. Bank side and floodplain roughness were set to a wide range of values depending on the type of land surface from 0.02 (roads), 0.03 for bogged areas, 0.06-0.08 for medium to dense vegetation and 0.1 for buildings.

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal-depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effect is expected, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The gauging station has a natural channel control so the bed roughness coefficient (Manning's n) was gradually varied from 0.026 to 0.023 for mud and from 0.036 to 0.033 for stone/rocks. Good agreement was found between the modelled water level at the gauging station and the check gauging levels when bed roughness coefficient of 0.023 for mud and 0.33 for stone/rock was used.

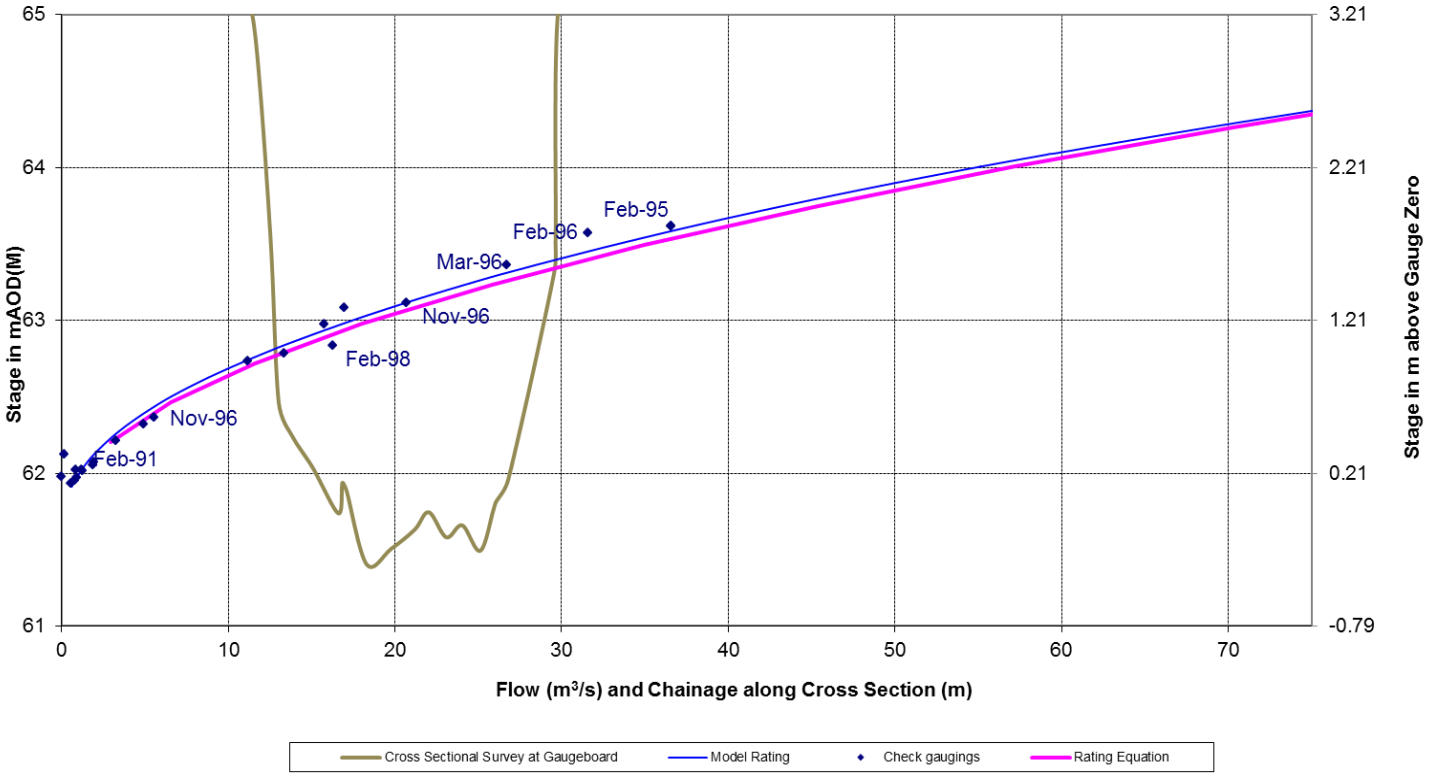
Once calibrated, the hydraulic model was run with flows ranging from 0.75 to 162 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS node BOYL01_2762).

Analysis and Results:

Data provided by OPW indicates that there was a major change in datum in August 1991, therefore check gaugings obtained prior to this date have been excluded from the graph below. Check gaugings obtained since August 1991 fit well with the model rating and confirm the validity of the model rating up to approximately 38 m^3/s. The model rating and OPW rating are very similar throughout the full flow range. Consequently, the OPW rating can be retained. It is recommended that additional high flow check gaugings are undertaken. The highest check gaugings date from 1995 and 1996 and measured flows below QMED.

It is not recommended that the AMAX series is reworked. However, the RBD Shannon Data Summary spreadsheet provided by OPW specifies that drainage works in the catchment were completed in 1992. A plot of the AMAX series shows an upward trend in the data of before 1992, and a step increase in flows during these works. Therefore, for the estimation of QMED and flood frequency analysis, only AMAX from 1993 onwards will be used. This results in an increase of QMED from 41.0 to 49.1 m^3/s.

A comparison of AMAX flows at this station with Boyle Abbey GS (26108) some 4 km downstream of Tinacarra shows that the peak flows at Tinacarra are consistently higher than at Boyle Abbey, and that this difference has increased over time since 1993. Given that Boyle Abbey has higher and more recent check gaugings, it is recommended that Boyle Abbey GS is used for QMED estimation and flood frequency analysis in preference to Tinacarra.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) for the cross section at the stilling well. As the model rating fits well with the OPW rating it is recommended that the current OPW rating is retained and the AMAX series need not be reworked. However, due to drainage works in the catchment completed in 1992, only the AMAX series from 1993 onwards will be used for QMED estimation and flood frequency analysis.

A comparison of AMAX flows at this station with Boyle Abbey GS some 4 km downstream of Tinacarra shows that peak flows at Tinacarra are consistently higher than at Boyle Abbey, and that this difference has increased over time since 1993. Given that Boyle Abbey has higher and more recent check gaugings; it is recommended that Boyle Abbey GS is used for QMED estimation and flood frequency analysis in preference to Tinacarra.

26014 – LUNG AT BANADA BRIDGE

Date of data collation: 22/05/2012, completed 24/10/2013

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank of the River Lung, approximately 70 m upstream of Lung Bridge. The channel upstream and downstream of the station is relatively straight, providing a good approach to the gauging station. The gauging station is situated in low-lying floodplain; therefore it is possible the gauging station is bypassed during high flows.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	163444, 294272	**Period of Record**	1975-2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2 m (~35 m^3/s; pre-rating review)

QMED synthetic	44.0 m^3/s
QMED (AMAX, pre rating review)	37.0 m^3/s (31 years)

Gauge Zero (from operator)	67.57 mAOD (P)
Gauge Zero (from survey)	64.74 mAOD (M)

Revised Rating Equations:

Q = 8.3522 (W+0)^1.9249	for the range: 1.82 ≤W< 2.61m (above Gauge Zero)
Q = 17.202 (W+0)^1.1714	for the range: 2.61 ≤W< 2.95m (above Gauge Zero)
Q = 3.1763 (W+0)^2.7354	for the range: 2.95 ≤W< 3.24m (above Gauge Zero)
Q = 0.8674 (W+0)^3.8431	for the range: 3.24 ≤W< 3.49m (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Hydraulic Model Name: 26014_BANADABR_GS_V7_v3.DAT

A one-dimensional hydraulic model of the River Lung near Banada Bridge gauging station was built using river survey data collected by Murphy Surveys in January 2012 (survey drawings 4281_26LUNG_BANADA BRIDGE_XS_PLAN, 4281_26LUNG_BANADA BRIDGE_XS_1 to 11, 4281_26LUNG_BANADA BRIDGE_LS_1 to 3) and the ISIS hydraulic modelling software.

The hydraulic model extends from 4802 m upstream of Banada Bridge (NGR: 162418, 293063) on the River Lung to 3797 m downstream of Banada Bridge (NGR: 164978, 295339). The gauging station is located 900 m downstream of Banada Bridge and around 70m upstream of Lung Bridge at ISIS node label LUNG01_2848 in the ISIS model. The model schematisation also includes 346 m of a side channel known as the Lung Cut which acts as a by-pass route under high flow conditions between ISIS node LUNG01_7283 and LUNG01_3528.

Seven bridges are represented in the hydraulic model: four across the River Lung (ISIS node labels LUNG1_8237, LUNG1_5374, LUNG1_3797 and LUNG1_2775) and three across the Lung Cut (ISIS nodes LCUT01_0424, LCUT01_0287, LCUT01_0179). All bridges are schematised using ISIS Arch Bridge units and spill units to allow for bridge overtopping. A weir located 370 m downstream of the gauging station is also included in the model using inline spill units (ISIS node LUNG_2475).

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of mud and stone (n=0.039). Bank side and floodplain roughness values range from road (0.020) to forest (0.90). However, the majority of the floodplain is designated as flat bog (0.030) and pasture (0.035).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. For flows above 10 m^3/s and using the original model schematisation described above, a good agreement was found between the modelled water level at the gauging station and the check gauging levels. For flows lower than 10 m^3/s, the model underpredicts the gaugings levels. This can be explained by the fact that the model does not represent localised obstructions due to dense vegetation and the bed. It should be noted that no attempt has been made to calibrate the model to the low flow check gaugings.

Once calibrated, the hydraulic model has been run with flows ranging from 3 to 147 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed good convergence with minor and a flow-level relationship (rating curve) has been extracted at the gauging station (ISIS Node LUNG01_2848).

Analysis and Results:

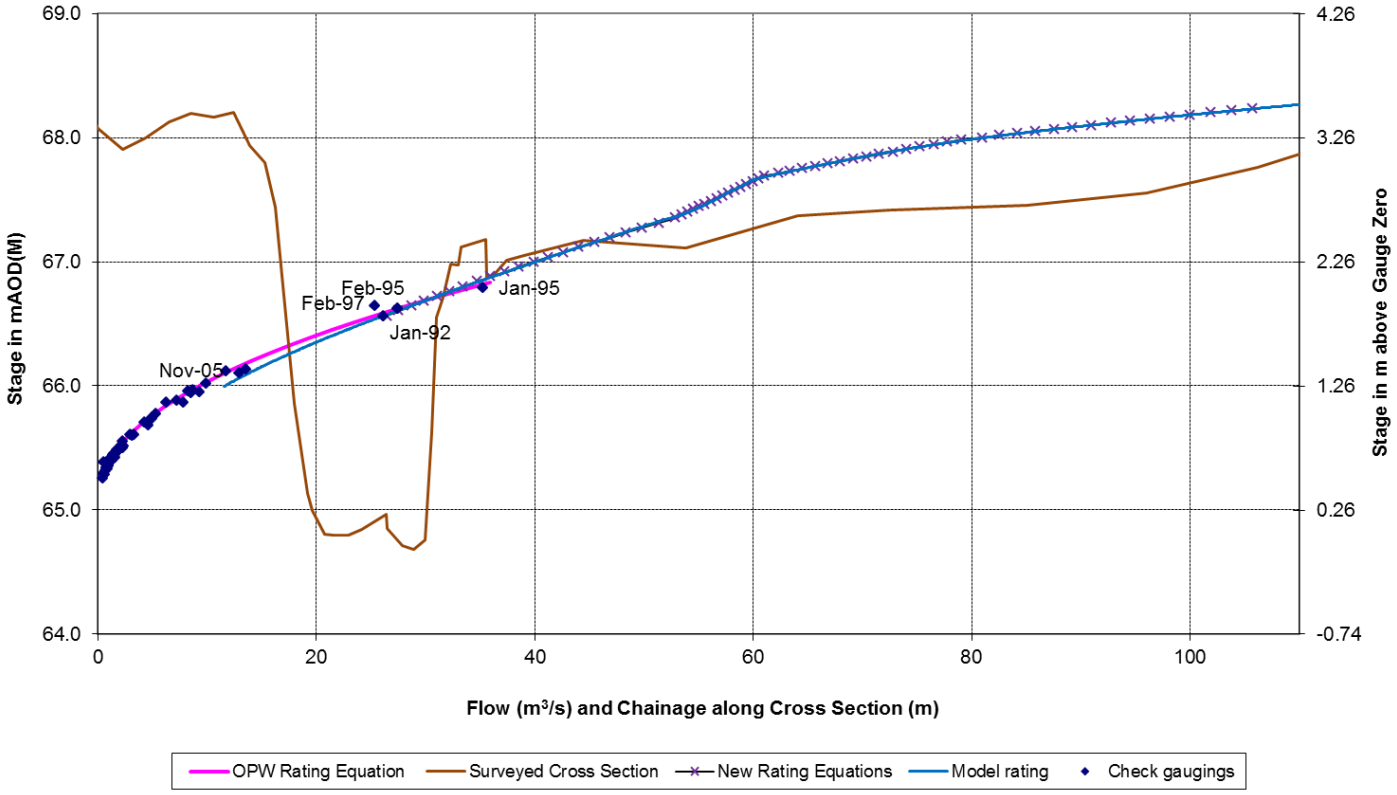
The RBD Shannon Data Summary Spreadsheet provided by OPW reports that the level recorder was removed during the period May 1985 to September 1989 and drainage works were undertaken during the summer of 1989. The subsequent re-siting of the gauge recorder in September 1989 resulted in a datum shift and development of a new rating.

AMAX flow estimates from before the drainage works (using the pre-1985 rating) are much lower than the AMAX flows from 1989 onwards. The ARTDRAIN2 parameter at this station is 50% which suggests that the effect of the drainage works on the catchment runoff characteristics has been considerable. The pre-drainage works AMAX series is therefore not suitable for flood frequency analysis and check gaugings prior to 1989 have been excluded from the plot below.

The model rating has a good fit with the medium to high flow check gaugings. A new set of rating equations based on the model rating has been derived in accordance with BS ISO 1100-2 for flows above the point where the OPW rating and the model rating intersect (26 m^3/s). The OPW rating can be used for flows below 26 m^3/s.

Medium to high flow check gaugings (from 1989) show little scatter. It is therefore considered appropriate that the AMAX flow series from 1989 is used with the new model rating giving a revised QMED of 39.1 m^3/s. The AMAX series 1989-2009 is suitable for QMED estimation and for flood frequency analysis.

With limited check gaugings in the medium and high flow range, it would be beneficial if further high flow gaugings were completed to verify the model rating.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) for a cross section at the gauging station. A new set of rating equations was established, to give a good fit with the modelled rating in the stage interval $1.82 \leq W < 3.49$m. The existing OPW rating can be used for stages below 1.82 m.

The AMAX series from 1989 has been revised based on the new set of rating equations. Following drainage works, it is recommended that only the AMAX data from 1989 is used for QMED estimation and flood frequency analysis. The revised ratings applied to the period 1989-2009 give an estimate of QMED of 39.1 m^3/s.

With limited check gaugings in the medium and high flow range, it would be beneficial if further high flow gaugings were completed to verify the model rating.

26016 – HIND AT BALLYMURRAY

Date of data collation: 16/01/2012 **completed:** 11/10/2012

Introduction:

For 44 selected hydrometric gauging stations within the Shannon River Basin District, high flow rating reviews have been undertaken. A Rating Review Summary Sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station has a natural control and is located on the upstream face of Athlone road bridge over the N61 road. There is a straight channel immediately upstream of the bridge after a sweeping left hand bend and a straight channel immediately downstream of the bridge. Flow bypassing the structure is considered unlikely.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	191635, 261560	**Period of Record**	1972-2010 (38 years)
Existing Rating Curve	No Rating	**Validity / Upper Limit**	N/A as level only.

QMED synthetic	6.2 m^3/s
QMED (AMAX, pre rating review)	N/A

Gauge Zero (from operator)	40.10 mAOD(P)
Gauge Zero (from survey)	37.32 mAOD(M)

Revised Rating Equations:

y = 5.1742 (x+0)^1.0665	for the range: 0.720<x<0.914m
y = 5.5919 (x+0)^1.9232	for the range: 0.914≤x<1.310m
y = 4.2286 (x+0)^2.958	for the range: 1.310≤x<1.790m

The derivation of these equations is detailed below.

Hydraulic Model Details:

Hydraulic Model Name: BALLYMURRAY_26016_ISIS_v2.DAT

A one-dimensional hydraulic model of the River Hind at Ballymurray gauging station was built using river survey data collected by Murphy Surveys in December 2011 (survey drawings 4281_26HIND_BALLYMURRAY_XS_1, 4281_26HIND_BALLYMURRAY_XS_2,4281_26HIND_BALLYMURRAY_XS_3,4281_26HIND_BALLYMURRAY_XS_4, 4281_26HIND_BALLYMURRAY_LS_1) and ISIS hydraulic modelling software.

The hydraulic model extends from 2500m upstream of Athlone Road (N61) bridge (NGR: 189658, 261436) on the River Hind to 1330m downstream of Athlone Road bridge (NGR: 192836, 261056). The gauging station is located at the upstream face of the bridge structure at node HIND01_1335u in the ISIS model.

Athlone Road Bridge and a Railway Bridge were schematised using ISIS Arch bridge units and spill units to allow for bridge overtopping at chainage 1335m and 3144m respectively.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of silt and gravel (n=0.040). Bank side and floodplain roughness values range from 0.035 (grass/pasture) to 0.08 (woodland).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model was carried out using the available check gaugings. Modelled water levels at the gauging station were low compared to the check gauging levels for original estimates of the hydraulic roughness. Manning's n values for the river and bank sides were therefore increased to a value of 0.048 to gain a better agreement between the model and check gaugings. It is not considered realistic to further increase the Manning's n value at this site, and a fit with the check gauging of Feb 2002 could not quite be obtained. It is noted however that the model rating is close to this check gauging. There are no check gaugings in the high flow range to verify the model rating further.

Once calibrated, the hydraulic model was run with flows ranging from 0.05m^3/s to 25m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS node HIND01_1335u).

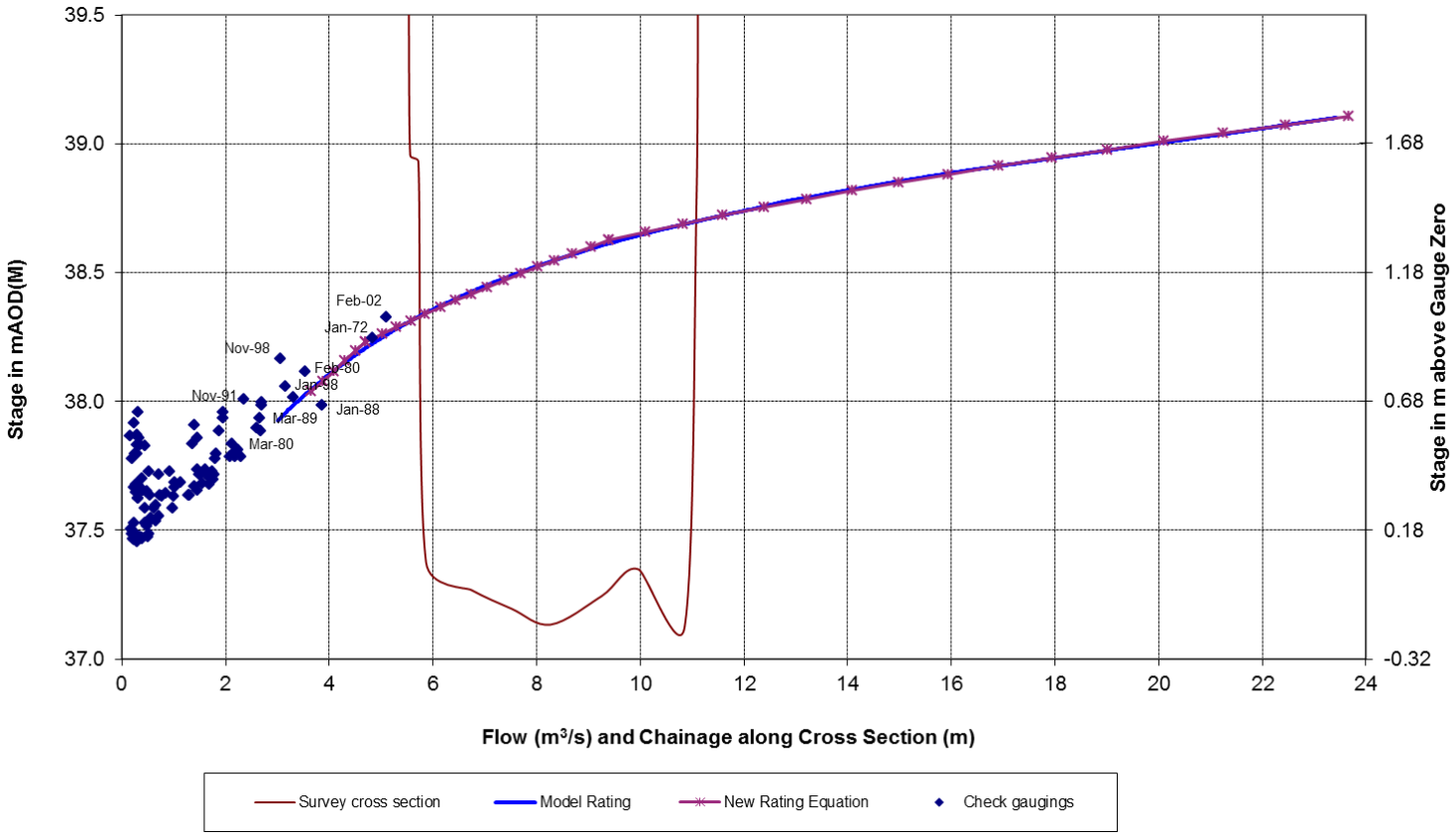
Analysis and Results:

The model rating fits reasonably well with the highest check gaugings. The fit with the February 2002 gauging is reasonable and a better fit could not be obtained without taking calibration parameters outside reasonable limits. The check gaugings show considerable scatter and the majority of the low and mid-flow gaugings lie above the model rating. A gauge datum shift is reported in August 1966.

There was no existing rating equation at this site, therefore a new set of rating equations has been created based on the modelled rating and have been derived in accordance with BS ISO 1100-2.

There is currently no AMAX data available prior to 1972. Check gaugings of before 1972 show a poor agreement with the most recent check gaugings and have been omitted from the plot. OPW has informed Jacobs that there is no significant known catchment change since 1972, so the entire AMAX flow series (based on the new rating) from 1972 can be used for flood estimation. The rating equations give an estimate of QMED of 8.9 m^3/s based on the available AMAX level data.

The available check gaugings are scattered and all significantly lower than QMED. High flow check gaugings are recommended to verify the model rating.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at the gauge board. A set of rating equations was established to give a good fit with the modelled rating in the stage interval 0.72<W<1.79m. It is noted that the check gaugings are all significantly lower than QMED and show considerable scatter. Therefore the modelled rating and the resulting AMAX flow series are subject to some uncertainty. High flow check gaugings are recommended to verify the model rating.

An AMAX flow series has been derived from the AMAX level data from 1972 to 2010 using the Jacobs rating. As there is no evidence of catchment change, the whole AMAX series from 1972 can be used for flood estimation.

26019 –CAMLIN AT MULLAGH

Date of data collation: 13/05/2012, completed 04/12/2013

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located approximately 24m upstream of Lisbrack Road Bridge on the right bank of the River Camlin. The station has a natural channel control. There are slight bends in the channel approximately 10 m downstream and upstream of the gauging station. Jacobs' site visit notes indicate that there are signs of erosion and deposition both upstream and downstream of the gauge and there may be potential for bypass at high flows.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	211668, 275905	**Period of Record**	1953 to 2009
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.67 m (~40 m^3/s; pre-rating review)

QMED synthetic	26.5 m^3/s
QMED (AMAX, pre rating review)	21.2 m^3/s (56 years)

Gauge Zero (from operator)	40.97 mAOD (P)
Gauge Zero (from survey)	38.24 mAOD (M)

Revised Rating Equations:

Q = 3.2292 (W+0)^2.4435	for the range: 2.010≤W<2.427 (above Gauge Zero)
Q = 1.7131 (W+0)^3.1586	for the range: 2.427≤W<2.915 (above Gauge Zero)
Q= 14.871(W+0)^1.1387	for the range: 2.915≤W<3.150 (above Gauge Zero)
Q= 3.9953(W+0)^2.284	for the range: 3.150≤W<3.920 (above Gauge Zero)

The derivation of these equations is detailed below.

Hydraulic Model Details:

Model Name: 26019_Mullagh_GS_8.dat

A one-dimensional hydraulic model of the River Camlin near Mullagh gauging station was built using river survey data collected by Murphy Surveys in July 2012 (survey drawings 4281_26CAMN_MULLAGH_XS_PLAN, 4281_26CAMN_MULLAGH_XS_1 to 5 and 4281_26CAMN_MULLAGH_LS_1) and the ISIS hydraulic modelling software.

The hydraulic model extends from 1519m upstream of Lisbrack Road Bridge (NGR: 212814, 275646) on the River Camlin to 1962m downstream of the bridge (NGR: 210295, 276984). The gauging station is located 24m upstream of the bridge (Lisbrack Road Bridge) at ISIS node CAMN01_1987 in the ISIS model.

Lisbrack Road Bridge and a Railway Bridge (ISIS node CAMN01_2429u) are the only hydraulic structures included in the model. Both were schematised using an ISIS Arch Bridge unit and a spill unit to allow for bridge overtopping. It should be noted that three other bridges crossing the River Camlin along the reach are not included in the model schematisation on the basis that they do not exert a significant impact on the hydraulics of the river under flood conditions.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of gravel and medium-size stones (n= 0.050). Banks are mostly vegetated with short grass to light scrubs (0.05). Floodplain is mostly designated as pasture (0.040) with some woodland areas (0.08-0.1).

Estimated roughness values were subsequently modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings.

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal-depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. The roughness coefficient was adjusted to achieve a reasonable fit to the check gaugings. With bed roughness values adjusted to 0.055 a relatively good agreement was found between the modelled water level at the gauging station and some of the check gauging levels, including the highest check gauging of January 2005.

Once calibrated, the hydraulic model has been run with flows ranging from 0.1 to 103m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no instability. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node CAMN01_1987).

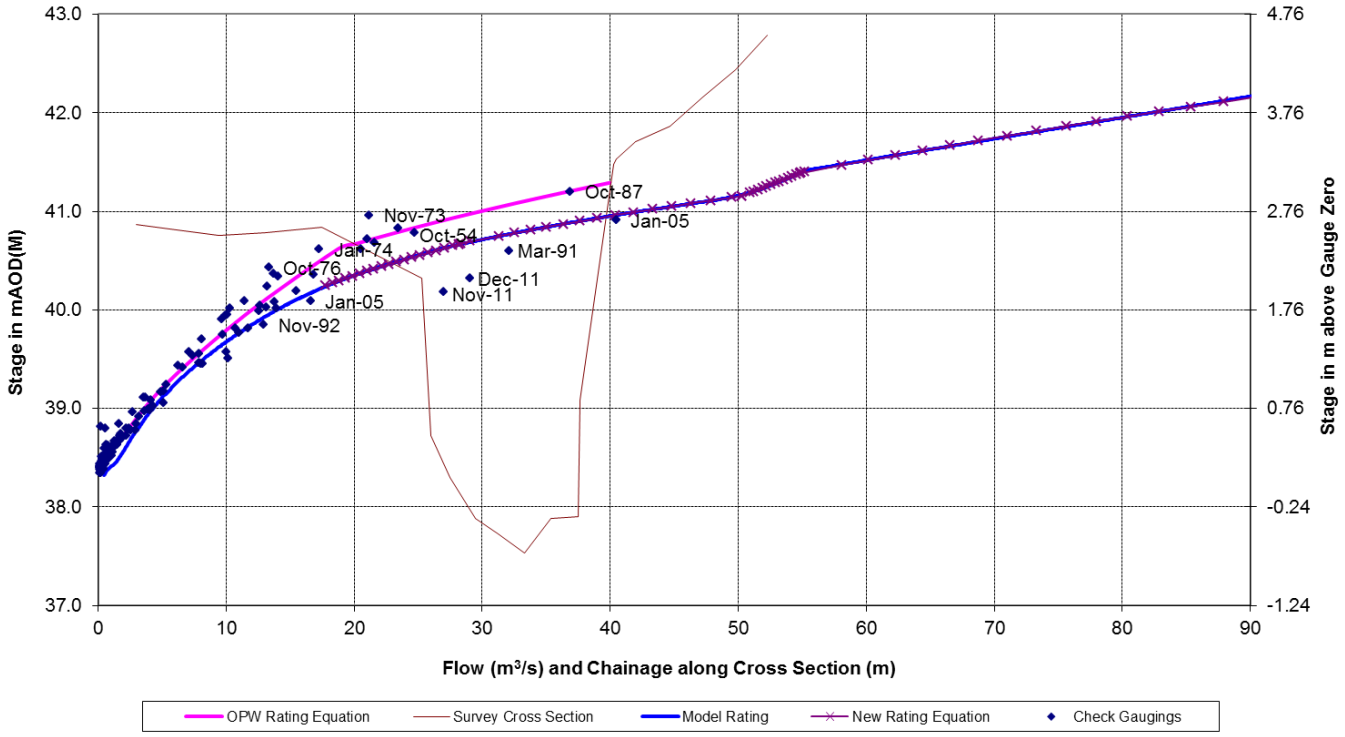
Additional information, received after the calibration, suggests that channel clearance work was carried out in October 2010 (before the topographic survey for the hydraulic model, but after the 2005 check gaugings were undertaken). Given the large scatter in the check gaugings and the dearth of check gaugings after October 2010 it was agreed not to pursue the calibration further, see Analysis and Results below.

Analysis and Results:

The check gaugings show large scatter, which suggests that the site may be unstable. However, OPW's medium and high flow rating equations have been unchanged since the station was first rated. Recent check gaugings (November and December 2011) lie significantly below the OPW and model rating and away from the majority of other check gaugings. This scatter was investigated and OPW confirmed in an email on 20th August 2013 that: *'OPW have records of an excavator cleaning the channel both upstream of the recording hut, and downstream of the bridge from October 2010. The rating will have changed since then so OPW are in the ongoing process of collecting a new set of gaugings over the measured range of stage so that a new rating can be developed'.*

The model rating is based on topographic survey data which was completed after the clearance works, but the site may take time to fully stabilise and there are only three check gaugings since the channel works, which are in the low to mid flow range. There are too few gaugings to identify whether the geomorphology at the site has stabilised and whether the model rating is reliable. Based on this, OPW have agreed that no further work should be completed on the rating review for Mullagh. Data post-2010 should be used with caution until the channel has stabilised and a new rating has been established. It is recommended that check gaugings are completed for high flows to verify the rating.

If the pre-2010 data at this station is considered for flood estimation it should be used with caution as the check gaugings from the 1990s and 2000s show that the latest rating is not representative for that 20 year period.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) for a cross section at the stilling well. A set of rating equations have been established based on the results from the model in the stage interval 2.01<W<3.92m. The model rating is based on the channel geometry since drainage works where completed in October 2010, potentially during a period when the site geometry may still have been stabilising. There is insufficient data to identify whether the model rating is suitable and whether the site is stable.

Following the channel works in October 2010 further high flow check gaugings are required to confirm the rating and allow for calibration of the model. It is recommended that only AMAX pre-2010 should be used for QMED estimation and flood frequency analysis. If the pre-2010 data at this station is considered for flood estimation it should be used with caution as the check gaugings from the 1990s and 2000s show that the latest rating is not representative for that 20 year period.

26021 – RIVER INNY AT BALLYMAHON

Date of data collation: 31/08/2012, completed 29/01/2014.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank of the River Inny upstream of Ballymahon Bridge. The gauging station has a natural channel control and the channel is clear of vegetation. Flow bypassing the gauging station is considered unlikely due to high bank embankment on both sides.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	216107, 256987	**Period of Record**	1975-2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 2.6 m (~83 m^3/s; pre-rating review)

QMED synthetic	42.6 m^3/s
QMED (AMAX, pre rating review)	69.2 m^3/s (35 years)

Gauge Zero (from operator)	44.25 mAOD (P)
Gauge Zero (from survey)	41.47 mAOD (M)

Revised Rating Equations:

Q = 30.4 (W-0.6)^1.5	for the range: 1.03≤W<2.08m (above Gauge Zero)*
Q = 12.884 (W+0)^2.022	for the range: 2.08≤W<2.64m (above Gauge Zero)
Q = 8.046 (W+0)^2.515	for the range: 2.64≤W<3.20m (above Gauge Zero)
Q = 12.042 (W+0)^2.165	for the range: 3.20≤W<3.78m (above Gauge Zero)

**OPW's existing rating up to a stage of 2.08*

The derivation of these equations is detailed below.

Hydraulic Model Details:

Hydraulic Model Name: 26021_Ballymahon_GS_C6.DAT

A one-dimensional hydraulic model of the River Inny near Ballymahon Gauging Station was built using river survey data collected by Murphy Surveys in May 2012 (Survey drawings 4281_26INNY_BALLYMAHON_XS_PLAN, 4281_26INNY_BALLYMAHON_XS_1 to 5, 4281_26INNY_BALLYMAHON _LS_1 and 4281_26INNY_BALLYMAHON _LS_2) and ISIS hydraulic modelling software.

The hydraulic model extends from 2540m upstream of Ballymahon Bridge (NGR: 218024, 256589) on the River Inny to 1420m downstream of Ballymahon Bridge (NGR: 214642, 256184). The gauging station is located approximately 300m upstream of bridge at node INNY01_1722 in the ISIS model.

Ballymahon Bridge is the only hydraulic structure included in the model (ISIS node INNY01_1420u) and it was schematised using ISIS Arch Bridge unit and a spill unit to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consist mainly of sand, gravel and cobbles (n=0.039). Bank side and floodplain roughness values vary widely from 0.02 (road) to 0.1 (dense woodland). However, the majority of the floodplain is designated as pasture (0.035) or dense wood land (0.1). Roughness values were then modified at calibration stage within acceptable limits to achieve a best fit to the available check gaugings.

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using check gaugings provided by OPW. The gauging station has a natural channel control so the roughness coefficient was the only parameter that was adjusted to achieve a reasonable fit to the check gaugings. With bed roughness values adjusted to 0.048, a reasonable agreement between the modelled water level at the gauging station and the check gauging water level was achieved.

Once calibrated, the hydraulic model has been run with flows ranging from 2 to 412 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) has been extracted from the model results at the rating section (ISIS Node: INNY01_1722).

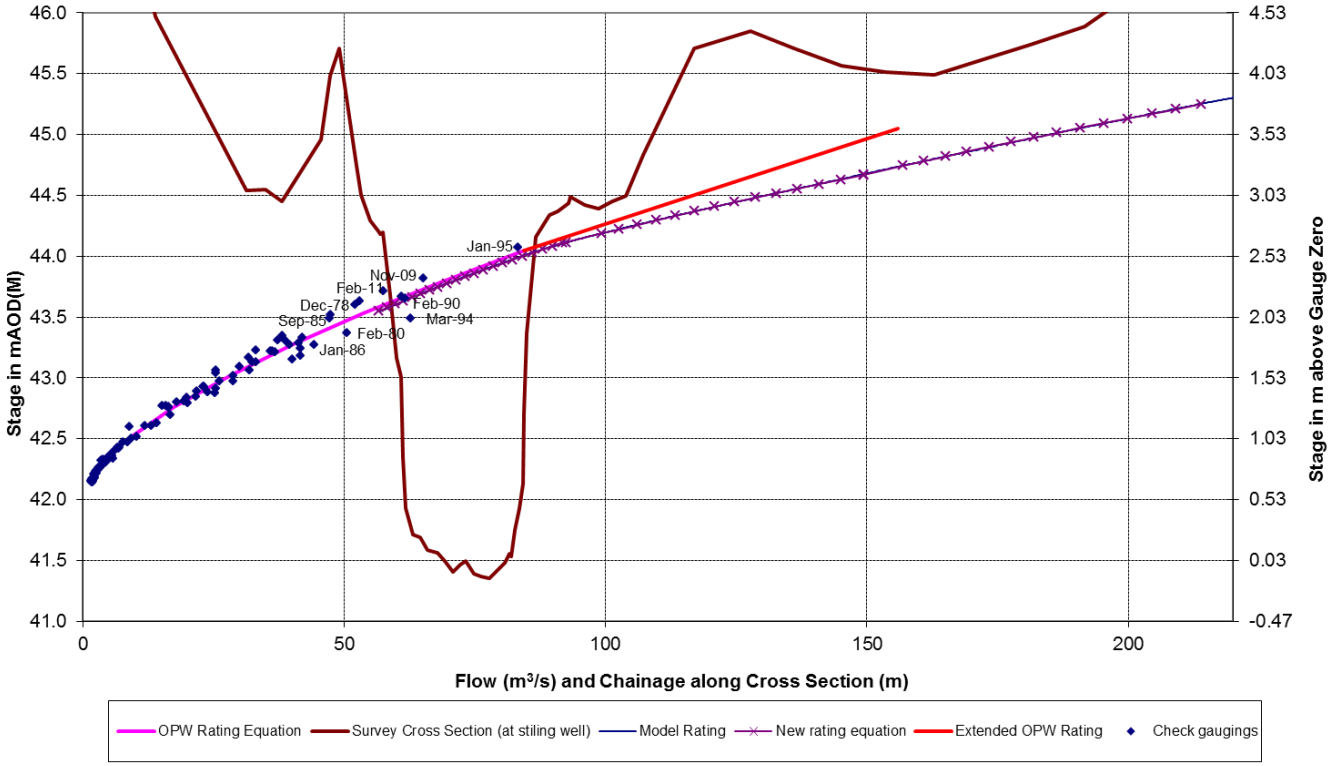
Analysis and Results:

The model rating shows a good fit with the check gaugings (which show limited scatter). The highest check gauging is 83 m^3/s, which is higher than QMED (1.17xQMED). The model rating diverges from the (extended) OPW rating for flows above the highest gauged flow, with the model rating giving a higher flow for a given stage. As the OPW rating is simply an extrapolation of a curve through the check gaugings and does not take the channel geometry into account the model rating is considered an improvement for high flows.

A new set of rating equations have been derived based on the model rating following BS ISO 1100-2, and it is recommended that the revised rating equations are used for QMED estimation and flood frequency analysis.

Since 1965 there has not been any change in the high flow rating equations, suggesting a stable site. However, analysis of the AMAX series (which only exists from 1975) suggests a positive trend in the flow and level data. OPW where contacted on this matter, and confirmed that there is no evidence of drainage works since 1965. It was noted that the first year of the record (1975) was an exceptionally dry year, and the last year (2009) an exceptionally wet period. Removing 1975 and 2009 from the series removes much (but not all) of the trend. Given that the remaining trend is small and no evidence of catchment change is reported, it is recommended that the whole (revised) AMAX series is used for QMED estimation and flood frequency analysis. The change to the rating increases QMED slightly from 69 to 71 m^3/s.

It is recommended that with only one gauging above Qmed, further high flow check gaugings be completed to verify the rating.



Summary, Conclusions and Recommendations:

A stable model was created, calibrated to observed check gaugings and run to provide the flow-level relationship (rating) at a cross section located close to the stilling well. A set of rating equations was established to give a reasonable fit with the modelled rating in the stage interval 2.08<W<3.78 m. Based on the stable nature of the site and the good fit with the check gaugings it is recommended that the whole AMAX flow series from 1975 is revised and used for QMED and single site analysis.

It is recommended that with only one gaugings above Qmed further high flow check gaugings be conducted to verify the rating.

26022 – FALLON AT KILMORE

Date of data collation: 16/01/2012, completed 20/05/2014.

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauging station to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the right bank of the River Fallon, on the upstream face of the bridge. The gauging station has a natural channel control, which can be affected by weed growth and maybe affected by the downstream bridge. Flow bypassing the gauging station is considered unlikely due to high road embankments.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	208474, 273384	**Period of Record**	1972-2009 (AMAX)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W < 1.3 m (~7m^3/s; pre-rating review)

QMED synthetic	5.7 m^3/s
QMED (AMAX, pre rating review)	6.4 m^3/s (38 years)

Gauge Zero (from operator)	41.85 mAOD (P)
Gauge Zero (from survey)	39.05 mAOD (M)

Revised Rating Equations:

Q = 5.6 (W-0.19)^1.707 for the range: 0.33≤W<2.04m (above Gauge Zero)*

* Existing OPW rating extended to 2.00 metres above gauge zero.

Hydraulic Model Details:

Hydraulic Model Name: 26022_KILMORE_GS_Cal3.DAT.

A one dimensional hydraulic model of the River Fallon near Kilmore was built using river survey data collected by Murphy Surveys in January 2012 and the ISIS hydraulic modelling software.
(survey drawings: 4281_26FALL_KILMORE_XS_PLAN, 4281_26FALL_KILMORE_XS_1, 4281_26FALL_KILMORE_XS_2, 4281_26FALL_KILMORE_XS_3, 4281_26FALL_KILMORE_XS_4, 4281_26FALL_KILMORE_XS_5, and 4281_26FALL_KILMORE_LS_1)

The hydraulic model extends from 1800m upstream of Kilmore Bridge (NGR: 209167, 271830) on the River Fallon to 2100m downstream of the Kilmore Bridge (NGR: 207784, 274925). The gauging station is located on the upstream face of the bridge (ISIS node FALL01_2091u) in the hydraulic model.

Four bridge structures were schematised using ISIS Arch Bridge units and spill units to allow for bridge overtopping.

Hydraulic roughness (Manning's n) values used in the model were estimated using site visit and survey information. The river bed consists mainly of natural silt and sand (n=0.035). Bank side and floodplain roughness values range from grass/pasture (0.035) to woodland (0.08).

Floodplain areas were represented in the model using extended cross sections as deemed appropriate.

A normal depth boundary unit was used at the downstream boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model was carried out using the check gauging data provided by OPW. The bed roughness coefficient was gradually increased from 0.035 to 0.042, at which point a good agreement was found between the modelled water level at the gauging station and the check gauging levels.

Once calibrated, the hydraulic model was run with flows ranging from 0.4 to 25 m^3/s, using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed no particular instabilities and a flow-level relationship (rating curve) was extracted from the model results at the stilling well (FALL01_2091u).

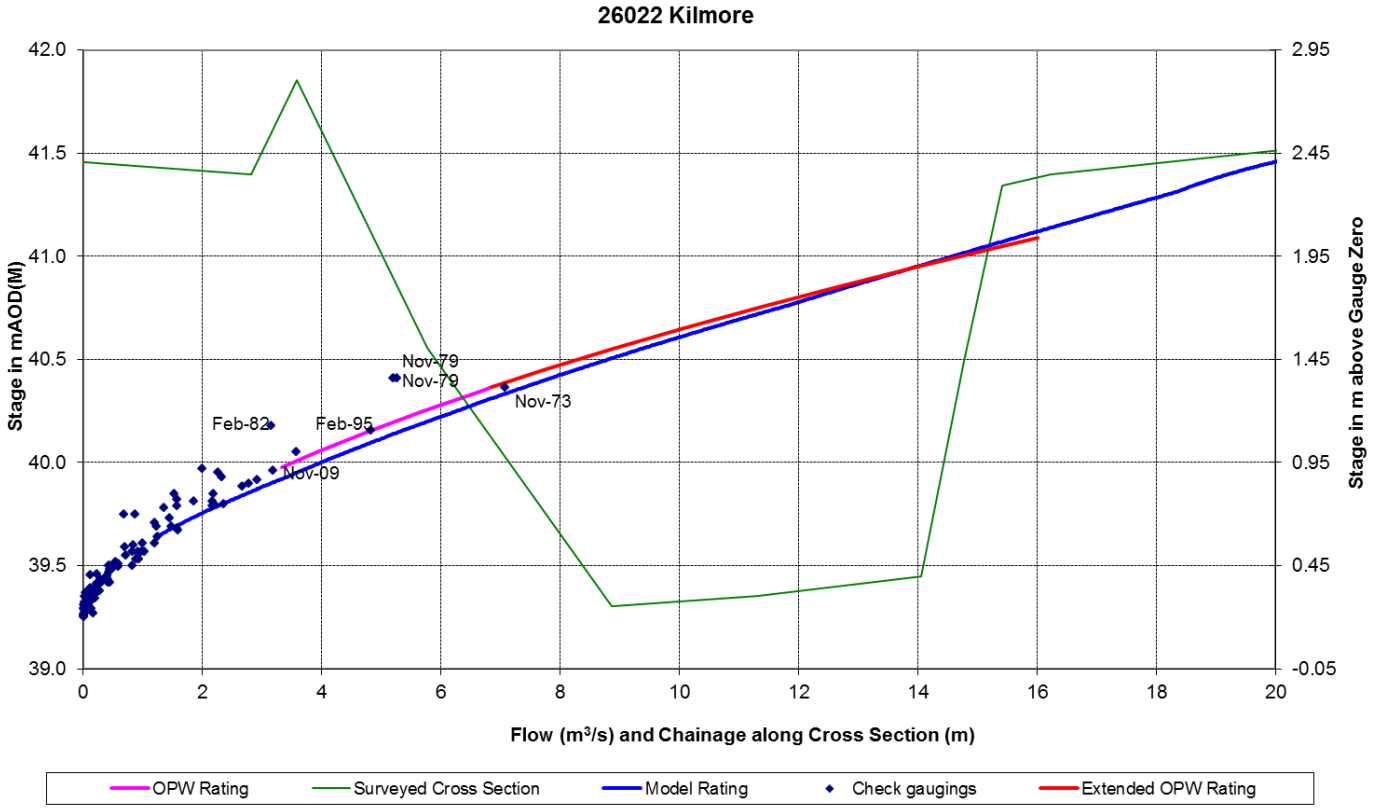
Analysis and Results:

There are very few high flow check gaugings available, with the most recent from the 1970s. The check gaugings show considerable scatter, which suggests that any flow estimate at this site may be subject to uncertainty. The OPW Hydro-Data website states that this is a poor site for flood estimation and recommends that the station should only be used for indicative purposes. Furthermore, the RBD Shannon Data Summary spreadsheet identified that the control is affected by weed growth, which may be the cause of the scatter.

The model and OPW ratings have a similar trend, and the extended OPW rating intersects with the model rating at a flow of just below 14 m^3/s (~2 x QMED). As a result of the similarity of the model and OPW rating, it is recommended that the existing OPW rating is retained and extended to a stage of 2.04 m (or a flow of 16 m^3/s, ~ 2.5 x QMED). Historic OPW ratings are very similar to the present OPW rating; it is therefore considered appropriate to retain the historic ratings. The AMAX level and flow series do not demonstrate any trends; it is thus appropriate to use the full AMAX series from 1972. QMED remains unchanged at 6.4 m^3/s.

It is recommended that further check gaugings are completed at high flows. We also recommend that weed growth at the control, suggested to have contributed to the scatter in the check gaugings, is managed at a regular basis.

Given the scatter in the check gaugings we would support OPW's conclusion that flows from this station should be treated with caution, but note that flood flow estimates from this site may still be useful in the absence of other data.



Conclusions and Recommendations:

As the model rating compares well to the existing OPW ratings, it is recommended that the existing OPW rating is retained and extended to a stage of 2.04 m (or a flow of 16 m^3/s, i.e. 2.5 x QMED). QMED remains unchanged at 6.4 m^3/s.

It is recommended that further check gaugings are completed at high flows, because the most recent high flow check gaugings were completed in the 1970s. We also recommend that weed growth at the control, suggested to have contributed to the scatter in the check gaugings, is managed at a regular basis.

Given the scatter in the check gaugings we would support OPW's conclusion that flows from this station should be treated with caution, but note that flood flow estimates from this site may still be useful in the absence of other data.

26108 – BOYLE AT BOYLE ABBEY BRIDGE

Date of data collation: 16/01/2012, completed 05/03/2014

Introduction:

High flow rating reviews have been undertaken for 44 selected hydrometric gauging stations within the Shannon River Basin District. A rating review summary sheet has been produced for each gauge to summarise the rating review process.

Gauging Station Description:

The gauging station is located on the left bank of the River Boyle at surveyed cross section 26BOYL01774. The channel is clear of vegetation and there is good capacity in the channel. The potential for flow bypassing at the station is low; all flows from upstream will have to pass through the bridge upstream of the gauging station.

Gauging Station Details:

Station Type	Recorder	**Gauging Authority**	OPW
Coordinates	180581, 302634	**Period of Record**	1978 to 2011 (Amax series only from 1990)
Existing Rating Curve	Yes	**Validity / Upper Limit**	W <1.45 m (~79m^3/s; pre-rating review)

QMED synthetic	35.6 m^3/s (urban)
QMED (AMAX, pre-rating review)	41.6 m^3/s (20 years)

Gauge Zero (from operator)	51.44 mAOD (P)
Gauge Zero (from survey)	48.62 mAOD (M)

Revised Rating Equations:

Q = 25.000 (W-0.17)^2.10	for the range: 0.00≤W<1.24m (above Gauge Zero)*
Q = 37.165 (W+0)^1.5029	for the range:1.24≤W<1.53m (above Gauge Zero)
Q = 32.320 (W+0)^1.8537	for the range:1.53≤W<1.73m (above Gauge Zero)

** Existing OPW rating*
The derivation of these equations is detailed below.

Hydraulic Model Details:

Hydraulic Model Name: 26108_Boyle Abbey bridge_GS_V16_V0i_.DAT

A one-dimensional hydraulic model of the River Boyle near Boyle Abbey Bridge gauging station was built using river survey data collected by Murphy Surveys in June 2012 (survey drawings: 4281_26BOYL_TINACARRA_XS_6, 4281_26BYOL_BOYLE ABBEY BRIDGE_XS_PLAN, 4281_26BOYL_BOYLE ABBEY BRIDG _XS_1 to 7, 4281_26BOYL_BOYLE ABBEY BRIDG _LS_1 and 4281_26MILL_MILL_XS_1) and the ISIS hydraulic modelling software.

The hydraulic model extends from 1520m upstream of Boyle Abbey Gauging Station (NGR: 179276, 302311) on the River Boyle to 745m downstream (NGR: 180552, 303305) of Boyle Abbey Gauging Station. The gauging station is located on the left bank just downstream of Sligo Road Bridge at ISIS node BOYL01_0745 in the ISIS model.

The modelled reach is divided into several parallel channels to represent the main River Boyle channel and a mill race running between surveyed cross sections 26BOYL01899 to 26BOYL01838. Appropriate junction and lateral spill units have been set up to ensure hydraulic connectivity between the two reaches for both low and high flow conditions. It should be noted that a detailed representation of a small by-pass reach within Town Park has not been included in the model schematisation as it was not considered to bear significant effect on the rating curve at the gauging station location.

There are 10 hydraulic structures included in the model. The weir across the River Boyle at surveyed label 26BOYL01893W was represented as a lateral spill between the main river reach (ISIS label BOYL01_1994u) and the upstream end of the Mill Race (ISIS label MILL01_0489). Low soffit footbridges (ISIS node labels MILL01_0199u and MILL01_0194u) across the Mill Race channel were represented using orifice units with spill units to allow for overtopping. The culverts under the Mill building (ISIS node label MILL01_0147) were represented using appropriate inlet and outlet units connected to rectangular conduits and sprung arch conduits. Other bridge structures were schematised using Arch bridge units with spill units to allow for overtopping (ISIS node labels BOY01_1535u, MILL1_0173u, MILL01_0060u, BOYL01_1239u, BOYL01_1108u, BOYL01_0762u, and BOYL01_0582u).

Hydraulic roughness (Manning's n) values used in the model were estimated using survey and site visit information. The river bed consists mainly of natural silt /sand with cobbles and stones (n=0.039). Bank side and floodplain roughness values vary widely as the main river runs across different type of land within the town of Boyle Abbey. Typical roughness coefficient ranges from 0.02 (Road), 0.035 (parks, short grass), 0.06 (medium vegetation) to 0.1 (Buildings).

Floodplain areas were generally represented in the model using extended cross sections. A parallel channel is provided between survey cross sections 26BOYL01926 and 26BOYL01882 to model the right bank floodplain.

A normal depth boundary unit was used as the downstream boundary condition. This is considered appropriate as no backwater effects are expected on the downstream model boundary, and the model extends far enough downstream of the gauge to be insensitive to this boundary condition.

Hydraulic Model Calibration:

Calibration of the hydraulic model has been carried out using the check gauging data provided by OPW. With the original estimates of roughness and spill unit coefficients, acceptable agreement was found between the modelled water level at the gauging station and the check gauging water levels.

Once calibrated, the hydraulic model was run with flows ranging from 2 to 165 m^3/s using the unsteady state solver in ISIS and a triangular shape hydrograph. The model showed a minor instability (jump) and a small degree of hysteresis around 90 m^3/s. A flow-level relationship (rating curve) has been extracted from the model results at the gauging station (ISIS Node BOYL01_0745).

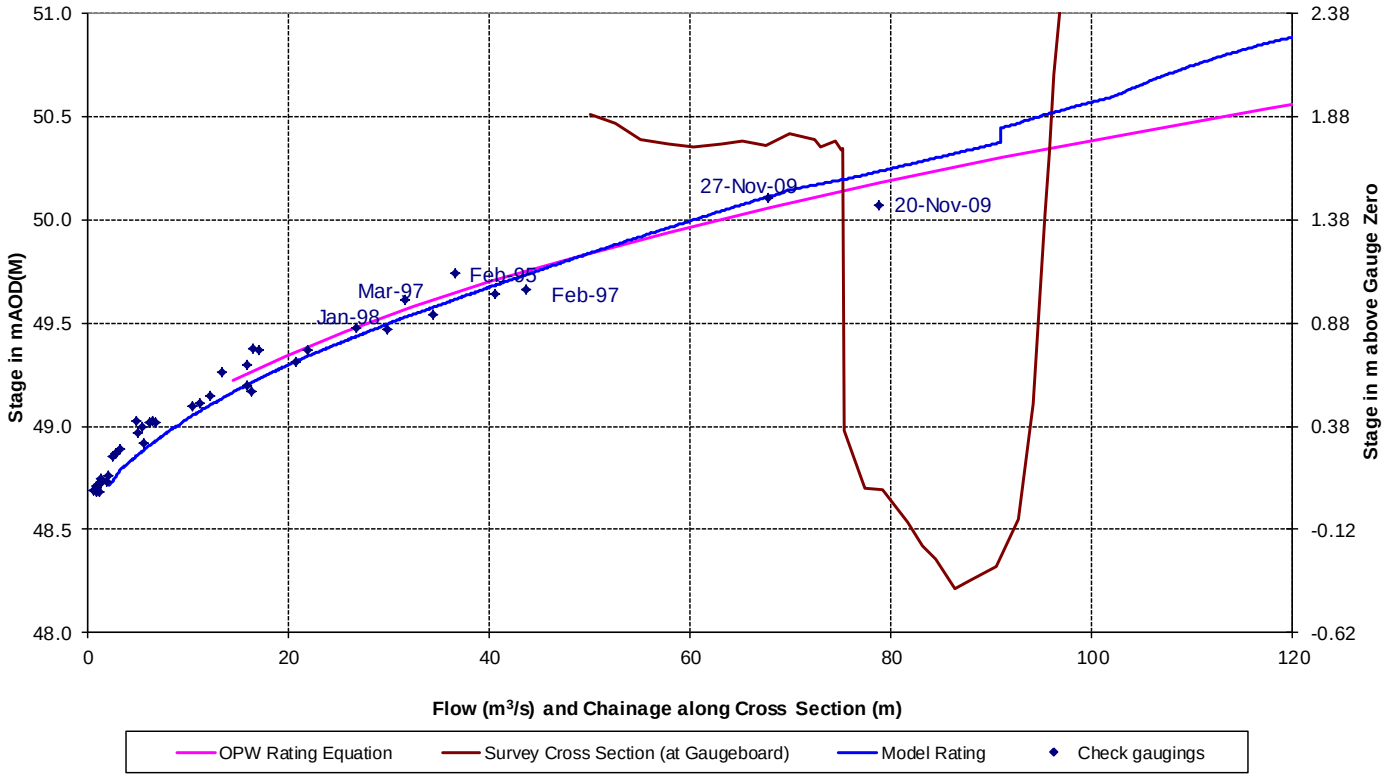
Analysis and Results:

Boyle Abbey has few high flow check gaugings with only two greater than the OPW estimate of QMED. The highest gauging is approximately 1.9xQMED. The two highest gaugings were taken seven days apart during the flood of November 2009. Although the observed levels are similar (40 mm difference), there is a notable difference in flow, with the latest gauging being 11 m^3/s lower than the first. The notable deviation from the rating curve of the first gauging could be a result of hysteresis, causing flows during the rising limb to be higher than it would have been with that water level in steady-state conditions. It may be that this hysteresis effect manifests itself at very high flows only. This hysteresis is not connected to the minor (numerical) hysteresis observed in the model results at 90 m^3/s described in the Hydraulic Model Calibration section above.

The model rating and the OPW rating are similar for flows up to 90 m^3/s (> 2 x QMED). The difference in flow (comparing the model rating with the OPW rating) for the highest AMAX value is 6% and lower for all other AMAX values, which is considered too small to amend the AMAX series. It is noted that the OPW rating fits well through the highest check gaugings. The model rating shows a small jump at 90 m^3/s, which appears to be associated with a backwater effect from the soffit of a downstream bridge. This adds some uncertainty to the accuracy of the model rating for flows of 90 m^3/s and higher.

It is not considered necessary to rework the AMAX series. The full AMAX series from 1990 can be used for QMED estimation and flood frequency analysis.

A comparison of AMAX flows at this station with Tinacarra GS (26012) some 4 km upstream of Boyle Abbey GS indicates that peak flows at Tinacarra are consistently higher than at Boyle Abbey, and that this difference has increased over time since 1993. Given that Boyle Abbey has higher and more recent check gaugings, it is recommended that Boyle Abbey GS is used for QMED estimation and flood frequency analysis in preference to Tinacarra.



Conclusions:

A stable model was created, calibrated to available check gaugings and run to provide the flow-level relationship (rating) at a cross section located at the stilling well.

Only a small difference between the model rating and OPW's rating in the range of the AMAX series is evident, it is therefore not considered necessary to rework the AMAX series. The full AMAX series from 1990 is considered appropriate for QMED estimation and flood frequency analysis. However, it is recommended that further high flow check gaugings should be conducted to confirm the rating.

A comparison of AMAX flows at this station with Tinacarra GS (26012) some 4 km upstream of Boyle Abbey GS shows that the peak flows at Tinacarra are consistently higher than at Boyle Abbey, and that this difference has increased over time since 1993. Given that Boyle Abbey has higher and more recent check gaugings, it is recommended that Boyle Abbey GS is used for QMED estimation and flood frequency analysis in preference to Tinacarra.

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26007 Bellagill

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The Gauging Station Information Sheets in this appendix show the original AMAX series as provided by OPW (if available) and the revised AMAX series as adopted for the at-site flood frequency analysis. If for a gauging station subject to a rating review the revised AMAX series is different from the original series then further information can be found on the Rating Review Summary Sheet for that station in Appendix C.

Station 25015 (Pollagh) is not included in this appendix as it does not have a reliable AMAX flow series and has not been used in this study for flood estimation purposes. Please read the Rating Review Summary Sheet in Appendix C for more details.

25001 – MULKEAR AT ANNACOTTY

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1953	127.6		03/12/1953
1954	123.8		31/12/1954
1955	106.8		14/01/1956
1956	125.7		25/09/1957
1957	125.7		03/09/1958
1958	107.4		06/11/1958
1959	125.7		14/09/1960
1960	149.9		04/12/1960
1961	112.8		03/04/1962
1962	87.3		05/11/1962
1963	112.8		17/08/1964
1964	147.9		12/12/1964
1965	158.1		09/12/1965
1966	123.8		22/02/1967
1967	143.9		07/10/1967
1968	155.3		25/12/1968
1969	126.4		22/02/1970
1970	103.2		19/11/1970
1971	117.0		21/11/1971
1972	118.1		13/11/1972
1973	137.9		28/11/1973
1974	137.3		22/01/1975
1975	135.6		30/01/1976
1976	N/A		N/A
1977	133.4	133.4	21/04/1978
1978	119.8	119.8	28/12/1978
1979	127.9	127.9	25/10/1979
1980	N/A	N/A	N/A
1981	90.6	90.6	14/12/1981
1982	139.3	139.3	31/01/1983
1983	147.9	147.9	06/02/1984
1984	95.9	95.9	14/08/1985
1985	137.6	137.6	06/08/1986
1986	112.6	112.6	19/11/1986
1987	114.2	114.2	01/02/1988
1988	128.7	128.7	22/10/1988
1989	154.9	154.9	06/02/1990
1990	122.1	122.1	02/01/1991
1991	126.6	126.6	13/09/1992
1992	119.1	119.1	30/09/1993
1993	129.4	129.4	12/12/1993
1994	150.4	150.4	22/02/1995
1995	114.3	114.3	12/02/1996
1996	134.9	134.9	05/08/1997
1997	126.1	126.1	06/03/1998
1998	128.8	128.8	21/09/1999
1999	114.3	114.3	25/12/1999
2000	133.3	133.3	06/11/2000
2001	84.6	84.6	26/02/2002
2002	85.5	85.5	10/06/2003
2003	111.2	111.2	14/11/2003
2004	131.6	131.6	08/01/2005
2005	100.0	100.0	22/05/2006
2006	114.3	114.3	14/12/2006
2007	136.1	136.1	07/12/2007
2008	128.8	128.8	13/12/2008
2009	118.0	118.0	19/11/2009

Length of AMAX series: 32 years

The AMAX series has not been revised.
AMAX data from 1976 used for QMED estimation and flood frequency analysis.

Gauging Authority: Office of Public Works	
Easting: 164265	**Northing:** 157679
Catchment: Mulkear	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 656.3 km^2

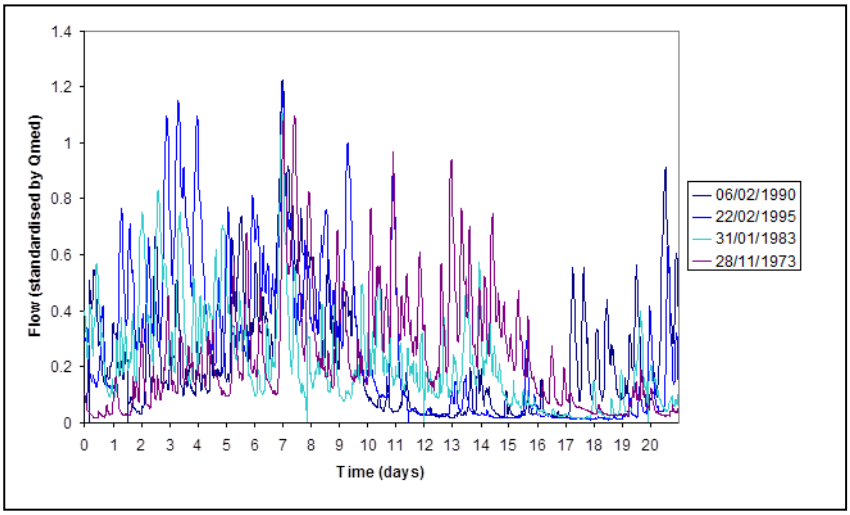
QMED (gauged): 125.7 m^3/s	**AREA:** 656.3 km^2
QMED (synthetic urban): 146.1 m^3/s	**SAAR:** 1163
QMED (CFRAM revised): 126.4 m^3/s	**FARL:** 0.99
BFIsoils: 0.52	**S1085:** 4.06
URBEXT: 0.69	**ARTDRAIN2:** 4.67
DRAIND: 1.37	

Comments:
Velocity area station installed in 1940 and automated in 1953. Gravel bed. Excavation for flood relief scheme in 1997 and 1999 doesn't appear to have any significant effect on stage discharge relationship. This station has been subject to a CFRAM rating review.

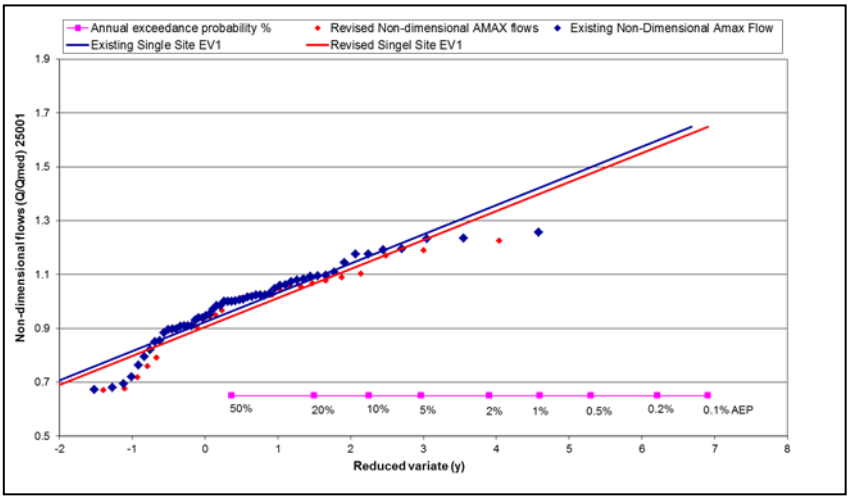
Nearby AFAs: Limerick City

Jacobs Rating Review: Yes	**FSU Station Classification:** A2

Normalised Hydrographs



Flood Frequency (EV1 with Gringorten plotting positions)



25003 – MULKEAR AT ABINGTON

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1954	77.0	84.1	31/12/1954
1955	65.0	70.4	13/01/1956
1956	78.7	86.1	24/09/1957
1957	68.7	74.7	29/10/1957
1958	63.4	68.6	05/11/1958
1959	71.4	77.8	14/09/1960
1960	83.9	92.2	04/12/1960
1961	77.0	84.1	02/04/1962
1962	60.3	65.0	08/12/1962
1963	78.7	86.1	30/10/1963
1964	86.8	95.8	12/12/1964
1965	88.6	98.1	09/12/1965
1966	78.1	85.4	22/02/1967
1967	83.9	92.2	06/10/1967
1968	92.8	103.4	24/12/1968
1969	67.6	73.4	21/02/1970
1970	61.3	66.2	19/11/1970
1971	68.2	74.0	20/11/1971
1972	69.0	75.0	12/11/1972
1973	74.7	81.6	29/11/1973
1974	74.7	81.6	22/01/1975
1975	73.1	79.7	30/01/1976
1976	50.6	53.9	12/10/1976
1977	70.3	74.0	21/04/1978
1978	66.8	70.1	27/12/1978
1979	70.9	74.7	25/10/1979
1980	64.4	67.4	22/10/1980
1981	53.7	55.3	13/12/1981
1982	77.6	82.2	31/01/1983
1983	83.9	89.4	06/02/1984
1984	50.6	51.7	14/08/1985
1985	77.6	82.2	06/08/1986
1986	59.8	62.1	19/11/1986
1987	59.0	61.2	01/02/1988
1988	48.9	52.0	24/03/1989
1989	74.2	80.9	06/02/1990
1990	58.7	63.2	16/11/1990
1991	62.3	67.4	12/09/1992
1992	67.4	73.1	30/09/1993
1993	70.3	76.5	03/04/1994
1994	77.8	85.1	27/12/1994
1995	64.2	69.5	11/02/1996
1996	67.1	72.8	04/08/1997
1997	72.5	79.0	06/03/1998
1998	72.3	78.7	28/02/1999
1999	60.3	65.0	05/06/1999
2000	76.4	83.5	06/11/2000
2001	61.8	66.8	26/02/2002
2002	54.7	58.7	02/12/2002
2003	58.2	62.7	14/11/2003
2004	66.8	72.5	08/01/2005
2005	56.7	60.9	21/05/2006
2006	55.0	58.9	04/12/2006
2007	63.4	68.6	19/01/2008
2008	64.4	69.8	31/01/2009
2009	65.0	70.4	01/11/2009

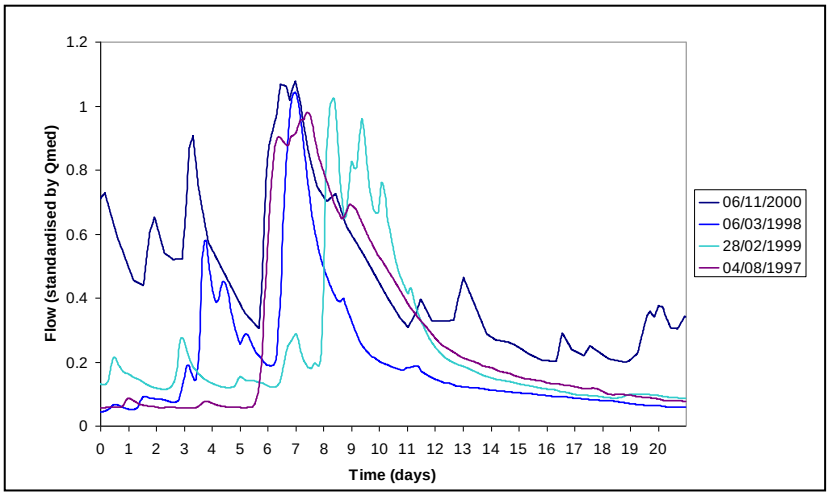
Length of AMAX series: 56 years

Model rating has a good fit with existing OPW rating. New set of rating equations is considered an improvement over the existing OPW rating for the range of AMAX values.

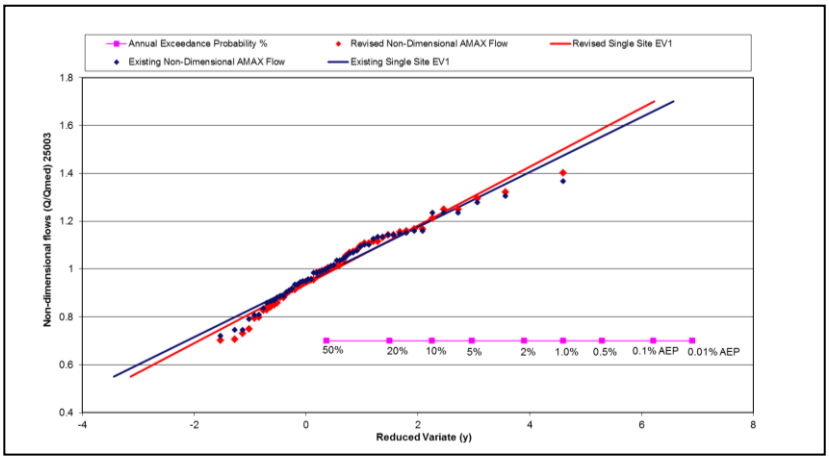
Gauging Authority: Office of Public Works	
Easting: 171538	**Northing:** 153428
Catchment: Mulkear	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 399.1 km^2

QMED (gauged): 67.9 m^3/s	**AREA:** 399.1km^2
QMED (synthetic urban): 68.7 m^3/s	**SAAR:** 1106
QMED (CFRAM revised): 73.7 m^3/s	**FARL:** 1.00
BFIsoils: 0.55	**S1085:** 5.34
URBEXT: 0.58	**ARTDRAIN2:** 3.00
DRAIND: 1.37	
Comments: Velocity-area station installed in 1940 and automated in 1954. Bridge location. Natural channel control. Weed growth effects low flows in summer and autumn.	
Nearby AFAs: Cappamore	
Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Normalised Hydrographs



Flood Frequency (EV1 with Gringorten plotting positions)



25006 – BROSNA AT FERBANE

Annual Maxima Series

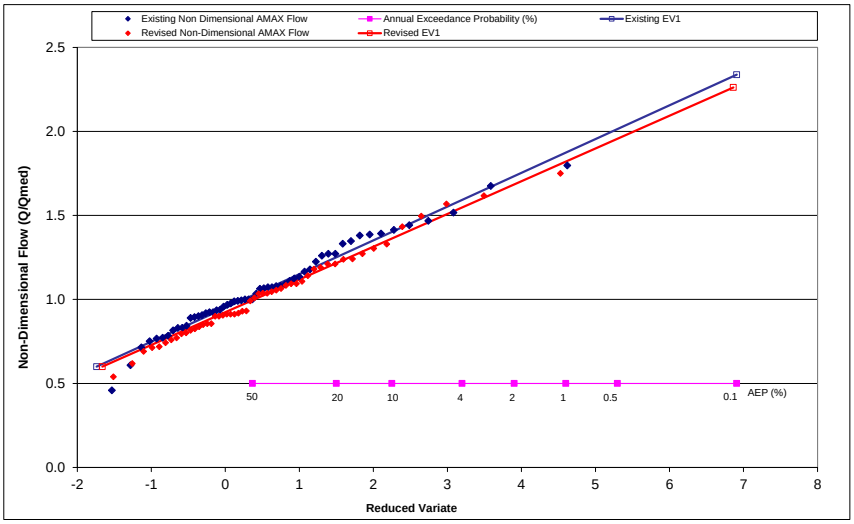
Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953	96.5		05/12/1953
1954	147.2		09/12/1954
1955	78.3		26/01/1956
1956	103.2		24/01/1957
1957	113.5		10/02/1958
1958*	76.9	76.9	07/01/1959
1959*	113.0	113.0	28/12/1959
1960*	118.1	118.1	04/12/1960
1961*	58.5	58.5	11/12/1961
1962*	69.0	69.0	06/11/1962
1963*	79.9	79.9	21/11/1963
1964*	114.0	114.0	13/12/1964
1965*	100.2	100.2	18/11/1965
1966*	120.2	120.2	28/02/1967
1967*	109.0	109.0	09/01/1968
1968*	137.2	137.2	26/12/1968
1969*	88.5	88.5	25/04/1970
1970*	68.0	68.0	28/11/1970
1971*	63.2	63.2	19/01/1972
1972	37.6	37.6	19/11/1972
1973	84.6	84.6	30/01/1974
1974	81.9	81.9	22/01/1975
1975	49.8	49.8	02/12/1975
1976	87.1	87.1	23/02/1977
1977	73.3	73.3	04/02/1978
1978	81.9	78.0	28/12/1978
1979	76.6	72.8	27/12/1979
1980	66.8	63.3	20/12/1980
1981	75.2	71.4	03/01/1982
1982	75.7	71.9	01/02/1983
1983	87.8	80.0	17/01/1984
1984	68.0	60.8	16/08/1985
1985	79.2	71.7	26/08/1986
1986	81.4	73.8	19/12/1986
1987	80.9	73.3	19/01/1988
1988	61.5	54.6	22/10/1988
1989	124.2	114.5	09/02/1990
1990	72.8	65.5	06/01/1991
1991	90.9	82.9	06/01/1992
1992	92.1	84.1	15/06/1993
1993	87.8	80.0	27/02/1994
1994	115.8	105.9	29/01/1995
1995	73.8	66.4	12/02/1996
1996	62.8	62.8	26/02/1997
1997	81.2	81.2	18/10/1997
1998	75.7	75.7	16/01/1999
1999	92.9	92.9	25/12/1999
2000	89.3	89.4	07/11/2000
2001	88.3	88.3	12/02/2002
2002	81.9	81.9	15/11/2002
2003	74.2	74.2	16/01/2004
2004	104.1	102.8	09/01/2005
2005	64.1	64.1	22/05/2006
2006	87.3	87.3	08/12/2006
2007	95.5	95.5	18/08/2008
2008	104.2	102.9	01/02/2009
2009	110.4	109.4	21/11/2009

* Flows 1958-1971 to be used with caution (rating uncertain)

Gauging Authority: Office of Public Works	
Easting: 211536	**Northing:** 224406
Catchment: Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 1163 km^2

QMED (gauged): 81.9	**AREA:** 1163 km^2
QMED (synthetic urban): 89.0 m^3/s	**SAAR:** 932 mm
QMED (CFRAM revised): 79.0 m^3/s (1972 to 2009)	**FARL:** 0.96
BFIsoils: 0.76	**S1085:** 0.75 m/km
URBEXT: 1.89 %	**ARTDRAIN2:** 51.0 %
DRAIND: 0.73	
Comments: Velocity-area station installed in 1940 and automated in 1947. Drainage works 1948-55. Stable sand/silt bed. Natural channel control. No check gaugings 1958-1969. *Catchment descriptors from FSU.*	
Nearby AFAs: Shannon Harbour and Pollagh	
Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 57 years
CFRAM Revised: 52 years

The CFRAM rating review suggests that the AMAX data of before 1958 may be affected by the drainage works from 1948 to 1955 and should not be used for flood estimation. AMAX flows from 1958 to 1971 should be used unaltered with caution (omitted for the QMED estimate as the record from 1972 is sufficiently long). AMAX flows from 1972 to 1977 have been used unaltered. Flows from 1977 onwards have been used with the revised CFRAM rating equations.

Further information can be found on the CFRAM Rating Review Summary Sheet for this station.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	N/A
Condition of structure	N/A

Gauging Station location description	On the right bank downstream of the N62 road bridge at Ferbane.
Describe potential for flow bypassing gauging station	Low probability of bypass, as the channel capacity at this location is very good.
Describe **left** bank **upstream** condition	The bank is very steep and well defined. There are trees and dense shrubbery on the bank. These trees encroach into the river.
Describe **right** bank **upstream** condition	The bank is very steep and well defined. There are trees and dense shrubbery on the bank. These trees encroach into the river.
Describe **left** bank **downstream** condition	The bank is very steep and well defined. It supports a path behind a secondary school.
Describe **right** bank **downstream** condition	The bank is very steep and well defined. There are trees and dense shrubbery on the bank. These trees encroach into the river.

25011 – BROSNA AT MOYSTOWN

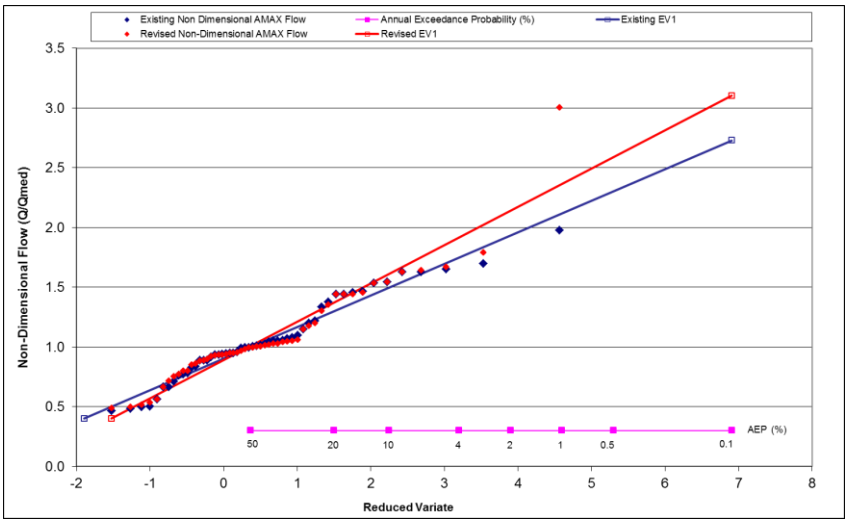
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954	194.3		09/12/1954
1955	106.3		26/01/1956
1956	98.7	98.7	24/01/1957
1957	118.8	118.8	11/02/1958
1958	77.6	77.6	07/01/1959
1959	133.9	133.9	28/12/1959
1960	83.5	83.5	04/12/1960
1961	54.6	54.6	16/01/1962
1962	46.5	46.5	08/12/1962
1963	41.1	41.1	31/10/1963
1964	82.0	82.0	13/12/1964
1965	86.6	86.6	13/12/1965
1966	94.6	94.6	28/02/1967
1967	82.8	82.8	09/01/1968
1968	118.8	118.8	26/12/1968
1969	73.2	73.2	26/04/1970
1970	63.6	63.6	29/11/1970
1971	41.4	44.2	03/02/1972
1972	38.3	40.1	12/12/1972
1973	73.2	72.9	30/01/1974
1974	77.9	76.6	25/01/1975
1975	40.0	42.4	02/12/1975
1976	82.0	79.8	23/02/1977
1977	64.2	65.8	02/04/1978
1978	76.8	76.9	28/12/1978
1979	75.4	75.8	15/12/1979
1980	58.4	62.1	20/12/1980
1981	69.0	70.7	01/03/1982
1982	79.0	78.6	02/01/1983
1983	83.2	81.8	17/01/1984
1984	87.0	84.8	15/12/1984
1985	68.3	70.2	26/08/1986
1986	85.9	83.9	19/12/1986
1987	78.3	78.1	02/03/1988
1988	54.6	58.9	15/03/1989
1989	126.3	126.3	02/09/1990
1990	76.8	76.9	01/06/1991
1991	81.6	80.7	01/06/1992
1992	86.6	84.5	15/06/1993
1993	90.6	87.5	28/02/1994
1994	135.9	137.5	29/01/1995
1995	62.9	65.8	13/02/1996
1996	78.3	78.1	26/02/1997
1997	88.2	85.7	01/09/1998
1998	89.0	86.3	16/01/1999
1999	119.7	118.7	26/12/1999
2000	109.8	107.4	07/11/2000
2001	113.4	111.5	12/02/2002
2002	100.4	96.8	16/11/2002
2003	84.3	82.7	16/01/2004
2004	133.9	135.2	09/01/2005
2005	73.21	74.1	22/05/2006
2006	127.20	127.4	08/12/2006
2007	120.74	119.9	21/01/2008
2008	139.84	147.5	01/02/2009
2009	162.65	247.6	21/11/2009

Gauging Authority: Office of Public Works	
Easting: 204607	**Northing:** 220857
Catchment: Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 1180 km^2

QMED (gauged): 82.8 m^3/s	**AREA (FSU):** 1180 km^2
QMED (synthetic urban): 88.7 m^3/s	**SAAR:** 931 mm
QMED (CFRAM revised): 81.9m^3/s	**FARL:** 0.96
BFIsoils (FSU): 0.71	**S1085:** 0.69 m/km
URBEXT: 1.93 %	**ARTDRAIN2:** 51.0 %
DRAIND: 0.72	
Comments: Automated velocity-area station installed in 1939 and automated in 1951. Stable bed. Seasonal weed growth. Natural channel. Bridge downstream. *Catchment descriptors from FSU.*	
Nearby AFAs: Shannon Harbour	
Jacobs Rating Review: Yes	**FSU Station Classification:** B

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 56 years
CFRAM Revised: 54 years

Due to scatter in the check gaugings this station should be used with caution. Station 25006 (Ferbane, 9 km upstream) is more suitable for at-site flood frequency analysis than this station.

AMAX data from before 1956 should not be used due to the effects of drainage works (1948-1955).

Refer to the CFRAM Rating Review Summary Sheet for more details.

Gauging Hut

Picture not available

Channel looking upstream

Channel looking downstream

Picture not available

Structure Details	
Type of Structure:	N/A
Condition of structure	N/A

Gauging Station location description	On the left bank downstream of the road bridge over the Brosna (unconfirmed).
Describe potential for flow bypassing gauging station	Low, channel upstream seems to have significant capacity and high banks. There could be some risk of out of bank flows bypassing the station.
Describe **left** bank **upstream** condition	The bank is steep and high, providing good in channel capacity. The bank is heavily vegetated with a heavy line of trees. The trees encroach on the river channel significantly.
Describe **right** bank **upstream** condition	The bank is steep and high, providing good in channel capacity. The bank is heavily vegetated with a heavy line of trees. The trees encroach on the river channel significantly.
Describe **left** bank **downstream** condition	Not observed due to lack of access, no reason to believe that there is any change from the upstream condition.
Describe **right** bank **downstream** condition	Not observed due to lack of access, no reason to believe that there is any change from the upstream condition.

25013 – BROSNA AT NEWELL'S BR.

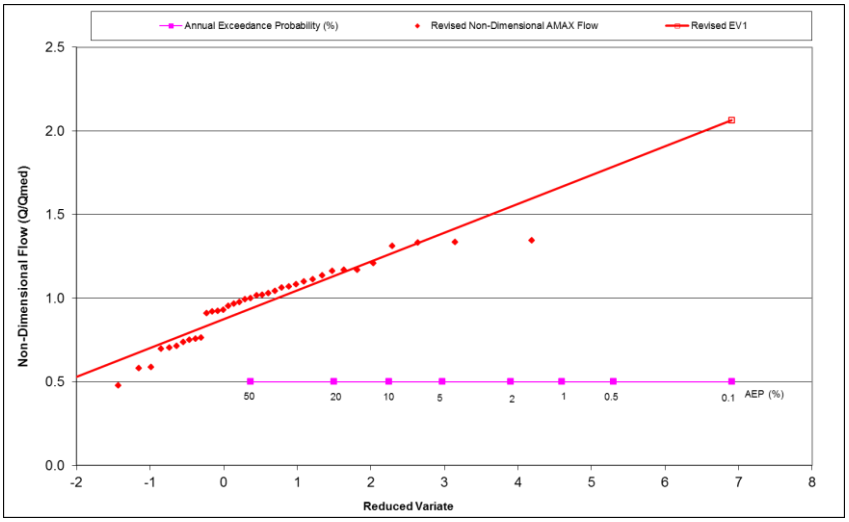
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972			
1973	N/A	12.2	30/01/1974
1974	N/A	13.1	25/01/1975
1975	N/A	7.7	02/12/1975
1976	N/A	13.9	23/02/1977
1977	N/A	11.9	04/02/1978
1978	N/A	14.9	28/12/1978
1979	N/A	17.5	15/12/1979
1980	N/A	14.2	07/10/1980
1981	N/A	9.1	03/01/1982
1982	N/A	12.1	31/01/1983
1983	N/A	9.2	07/02/1984
1984	N/A	13.6	15/12/1984
1985	N/A	13.4	26/08/1986
1986	N/A	12.0	18/12/1986
1987	N/A	13.3	24/01/1988
1988	N/A	10.0	26/10/1988
1989	N/A	17.6	06/02/1990
1990	N/A	13.0	06/01/1991
1991	N/A	12.5	08/01/1992
1992	N/A	9.7	15/06/1993
1993	N/A	9.9	03/01/1994
1994	N/A	17.2	31/01/1995
1995	N/A	7.6	12/02/1996
1996	N/A	9.4	26/02/1997
1997	N/A	14.4	18/10/1997
1998	N/A	14.0	24/10/1998
1999	N/A	13.5	25/12/1999
2000	N/A	15.2	06/11/2000
2001	N/A	15.3	11/02/2002
2002	N/A	12.6	15/11/2002
2003	N/A	9.8	17/01/2004
2004	N/A	12.8	08/01/2005
2005	N/A	6.3	22/05/2006
2006	N/A	15.3	11/12/2006
2007	N/A	15.8	17/08/2008
2008	N/A	14.5	20/08/2009
2009	N/A	17.4	20/11/2009

Gauging Authority: Office of Public Works	
Easting: 238327	**Northing:** 242315
Catchment: Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 188 km^2

QMED (gauged): N/A m^3/s	**AREA (FSU):** 210 km^2
QMED (synthetic urban): 11.5 m^3/s	**SAAR:** 954 mm
QMED (CFRAM revised): 13.1 m^3/s	**FARL:** 0.78
BFIsoils (FSU): 0.84	**S1085:** 2.26 m/km
URBEXT: 3.53 %	**ARTDRAIN2:** 58.8 %
DRAIND: 0.55	
Comments: Automated velocity-area station installed in 1939 and automated in 1951. Stable bed. Seasonal weed growth. Natural channel. Bridge downstream. *Catchment descriptors from FSU.*	
Nearby AFAs: Kilbeggan and Mullingar	
Jacobs Rating Review: Yes	**FSU Station Classification:** None

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 37 years
CFRAM Revised: 37 years

Prior to the CFRAM project only an AMAX level series was available at this site. The CFRAM rating review highlighted that there is little confidence in any rating at this site due to the large scatter in the check gaugings. It is recommended that this station is not used for design flow estimation. More details can be found on the CFRAM Rating Review Summary Sheet for this station.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	N/A
Condition of structure	N/A

Gauging Station location description	On the left bank downstream of the road bridge over the River Brosna.
Describe potential for flow bypassing gauging station	Water may go out of bank upstream of the bridge. It is unlikely that the road would be overtopped so any water returning to the watercourse would do so upstream of the station.
Describe **left** bank **upstream** condition	The bank is steep, well defined and generally clear of vegetation.
Describe **right** bank **upstream** condition	The bank is approximately at a 1 to 1 slope, well defined and has some long grass growing on it. Beyond the immediate bank there are short grassed fields.
Describe **left** bank **downstream** condition	The bank is steep and well defined. There are some trees and shrubbery growing on and around the bank downstream of the station. Generally, land is slightly higher downstream compared to upstream. There appears to be some forestry further downstream (conifers).
Describe **right** bank **downstream** condition	The bank is steep and well defined. There is a small cluster of conifers growing on the bank. Generally, land is slightly higher downstream compared to upstream.

25014 – SILVER AT MILLBROOK

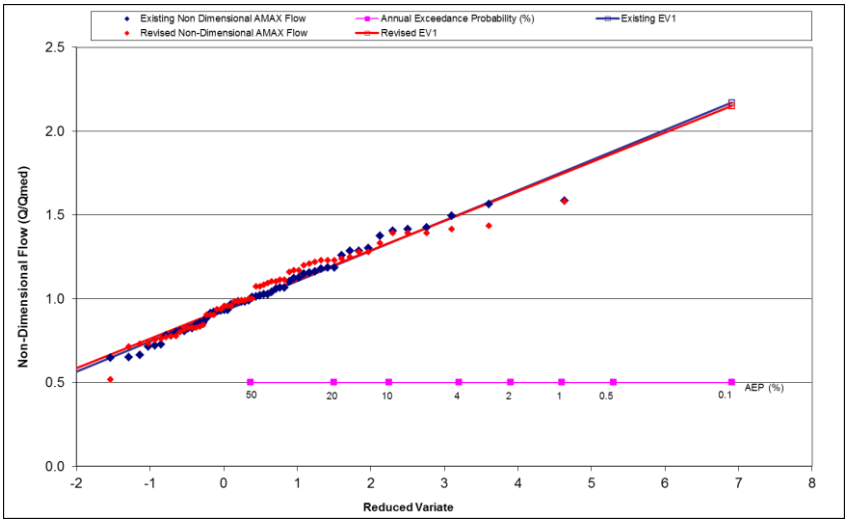
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951	20.0		24/12/1951
1952	11.1	10.4	18/09/1953
1953	16.8	16.5	03/12/1953
1954	21.9	22.4	08/12/1954
1955	15.7	15.3	06/09/1956
1956	19.9	20.0	30/12/1956
1957	23.4	24.2	10/02/1958
1958	19.2	19.3	19/12/1958
1959	23.9	24.8	27/12/1959
1960	26.7	28.1	03/12/1960
1961	15.9	15.5	28/09/1962
1962	16.9	16.7	05/11/1962
1963	17.2	17.0	30/10/1963
1964	24.1	25.0	13/12/1964
1965	21.9	22.4	17/11/1965
1966	21.5	21.8	27/02/1967
1967	19.7	19.8	08/01/1968
1968	27.0	28.5	24/12/1968
1969	24.3	25.2	25/04/1970
1970	16.5	16.2	23/11/1970
1971	14.6	20.2	19/01/1972
1972	15.9	22.2	20/01/1973
1973	20.1	28.9	30/01/1974
1974	18.2	25.8	22/01/1975
1975	13.7	18.2	17/05/1976
1976	16.8	23.6	22/02/1977
1977	16.7	23.4	22/02/1978
1978	17.4	24.6	01/02/1979
1979	17.5	24.8	31/01/1980
1980	17.3	24.4	19/12/1980
1981	14.0	19.3	03/01/1982
1982	18.8	26.8	02/05/1983
1983	14.0	19.3	17/01/1984
1984	18.1	14.7	15/12/1984
1985	25.5	21.7	26/08/1986
1986	19.1	15.7	05/04/1987
1987	20.2	16.7	19/01/1988
1988	17.7	14.4	22/10/1988
1989	20.2	28.1	07/02/1990
1990	12.2	15.7	25/12/1990
1991	15.1	20.0	05/01/1992
1992	15.6	21.7	13/06/1993
1993	13.3	18.2	28/02/1994
1994	19.6	28.1	29/01/1995
1995	11.3	15.2	09/02/1996
1996	14.4	19.8	11/05/1997
1997	15.9	22.2	18/10/1997
1998	13.3	18.2	30/12/1998
1999	14.6	20.2	22/12/1999
2000	15.8	22.0	06/11/2000
2001	12.3	16.7	11/02/2002
2002	11.1	14.8	15/11/2002
2003	12.4	16.8	16/01/2004
2004	17.5	24.8	08/01/2005
2005	13.8	18.9	22/05/2006
2006	13.8	18.9	08/12/2006
2007	16.8	23.5	18/08/2008
2008	22.2	31.8	01/02/2009
2009	18.2	25.8	20/11/2009

Gauging Authority: Office of Public Works	
Easting: 213546	**Northing:** 218813
Catchment: Silver	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 153 km^2

QMED (gauged): 17.2 m^3/s	**AREA (FSU):** 164 km^2
QMED (synthetic urban): 26.5 m^3/s	**SAAR:** 1008 mm
QMED (CFRAM revised): 20.2 m^3/s	**FARL:** 1.00
BFIsoils (FSU): 0.64	**S1085:** 5.90 m/km
URBEXT: 0.47 %	**ARTDRAIN2:** 37.0 %
DRAIND: 0.91	
Comments: Automated velocity-area station installed in 1939 and automated in 1951. Stable bed. Seasonal weed growth. Natural channel. Bridge downstream. *Catchment descriptors from FSU.*	
Nearby AFAs: Pollagh	
Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 59 years
CFRAM Revised: 58 years

The AMAX series has been revised from 1952. The AMAX flow of 1951 should be ignored due to drainage works which where completed in that year. More details can be found on the CFRAM Rating Review Summary Sheet for this station.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	N/A
Condition of structure	N/A

Gauging Station location description	On the right bank just downstream of the road bridge
Describe potential for flow bypassing gauging station	Low. Channel capacity is good, there may be some constriction in high flows at the bridge but no obvious alternative flow paths.
Describe **left** bank **upstream** condition	The bank is steep and high, providing good in channel capacity. The bank is heavily vegetated including trees. This vegetation and trees encroach on the river channel.
Describe **right** bank **upstream** condition	The bank is steep and high, providing good in channel capacity. The bank is heavily vegetated including trees. This vegetation and trees encroach on the river channel.
Describe **left** bank **downstream** condition	The bank is steep and high, providing good in channel capacity. The bank is heavily vegetated. This vegetation encroaches on the river channel. There are some trees on this bank.
Describe **right** bank **downstream** condition	The bank is steep and high, providing good in channel capacity. The bank is heavily vegetated including trees. This vegetation and trees encroach on the river channel.

25016 – CLODIAGH AT RAHAN

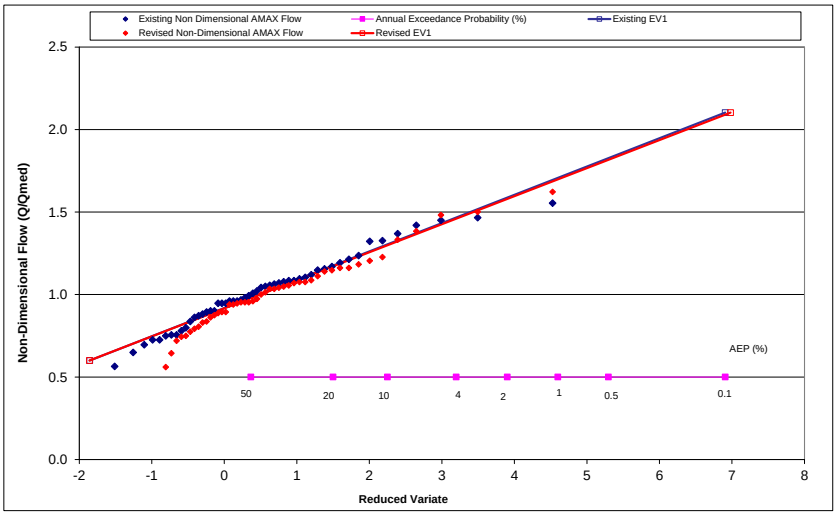
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954	26.6		09/12/1954
1955	N/A		N/A
1956	N/A		N/A
1957	N/A		N/A
1958	20.3		20/12/1958
1959	30.7		27/12/1959
1960	33.0		04/12/1960
1961	23.1		30/09/1962
1962	25.7		05/11/1962
1963	22.0	22.0	30/10/1963
1964	26.9	26.9	12/12/1964
1965	24.2	24.2	18/11/1965
1966	25.0	25.0	06/10/1966
1967	27.7	27.7	09/01/1968
1968	33.7	34.7	25/12/1968
1969	20.9	20.9	21/02/1970
1970	16.9	16.9	23/11/1970
1971	17.6	17.6	19/01/1972
1972	16.2	18.1	15/07/1973
1973	22.0	24.2	30/01/1974
1974	20.0	22.2	25/01/1975
1975	16.9	18.9	03/10/1975
1976	17.6	19.6	23/02/1977
1977	18.1	20.2	31/10/1977
1978	24.9	27.2	28/12/1978
1979	20.5	20.5	25/12/1979
1980	17.4	17.4	23/10/1980
1981	13.1	13.1	04/01/1982
1982	15.1	15.1	06/11/1982
1983	22.8	22.8	09/12/1983
1984	25.2	25.2	15/12/1984
1985	23.8	23.8	26/08/1986
1986	22.3	22.3	15/12/1986
1987	24.6	24.6	21/10/1987
1988	20.9	20.9	22/10/1988
1989	36.1	38.0	08/02/1990
1990	22.0	22.0	25/12/1990
1991	24.4	24.4	06/01/1992
1992	28.7	28.7	15/06/1993
1993	26.0	26.0	27/02/1994
1994	34.1	35.2	29/01/1995
1995	18.6	18.6	04/01/1996
1996	19.4	19.4	20/02/1997
1997	27.2	27.2	18/10/1997
1998	23.4	23.4	16/01/1999
1999	26.7	26.7	25/12/1999
2000	25.2	25.2	06/11/2000
2001	22.3	22.3	01/02/2002
2002	30.8	31.2	29/10/2002
2003	20.8	20.8	16/01/2004
2004	25.5	25.5	08/01/2005
2005	22.3	22.3	22/05/2006
2006	22.5	22.5	08/12/2006
2007	31.8	32.4	18/08/2008
2008	24.7	24.7	01/02/2009
2009	28.2	28.2	20/11/2009

Gauging Authority: Office of Public Works	
Easting: 225669	**Northing:** 225645
Catchment: Clodiagh	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 254 km^2

QMED (gauged): 23.4 m^3/s	**AREA (FSU):** 275 km^2
QMED (synthetic urban): 40.2 m^3/s	**SAAR:** 947 mm
QMED (CFRAM revised): 23.4 m^3/s (1963-2009)	**FARL:** 1.00
BFIsoils (FSU): 0.66	**S1085:** 6.00 m/km
URBEXT: 2.75%	**ARTDRAIN2:** 53.0 %
DRAIND: 0.65	
Comments: Velocity-area station installed in 1939 and automated in 1951. Bridge location. Seasonal weed growth. Natural channel control. Stable bed consisting of mud/silt/sand. *Catchment descriptors from FSU.*	
Nearby AFAs: Rahan, Pollagh and Clara	
Jacobs Rating Review: Yes	**FSU Station Classification:** B

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 53 years
CFRAM Revised: 47 years

It is recommended that only AMAX data from 1963 is used for flood estimation. More details can be found on the CFRAM Rating Review Summary Sheet for this station.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	N/A
Condition of structure	N/A

Gauging Station location description	Station on right bank downstream of bridge in Rahan
Describe potential for flow bypassing gauging station	Low risk of bypassing. Channel capacity approaching the station is good. The road and bridge beyond the station will not be overtopped. There may be some potential for water to get out of bank and not return to the watercourse. If the relief arches were to be reopened or breached there could be some bypassing.
Describe **left** bank **upstream** condition	Dense hedgerow and trees, with well defined bank line
Describe **right** bank **upstream** condition	Well defined bank, grassed wedge beyond which is agricultural land.
Describe **left** bank **downstream** condition	Well defined bank, grassed wedge beyond which is agricultural land. Some trees and embankments
Describe **right** bank **downstream** condition	Dense hedgerow and trees, with well defined bank line. There are some properties extending up to the bank.

25017 – SHANNON AT BANAGHER

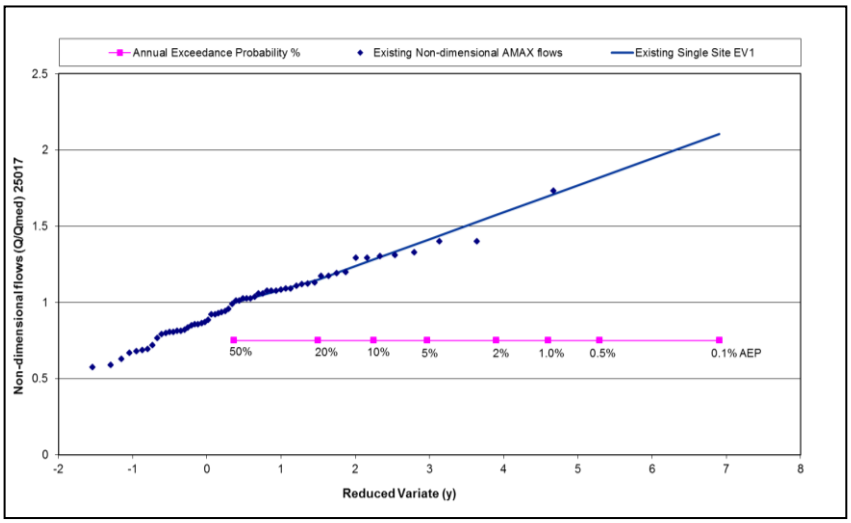
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1950	337.0		05/02/1951
1951	430.5		02/01/1952
1952	267.9		29/12/1952
1953	354.8		28/02/1954
1954	596.5		10/12/1954
1955	283.8		31/01/1956
1956	450.6		05/01/1957
1957	363.9		15/02/1958
1958	342.9		07/01/1959
1959	550.6		28/12/1959
1960	457.4		06/12/1960
1961	366.9		14/12/1961
1962	291.9		13/12/1962
1963	440.5		27/11/1963
1964	506.5		20/01/1965
1965	510.1		10/12/1965
1966	370.0		01/03/1967
1967	464.3		17/01/1968
1968	499.3		22/01/1969
1969	363.9		26/02/1970
1970	391.7		29/11/1970
1971	289.2		11/04/1972
1972	245.0		16/12/1972
1973	391.7		17/01/1974
1974	471.2		29/01/1975
1975	305.6		12/01/1976
1976	437.2		23/02/1977
1977	345.9		06/02/1978
1978	401.3		16/12/1978
1979	457.4		17/12/1979
1980	376.1		26/12/1980
1981	394.9		16/03/1982
1982	407.7		10/01/1983
1983	457.4		18/01/1984
1984	348.8		27/12/1984
1985	360.8		24/01/1986
1986	460.9		22/12/1986
1987	499.3		04/02/1988
1988	325.4		16/03/1989
1989	558.1		09/02/1990
1990	481.6		08/01/1991
1991	345.9		09/01/1992
1992	398.1		07/12/1992
1993	437.2		04/01/1994
1994	550.6		02/02/1995
1995	294.6		19/02/1996
1996	437.2		26/02/1997
1997	420.7		10/01/1998
1998	430.5		20/01/1999
1999	565.7		27/12/1999
2000	478.1		14/12/2000
2001	554.3		13/02/2002
2002	340.0		11/11/2002
2003	342.9		08/02/2004
2004	476.4		11/01/2005
2005	250.0		17/01/2006
2006	596.5		16/12/2006
2007	464.3		24/01/2008
2008	450.6		02/02/2009
2009	736.4		27/11/2009

Gauging Authority: Office of Public Works	
Easting: 200506	**Northing:** 215829
Catchment: Lower Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 7980 km^2

QMED (gauged): 426 m^3/s	**AREA (FSU):** 7980 km^2
QMED (synthetic urban): 325 m^3/s	**SAAR:** 1024.05
QMED (CFRAM revised): not revised	**FARL:** 0.79
BFIsoils: 0.65	**S1085:** 0.25
URBEXT: 0.82	**ARTDRAIN2:** 20.9
DRAIND: 0.81	
Comments: Catchment descriptors from FSU data.	
Nearby AFAs: N/A	
Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions)



Structure control

Photo not available

Channel looking upstream

Photo not available

Channel looking downstream

Photo unavailable

Structure Details	
Type of Structure:	Multi arch bridge
Condition of structure	Good

Gauging Station location description	Station on right bank upstream of the bridge over the Shannon at Banagher
Describe potential for flow bypassing gauging station	Low/Medium. The bridge upstream will act as a barrier to flows so the alternative flow path is not evident
Describe **left** bank **upstream** condition	There is a marina on the left bank, further upstream there are some properties but generally farmland with shallow banks
Describe **right** bank **upstream** condition	Shallow banks supporting agricultural land.
Describe **left** bank **downstream** condition	Well defined bank, grassed wedge beyond which is agricultural land. Some trees and embankments.
Describe **right** bank **downstream** condition	Shallow banks with agricultural land. There is a castle and pitch and putt course adjacent to the gauging station.

25021 – LITTLE BROSNA AT CROGHAN

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961	24.3	24.3	10/12/1961
1962	35.8	35.8	05/11/1962
1963	23.9	23.9	30/10/1963
1964	29.5	29.5	12/12/1964
1965	26.4	26.4	18/12/1964
1966	26.8	26.8	06/10/1966
1967	26.2	26.2	09/01/1968
1968	31.1	31.1	26/12/1968
1969	20.9	20.9	25/04/1970
1970	22.4	22.4	28/11/1970
1971	23.0	23.0	02/02/1972
1972	24.1	24.1	19/01/1973
1973	30.1	30.1	01/12/1973
1974	29.5	29.5	26/01/1975
1975	22.1	22.1	04/10/1975
1976	25.1	25.1	22/02/1977
1977	22.3	22.3	22/02/1978
1978	29.1	29.1	15/12/1978
1979	26.8	26.8	27/12/1979
1980	28.6	28.6	19/12/1980
1981	25.7	25.7	03/01/1982
1982	30.6	30.6	01/02/1983
1983	31.2	31.2	16/01/1984
1984	28.4	28.4	16/08/1985
1985	32.7	32.7	26/08/1986
1986	28.6	28.6	18/12/1986
1987	29.8	29.8	13/02/1988
1988	25.3	25.3	23/10/1988
1989	32.3	32.3	08/02/1990
1990	26.2	26.2	31/12/1990
1991	27.0	27.0	06/01/1992
1992	32.9	32.9	13/06/1993
1993	29.3	29.3	27/02/1994
1994	33.1	33.1	28/01/1995
1995	29.2	29.2	12/02/1996
1996	26.0	26.0	25/02/1997
1997	32.5	32.5	19/10/1997
1998	30.4	30.4	02/11/1998
1999	33.3	33.3	25/12/1999
2000	35.3	35.3	06/11/2000
2001	31.2	31.2	11/02/2002
2002	29.2	29.2	15/11/2002
2003	18.2	18.2	15/01/2004
2004	21.7	21.7	08/01/2005
2005	28.0	28.0	03/11/2005
2006	31.8	31.8	11/12/2006
2007	28.0	28.0	03/11/2007
2008	32.7	32.7	31/01/2009
2009	34.6	34.6	23/11/2009

Gauging Authority: Office of Public Works	
Easting: 205365	**Northing:** 205654
Catchment: Little Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 479.2 km^2

QMED (gauged): 29.10 m^3/s	**AREA:** 479.2 km^2
QMED (synthetic urban): 49.2 m^3/s	**SAAR:** 928
QMED (CFRAM revised): N/A	**FARL:** 0.99
BFIsoils: 0.58	**S1085:** 1.49
URBEXT: 1.25	**ARTDRAIN2:** 0
DRAIND: 0.77	

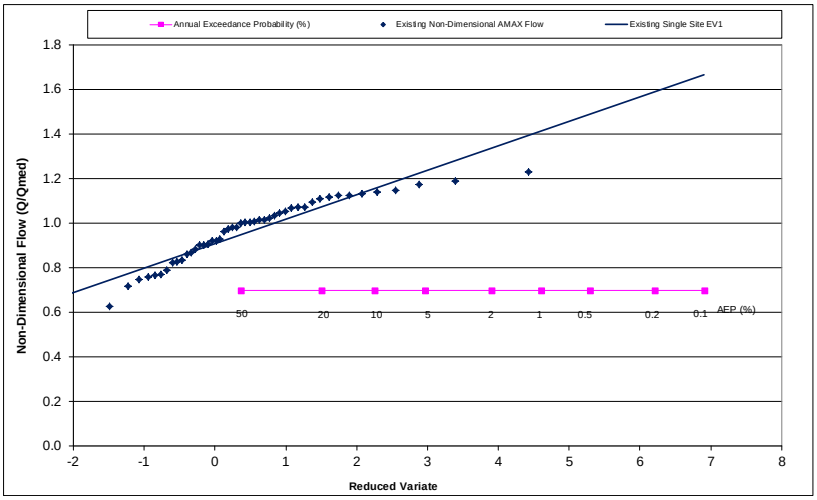
Comments:
OPW rating is subject to uncertainty due to scatter in the check guagings. Jacobs revised rating is not considered to be improvement. OPW rating remains unchanged.

Catchment descriptors from FSU data.

Nearby AFAs: Birr

Jacobs Rating Review: Yes	**FSU Station Classification:** A2

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 47 years

Sedimentation is thought to be a problem at this site.

The OPW rating based AMAX series remain unchanged.
Based on the results of rating review, this site should not be used for single site or flood frequency analysis.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	There is a 3 arch bridge upstream of the station
Condition of structure	Good

Gauging Station location description	On the right bank of local road north of Birr.
Describe potential for flow bypassing gauging station	Low/Medium, The road upstream of the station would not be overtopped.
Describe **left** bank **upstream** condition	The bank is steep with trees and shrubbery growing on it. The area upstream of the station is generally overgrown parkland.
Describe **right** bank **upstream** condition	The bank is steep with a lot of trees and shrubbery growing on it. The area upstream of the station is generally overgrown parkland.
Describe **left** bank **downstream** condition	The bank is in good condition with steep banks, there are trees growing on top of the bank which supports agricultural land.
Describe **right** bank **downstream** condition	The bank is in good condition with steep banks, there are trees growing on top of the bank which supports agricultural land.

25022 – CAMCOR AT SYNGEFIELD

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953	27.4	27.39	03/12/1953
1954	33.6	33.61	07/02/1955
1955	26.2	26.15	13/12/1955
1956	23.6	23.55	30/12/1956
1957	38.9	38.95	24/09/1958
1958	31.4	31.37	18/12/1958
1959	30.4	30.37	14/09/1960
1960	33.8	33.77	04/12/1960
1961	31.0	31.03	30/09/1962
1962	35.2	35.21	05/11/1962
1963	26.7	26.71	30/10/1963
1964	32.3	32.29	12/12/1964
1965	39.3	39.26	12/06/1966
1966	42.8	42.77	06/10/1966
1967	27.2	27.15	09/01/1968
1968	40.3	40.30	24/12/1968
1969	27.6	27.60	25/04/1970
1970	23.6	23.65	19/11/1970
1971	24.9	24.93	03/02/1972
1972	28.0	28.03	19/01/1973
1973	32.5	32.48	08/01/1974
1974	32.8	32.79	25/01/1975
1975	23.0	23.02	17/05/1976
1976	21.4	21.91	10/02/1977
1977	23.3	24.08	31/10/1977
1978	23.6	25.25	07/12/1978
1979	22.0	22.66	21/09/1980
1980	24.6	25.51	19/12/1980
1981	18.5	18.75	03/01/1982
1982	24.9	25.78	31/01/1983
1983	25.2	26.20	09/12/1983
1984	22.8	23.47	15/08/1985
1985	32.6	34.56	26/08/1986
1986	24.0	24.78	08/12/1986
1987	26.9	28.99	19/01/1988
1988	29.2	31.58	22/10/1988
1989	36.1	39.65	06/02/1990
1990	22.6	24.14	24/11/1990
1991	23.8	25.51	25/11/1991
1992	30.3	32.85	12/06/1993
1993	25.5	26.20	25/02/1994
1994	35.1	38.55	28/01/1995
1995	25.8	27.73	24/10/1995
1996	19.5	20.66	01/09/1997
1997	29.1	31.54	17/10/1997
1998	23.1	24.69	29/12/1998
1999	25.0	26.78	25/12/1999
2000	30.0	32.55	06/11/2000
2001	23.0	24.54	26/02/2002
2002	22.1	23.53	22/11/2002
2003	20.3	21.58	15/01/2004
2004	26.3	28.32	08/01/2005
2005	19.6	20.76	03/11/2005
2006	21.3	22.68	12/08/2007
2007	29.4	31.88	17/08/2008
2008	33.8	36.99	31/01/2009
2009	24.1	25.87	01/11/2009

Gauging Authority: Office of Public Works	
Easting: 207996	**Northing:** 204655
Catchment: Little Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 147.9 km^2

QMED (gauged): 26.31 m^3/s	**AREA:** 147.9 km^2
QMED (synthetic urban): 25.54 m^3/s	**SAAR:** 998
QMED (CFRAM revised): 27.15 m^3/s	**FARL:** 1.00
BFIsoils: 0.61	**S1085:** 0.77
URBEXT: 0.26	**ARTDRAIN2:** 0
DRAIND: 0.87	

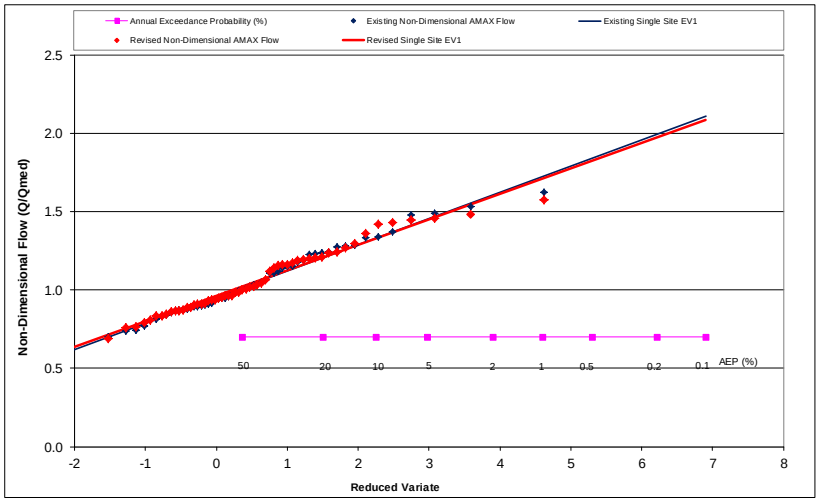
Comments:
Revised QMED is based on the entire AMAX values with revised rating curve applied to 1975 onward due to the relocation of the station.

Catchment descriptors from FSU data.

Nearby AFAs: Birr

Jacobs Rating Review: Yes	**FSU Station Classification:** B

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 57 years

The AMAX series from 1975 (post-relocations) was revised according to Jacobs rating review.

All of the AMAX flow series from 1953 to date can be used for QMED estimation and flood frequency analysis.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	There is a twin box culvert bridge upstream of the station.
Condition of structure	Good

Gauging Station location description	On the right bank upstream of the R440, east of Birr.
Describe potential for flow bypassing gauging station	Low. The channel has good capacity. The bridge upstream will reduce the likelihood of out of bank flows between the bridge and the station. Unsure if out of bank flows upstream of the bridge would be recorded. Channel capacity upstream is good.
Describe **left** bank **upstream** condition	The bank is steep with trees and shrubbery growing on it. There is a pumping station just upstream of the bridge.
Describe **right** bank **upstream** condition	The bank is steep with trees and shrubbery growing on it.
Describe **left** bank **downstream** condition	The bank is steep with trees and shrubbery growing on it.
Describe **right** bank **downstream** condition	The bank is steep with trees and shrubbery growing on it.

25023 – LITTLE BROSNA AT MILLTOWN

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972			
1973			
1974			
1975	10.5	N/A	05/02/1954
1976	10.2	N/A	12/08/1954
1977	11.5	N/A	09/06/1956
1978	10.1	N/A	30/12/1956
1979	8.5	N/A	25/02/1958
1980	10.0	N/A	20/12/1958
1981	10.0	N/A	30/12/1959
1982	11.0	N/A	12/04/1960
1983	5.7	N/A	30/09/1962
1984	9.7	N/A	11/06/1962
1985	8.6	N/A	31/11/1963
1986	9.5	N/A	14/12/1964
1987	6.6	N/A	29/01/1966
1988	9.3	N/A	28/02/1967
1989	12.4	N/A	01/09/1968
1990	17.6	N/A	25/12/1968
1991	8.6	N/A	22/02/1970
1992	9.5	N/A	29/11/1970
1993	7.6	N/A	23/02/1972
1994	8.0	N/A	20/01/1973
1995	17.7	N/A	26/11/1973
1996	13.4	N/A	25/01/1975
1997	11.1	N/A	12/02/1975
1998	12.0	N/A	20/02/1977
1999	14.3	N/A	30/02/1978
2000	14.9	N/A	15/12/1978
2001	12.0	N/A	27/12/1979
2002	13.1	N/A	02/09/1981
2003	12.6	N/A	29/12/1981
2004	13.0	N/A	11/09/1982
2005	17.3	N/A	17/01/1984
2006	11.4	N/A	16/08/1985
2007	18.2	N/A	26/08/1986
2008	18.6	N/A	16/12/1986
2009	12.9	N/A	02/03/1988

Gauging Authority: Office of Public Works	
Easting: 206952	**Northing:** 190914
Catchment: Little Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 113.9 km^2

QMED (gauged): 11.99 m^3/s	**AREA:** 113.9 km^2
QMED (synthetic urban): 12.23 m^3/s	**SAAR:** 923
QMED (CFRAM revised): N/A	**FARL:** 1.00
BFIsoils: 0.65	**S1085:** 2.85
URBEXT: 0.25	**ARTDRAIN2:** 0
DRAIND: 0.82	

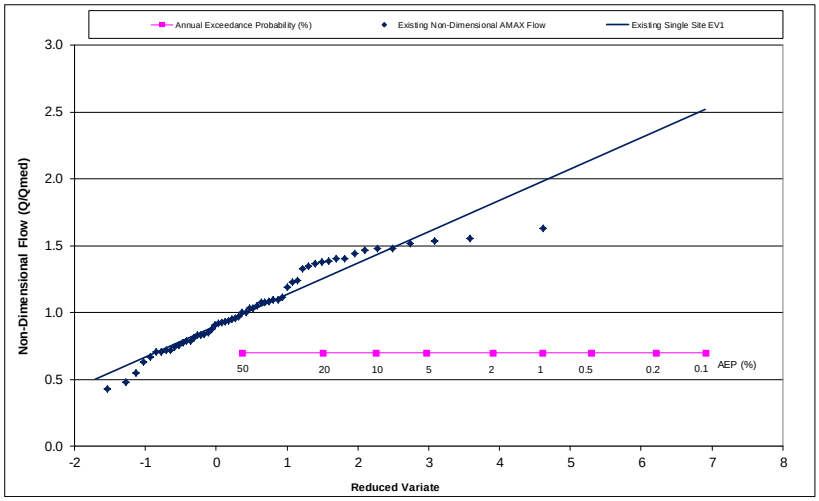
Comments:
Outside of the model extent; no Jacobs rating review

Catchment descriptors from FSU data.

Nearby AFAs: N/A

Jacobs Rating Review: No	**FSU Station Classification:** A2

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 57 years

OPW existing AMAX series are considered to be suitable for QMED estimation and flood frequency analysis.

Gauging Hut

Not available

Channel looking upstream

Not available

Channel looking downstream

Not available

Structure Details	
Type of Structure:	Not available
Condition of structure	Not available

Gauging Station location description	N/A
Describe potential for flow bypassing gauging station	N/A
Describe **left** bank **upstream** condition	N/A
Describe **right** bank **upstream** condition	N/A
Describe **left** bank **downstream** condition	N/A
Describe **right** bank **downstream** condition	N/A

25025 – BALLYFINBOY AT BALLYHOONEY

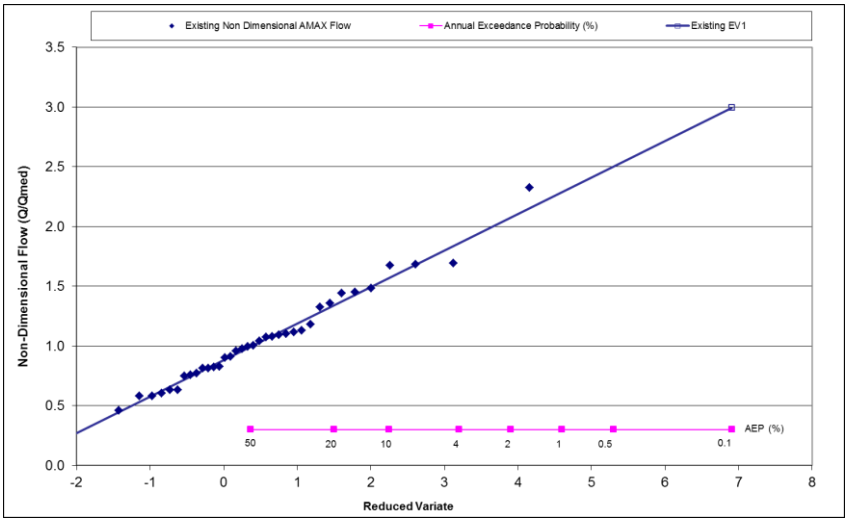
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972	6.0		12/12/1972
1973	11.6		02/12/1973
1974	10.8		27/01/1975
1975	6.0		05/01/1976
1976	8.4		23/02/1977
1977	6.6		05/02/1978
1978	11.2		16/12/1978
1979	9.5		28/12/1979
1980	7.8		20/12/1980
1981	8.4		05/01/1982
1982	10.4		09/01/1983
1983	N/A		N/A
1984	N/A		N/A
1985	6.3	6.3	26/08/1986
1986	8.6	8.6	18/12/1986
1987	9.4	9.4	04/02/1988
1988	4.8	4.8	28/03/1989
1989	13.8	13.8	08/02/1990
1990	8.0	8.0	02/01/1991
1991	8.6	8.6	06/01/1992
1992	7.9	7.9	14/06/1993
1993	11.5	11.5	24/12/1993
1994	17.4	17.4	31/01/1995
1995	10.2	10.2	12/02/1996
1996	14.1	14.1	08/08/1997
1997	11.4	11.4	08/01/1998
1998	11.2	11.2	05/01/1999
1999	15.1	15.1	26/12/1999
2000	11.8	11.8	03/11/2000
2001	12.3	12.3	11/02/2002
2002	10.0	10.0	29/10/2002
2003	10.4	10.4	15/01/2004
2004	15.4	15.4	08/01/2005
2005	6.6	6.6	04/11/2005
2006	15.0	15.0	15/12/2006
2007	17.6	17.6	21/01/2008
2008	17.5	17.5	31/01/2009
2009	24.2	24.2	25/11/2009

Gauging Authority: Office of Public Works	
Easting: 186247	**Northing:** 195967
Catchment: Ballyfinboy	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 63 km^2

QMED (gauged): 10.4 m^3/s	**AREA (FSU):** 63 km^2
QMED (synthetic urban): 6.7 m^3/s	**SAAR:** 932 mm
QMED (CFRAM revised): 11.4m^3/s	**FARL:** 1.00
BFIsoils (FSU): 0.69	**S1085:** 2.80 m/km
URBEXT: 1.95 %	**ARTDRAIN2:** 0.0 %
DRAIND: 0.51	
Comments: Velocity-area station installed in 1939 and automated in 1951. Bridge location. Seasonal weed growth. Natural channel control. Stable bed consisting of mud/silt/sand. *Catchment descriptors from FSU.*	
Nearby AFAs: Borrisokane	
Jacobs Rating Review: No	**FSU Station Classification:**

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 36 years **CFRAM Reduced AMAX series**: 25 years
Catchment change occurred prior to 1985, so only AMAX values from 1985 have been used for flood estimation.

25040 – BUNOW AT ROSCREA

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972			
1973			
1974			
1975			
1976			
1977			
1978			
1979			
1980	3.3	N/A	22/10/1980
1981	3.0	N/A	29/12/1981
1982	2.6	N/A	17/05/1983
1983	3.6	N/A	17/12/1983
1984	2.5	N/A	16/08/1985
1985	5.6	N/A	26/08/1986
1986	3.6	N/A	08/12/1986
1987	4.4	N/A	03/02/1988
1988	3.5	N/A	21/10/1988
1989	4.0	N/A	25/01/1990
1990	3.6	N/A	25/12/1990
1991	3.1	N/A	25/11/1991
1992	4.0	N/A	12/06/1993
1993	3.8	N/A	27/02/1994
1994	5.1	N/A	22/02/1995
1995	3.5	N/A	07/01/1996
1996	2.8	N/A	05/08/1997
1997	6.3	N/A	17/10/1997
1998	4.8	N/A	02/11/1998
1999			
2000			
2001			
2002			
2003			
2004			
2005			
2006			
2007			
2008			
2009			

Gauging Authority: North Tipperary County Council	
Easting: 213572	**Northing:** 189027
Catchment: Little Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 28.0 km^2

QMED (gauged): 3.63 m^3/s	**AREA:** 28.0 km^2
QMED (synthetic urban): 6.58 m^3/s	**SAAR:** 990
QMED (CFRAM revised): N/A	**FARL:** 1.00
BFIsoils: 0.63	**S1085:** 14.39
URBEXT: 5.93	**ARTDRAIN2:** 0
DRAIND: 1.16	

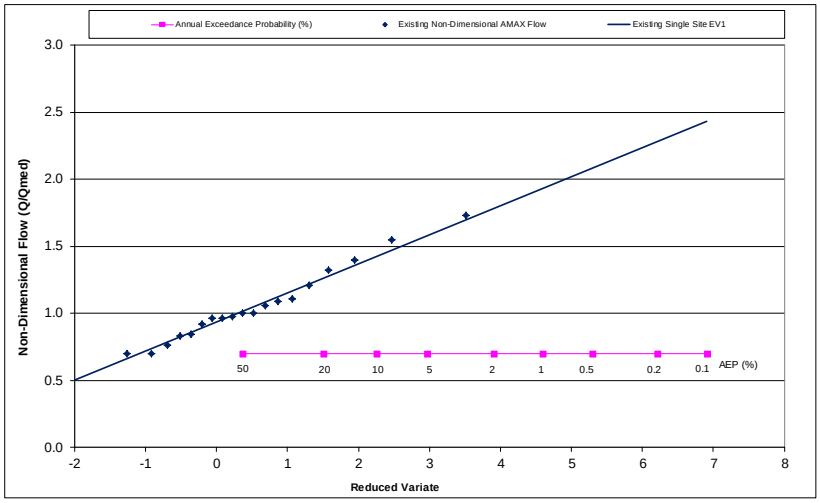
Comments:
This station was not subject to a CFRAM rating review. The AMAX series provided by OPW was used for flood estimation

Catchment descriptors from FSU data.

Nearby AFAs: Roscrea

Jacobs Rating Review: No	**FSU Station Classification:** N/A

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 19 years

The OPW AMAX series has no data after 1998 due to station vandalisation.
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Gauging Hut

Not available

Channel looking upstream

Not available

Channel looking downstream

Not available

Structure Details	
Type of Structure:	N/A
Condition of structure	N/A

Gauging Station location description	N/A
Describe potential for flow bypassing gauging station	N/A
Describe **left** bank **upstream** condition	N/A
Describe **right** bank **upstream** condition	N/A
Describe **left** bank **downstream** condition	N/A
Describe **right** bank **downstream** condition	N/A

25044 – KILMASTULLA AT COOLE

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1961	18.8		02/04/1962
1962	13.8		05/11/1962
1963	17.1		21/11/1963
1964	45.8		12/12/1964
1965	22.5		09/12/1965
1966	33.0		27/02/1967
1967	25.4		07/10/1967
1968	41.7		24/12/1968
1969	17.6		25/04/1970
1970	21.2		18/11/1970
1971	19.0		20/11/1971
1972	24.0		12/11/1972
1973	24.9		08/01/1974
1974	36.4		22/01/1975
1975	27.8		01/12/1975
1976	10.4		30/09/1977
1977	16.6		30/10/1977
1978	---		01/10/1978
1979	---		01/10/1979
1980	---		01/10/1980
1981	---		01/10/1981
1982	28.2		31/01/1983
1983	40.5		09/12/1983
1984	21.8		30/11/1984
1985	23.1		26/08/1986
1986	22.7		08/12/1986
1987	21.8		01/02/1988
1988	21.9		21/10/1988
1989	44.1		06/02/1990
1990	24.2		26/12/1990
1991	23.0		12/09/1992
1992	14.3		06/04/1993
1993	24.2		18/12/1993
1994	5.8		02/10/1994
1995	21.4		11/02/1996
1996	32.1		04/08/1997
1997	29.3		06/03/1998
1998	25.2		02/03/1999
1999	26.8		04/11/1999
2000	14.9		27/10/2000
2001	19.6		23/01/2002
2002	18.4		21/10/2002
2003	18.8		15/01/2004
2004	35.6		07/01/2005

Length of AMAX series: 40 years

No CFRAMS rating review. No changes made to OPW rating.

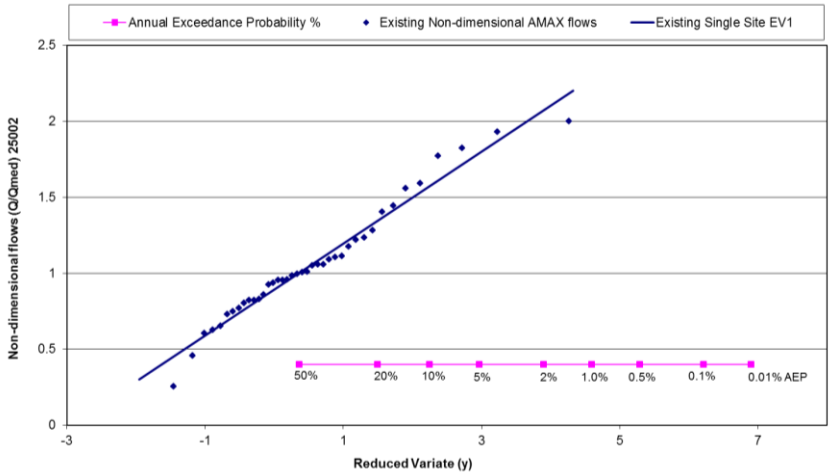
Gauging Authority: North Tipperary County Council	
Easting: 170946	**Northing:** 169510
Catchment: Lower Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 92. 50 km^2

QMED (gauged): 22.85m^3/s	**AREA:** 92.55 km^2
QMED (synthetic urban): 22.85m^3/s	**SAAR:** 1186.86
QMED (CFRAM revised): N/A m^3/s	**FARL:** 1.00
BFIsoils: 0.57	**S1085:** 2.67
URBEXT: 0.0	**ARTDRAIN2:** 0.0
DRAIND: 1.37	
Comments: Catchment descriptors from FSU data.	
Nearby AFAs: Killaloe/Ballina	
Jacobs Rating Review: No	**FSU Station Classification:** A2

Normalised Hydrographs

Chart not available

Flood Frequency (EV1 with Gringorten plotting positions)



Structure control

Photo not available

Channel looking upstream

Photo not available

Channel looking downstream

Photo not available

Structure Details	
Type of Structure:	Information not available
Condition of structure	Information not available

Gauging Station location description	Information not available
Describe potential for flow bypassing gauging station	Information not available
Describe **left** bank **upstream** condition	Information not available
Describe **right** bank **upstream** condition	Information not available
Describe **left** bank **downstream** condition	Information not available
Describe **right** bank **downstream** condition	Information not available

25050 – BROSNA AT MULLINGAR PUMP HOUSE

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1977	1.72	N/A	03/02/1978
1978	2.80	N/A	27/12/1978
1979	4.06	N/A	15/12/1979
1980	5.24	N/A	09/06/1981
1981	2.70	N/A	03/01/1982
1982	4.88	N/A	31/01/1983
1983	3.20	N/A	16/01/1984
1984	4.29	N/A	14/12/1984
1985	6.00	N/A	26/08/1986
1986	1.56	N/A	18/12/1986
1987	4.18	N/A	19/01/1988
1988	4.06	N/A	23/12/1988
1989	4.29	N/A	06/02/1990
1990	2.24	N/A	24/02/1991
1991	2.42	N/A	05/01/1992
1992	4.64	N/A	12/06/1993
1993	4.64	N/A	27/02/1994
1994	5.49	N/A	31/01/1995
1995	2.80	N/A	24/10/1995
1996	3.41	N/A	19/02/1997
1997	3.62	N/A	17/10/1997
1998	6.39	N/A	24/10/1998
1999	5.49	N/A	22/12/1999
2000	4.76	N/A	05/11/2000
2001	4.29	N/A	11/02/2002
2002	2.51	N/A	10/06/2003
2003	3.62	N/A	16/01/2004
2004	1.97	N/A	29/10/2004
2005	3.41	N/A	28/09/2006
2006	5.61	N/A	03/12/2006
2007	8.78	N/A	16/08/2008
2008	5.87	N/A	30/01/2009
2009	7.62	N/A	19/11/2009

Gauging Authority: Office of Public Works	
Easting: 244171	**Northing:** 253301
Catchment: Brosna	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 53.3 km^2 (amended)

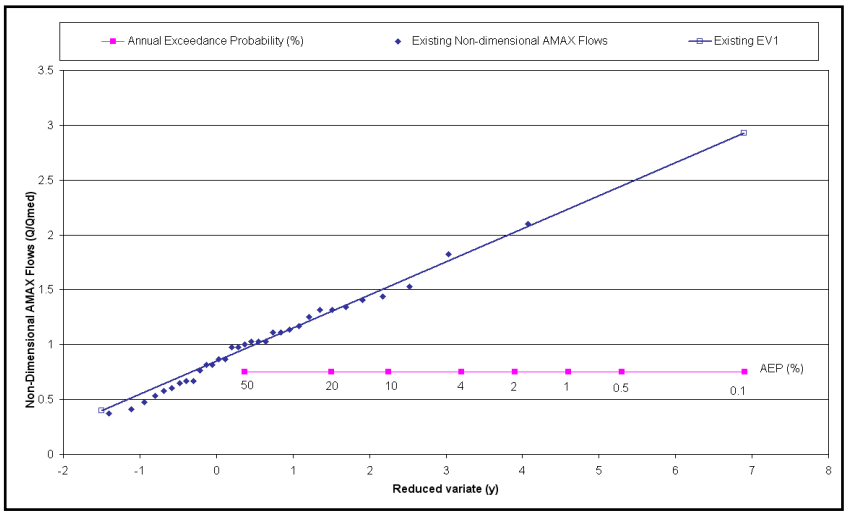
QMED (gauged): 4.18 m^3/s	**AREA (FSU):** 17.16 km^2
QMED (synthetic urban): 0.66 m^3/s (FSU)	**SAAR (FSU):** 930 mm
QMED (CFRAM revised): N/A	**FARL (FSU):** 1.00
BFIsoils (FSU): 0.68	**S1085 (FSU):** 0.10 m/km
URBEXT (FSU): 13.18 %	**ARTDRAIN2 (FSU):** 97.0 %
DRAIND (FSU): 0.04	

Comments:
Natural channel section. Bridge located downstream.

The catchment descriptors for AREA, FARL, S1085 and URBEXT from the FSU data set were found to be incorrect. Upon further investigation more appropriate values were determined and they are: AREA = 53.3 km^2 (based on an outline derived from the NDHM), FARL = 0.61 (using the FSU/FEH FARL equation), S1085 = 2.50 m/km (estimated using OSi mapping), URBEXT = 5.44 % (estimated using OSi mapping). Using these revised catchment descriptor values the amended synthetic QMED value is 1.05 m^3/s.

Nearby AFAs: Mullingar	
Jacobs Rating Review: No	**FSU Station Classification:** N/A

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 33 years
CFRAM Revised: N/A

The AMAX series has not been revised as this is not a rating review site.

QMED (gauged) is estimated using the entire 33 year AMAX flow record.

25075 – SHANNON AT PARTEEN WEIR

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Hydrological Year	Existing Flow (m^3/s)
1932	556	2003	458
1933	451	2004	577
1934	466	2005	394
1935	504	2006	731
1936	544	2007	599
1937	402	2008	496
1938	574	2009	842
1939	530	2010	589
1940	517		
1941	449		
1942	468		
1943	437		
1944	605		
1945	682		
1946	597		
1947	640		
1948	636		
1949	479		
1950	471		
1951	591		
1952	378		
1953	464		
1954	701		
1955	374		
1956	577		
1957	499		
1958	401		
1959	750		
1960	630		
1961	439		
1962	374		
1963	557		
1964	656		
1965	613		
1966	474		
1967	585		
1968	656		
1969	502		
1970	507		
1971	363		
1972	355		
1973	507		
1974	622		
1975	400		
1976	545		
1977	392		
1978	522		
1979	547		
1980	517		
1981	527		
1982	574		
1983	611		
1984	390		
1985	398		
1986	586		
1987	573		
1988	400		
1989	705		
1990	597		
1991	394		
1992	478		
1993	559		
1994	742		
1995	405		
1996	571		
1997	545		
1998	532		
1999	701		
2000	585		
2001	667		
2002	565		

Gauging Authority: ESB	
Easting: 167975	**Northing:** 167919
Catchment: Lower Shannon	**Telemetry:** No
Station Type: Recorder	**Catchment Area:** 10,782 km^2

QMED (gauged): 544 m^3/s	**AREA (FSU):** 10,803 km^2
QMED (synthetic urban): 282 m^3/s	**SAAR:** 1025 mm
QMED (CFRAM revised): Not revised	**FARL:** 0.69
BFIsoils: 0.73	**S1085:** 0.193 m/km
URBEXT: 0.78 %	**ARTDRAIN2:** 20.3%
DRAIND: 0.824	

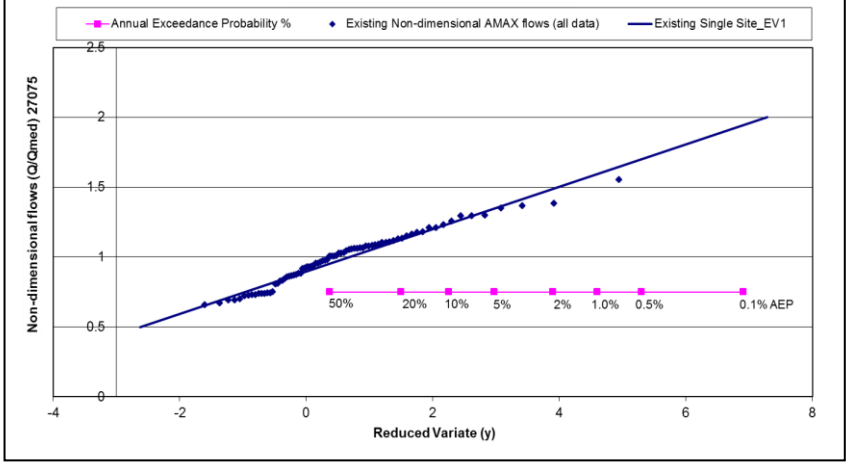
[1]Comments:

Catchment descriptors from FSU data.

Nearby AFAs: O'Briens Bridge

Jacobs Rating Review: No	**FSU Station Classification:** None

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 25 years

The station was not subject to a CFRAM rating review. No changes to existing ESB rating.

Structure control

Photo not available

Channel looking upstream

Photo not available

Channel looking downstream

Photo not available

Structure Details	
Type of Structure:	Information not available
Condition of structure	Information not available

Gauging Station location description	Information not available
Describe potential for flow bypassing gauging station	Information not available
Describe **left** bank **upstream** condition	Information not available
Describe **right** bank **upstream** condition	Information not available
Describe **left** bank **downstream** condition	Information not available
Describe **right** bank **downstream** condition	Information not available

25149 – RIVER TULLAMORE AT TULLAMORE

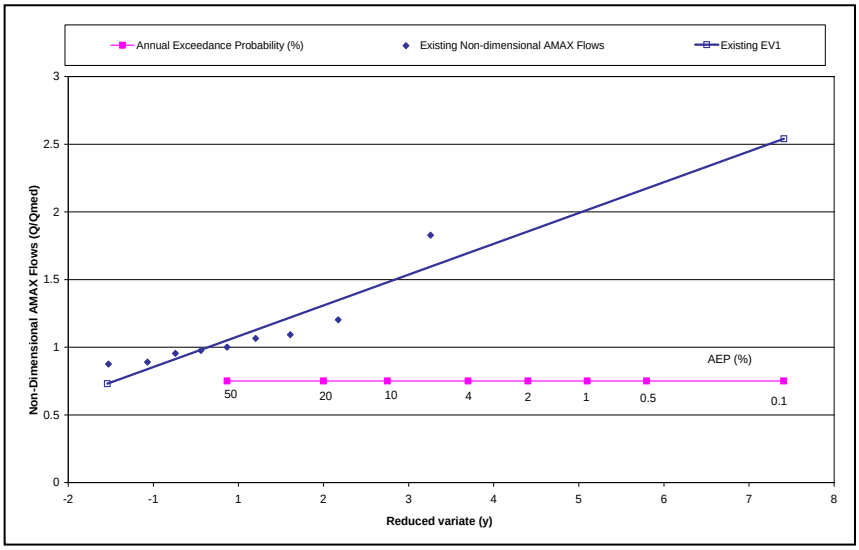
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
2001	7.79	N/A	27/02/2002
2002	7.66	N/A	16/11/2002
2003	8.75	N/A	16/01/2004
2004	9.31	N/A	09/01/2005
2005	8.54	N/A	22/05/2006
2006	9.56	N/A	08/12/2006
2007	15.99	N/A	18/08/2008
2008	8.35	N/A	01/02/2009
2009	10.52	N/A	20/11/2009

Gauging Authority: Office of Public Works	
Easting: 233324	**Northing:** 224852
Catchment: Tullamore	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 111.3 km^2

QMED (gauged): 8.75 m^3/s	**AREA:** 111.3 km^2
QMED (synthetic urban): 11.8 m^3/s	**SAAR:** 846 mm
QMED (CFRAM revised): N/A	**FARL:** 1.00
BFIsoils: 0.63	**S1085:** 1.07 m/km
URBEXT: 4.03 %	**ARTDRAIN2:** 51.5 %
DRAIND: 0.69	
Comments: *Catchment descriptors from FSU data.*	
Nearby AFAs: Rahan	
Jacobs Rating Review: No	**FSU Station Classification:** None

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 9 years

AMAX level and flow data available at this site since the 01/02/2001.

Although OPW has reported weed growth issues at this station, an inspection of the check gaugings and the AMAX series has not revealed any concerns, suggesting that the effects of weed growth are small during floods. The entire AMAX series has been used to estimate QMED However, flood frequency analysis at station 25149 cannot be undertaken due to the limited length of the AMAX record available.

No photographs are available for gauging station 25149 as no site visit was undertaken by Jacobs.

Structure Details	
Type of Structure:	Unknown
Condition of structure	Unknown

Gauging Station location description	Not known. Site visit not undertaken for gauging station 25149 (Tullamore).
Describe potential for flow bypassing gauging station	Not known. Site visit not undertaken for gauging station 25149 (Tullamore).
Describe **left** bank **upstream** condition	Not known. Site visit not undertaken for gauging station 25149 (Tullamore).
Describe **right** bank **upstream** condition	Not known. Site visit not undertaken for gauging station 25149 (Tullamore).
Describe **left** bank **downstream** condition	Not known. Site visit not undertaken for gauging station 25149 (Tullamore).
Describe **right** bank **downstream** condition	Not known. Site visit not undertaken for gauging station 25149 (Tullamore).

26002 – SUCK AT ROOKWOOD

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952	40.1	40.1	03/09/1953
1953	49.7	49.7	18/09/1954
1954	104.9	104.9	20/10/1954
1955	37.0	37.0	09/09/1956
1956	56.8	56.8	02/01/1957
1957	53.0	53.0	13/02/1958
1958	47.6	47.6	21/12/1958
1959	53.0	53.0	30/12/1959
1960	58.4	58.4	07/12/1960
1961	62.3	62.3	13/12/1961
1962	49.3	49.3	11/12/1962
1963	59.3	59.3	26/11/1963
1964	67.3	67.3	09/10/1964
1965	83.5	83.5	20/11/1965
1966	41.5	41.5	04/12/1966
1967	68.7	68.7	11/10/1967
1968	103.8	103.8	03/11/1968
1969	62.5	62.5	23/12/1969
1970	56.6	56.6	03/11/1970
1971	41.5	41.5	13/01/1972
1972	46.4	46.4	14/12/1972
1973	63.7	63.7	03/12/1973
1974	57.2	57.2	24/01/1975
1975	56.6	56.6	11/01/1976
1976	42.9	44.0	23/01/1977
1977	60.6	62.4	11/11/1977
1978	50.6	53.5	29/12/1978
1979	56.8	61.1	29/11/1979
1980	50.6	53.5	05/11/1980
1981	46.0	47.8	06/01/1982
1982	55.8	59.8	25/11/1982
1983	53.6	57.1	18/01/1984
1984	55.8	59.8	18/08/1985
1985	57.3	61.8	09/08/1986
1986	57.9	62.4	27/11/1986
1987	57.1	64.8	05/02/1988
1988	44.1	48.4	25/12/1988
1989	69.2	85.8	08/02/1990
1990	72.8	92.3	26/12/1990
1991	58.4	67.1	11/01/1992
1992	59.5	69.0	04/12/1992
1993	52.1	58.5	11/11/1993
1994	50.1	62.4	31/01/1995
1995	61.7	82.7	29/10/1995
1996	56.3	72.7	21/02/1997
1997	47.2	58.5	10/01/1998
1998	52.1	65.1	30/10/1998
1999	64.5	87.9	26/12/1999
2000	47.2	58.5	07/12/2000
2001	59.0	77.6	06/02/2002
2002	49.6	61.8	31/10/2002
2003	51.1	63.8	05/02/2004
2004	59.5	78.6	11/01/2005
2005	38.0	46.3	25/09/2006
2006	69.2	96.8	07/12/2006
2007	63.4	85.8	12/12/2007
2008	48.9	60.8	26/08/2009
2009	99.4	158.1	21/11/2009

Gauging Authority: Office of Public Works	
Easting: 180656	**Northing:** 257075
Catchment: Suck	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 641.5 km^2

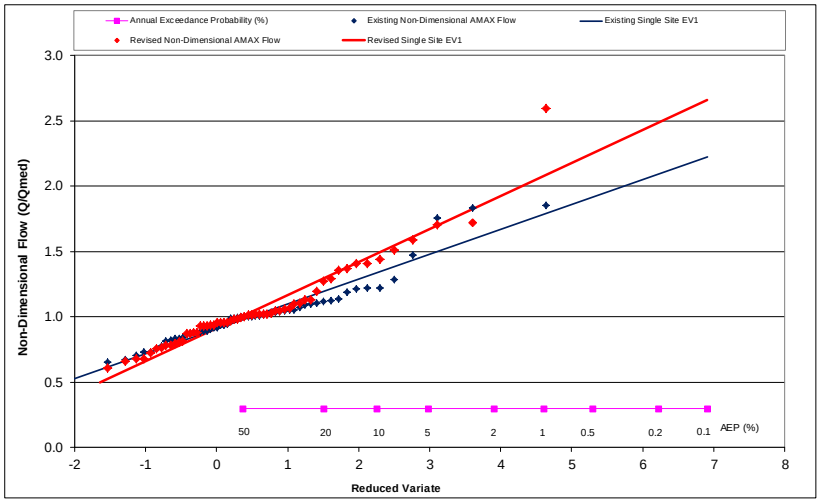
QMED (gauged): 56.6 m^3/s	**AREA:** 641.5 km^2
QMED (synthetic urban): 60.1 m^3/s	**SAAR:** 1067
QMED (CFRAM revised): 61.0 m^3/s	**FARL:** 0.98
BFIsoils: 0.61	**S1085:** 0.55
URBEXT: 0.26	**ARTDRAIN2:** 0.00
DRAIND: 0.80	

Comments:
Revised QMED based the entire AMAX values with revised rating curve applied to post-draingage values (after1976) only.

Catchment descriptors from FSU data.

Nearby AFAs: Roscommon	
Jacobs Rating Review: Yes	**FSU Station Classification:** A2

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 58 years

The AMAX series from 1977 (post-drainage) was revised according to Jacobs rating review.

All of the AMAX flow series from 1952 to date can be used for QMED estimation and flood frequency analysis.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	No control at this location, bird house gauging station, offset from the right bank
Condition of structure	Good

Gauging Station location description	In farmers field 1-2 km off local road.
Describe potential for flow bypassing gauging station	There is potential for low flows to bypass the station by the bifurcation channel becoming blocked upstream. Station is offset by about 5 to 10 m from the main channel.
Describe **left** bank **upstream** condition	The left bank has a line of mature trees growing on it. The line is dense and it is difficult to see beyond these. These extrude on the channel..
Describe **right** bank **upstream** condition	The right bank is an island with mature trees and vegetation growing on it, which would be flooded in moderate events. Right of this there is a shallow slow flowing channel,; the gauging station is on this right hand channel. The right bank to this channel has some old buildings set back from it as well as agricultural land.
Describe **left** bank **downstream** condition	The left bank has a line of mature trees growing on it. The line is dense and it is difficult to see beyond these. These extrude on the channel.
Describe **right** bank **downstream** condition	Immediately right is a low/medium flow channel which was dry and effectively an island within 300mm of top of water level and would be flooded in minor events. Right of this is a second channel with a very shallow depth of water (100mm) beyond this the main river bank rises by about 1m before slowly continuing to rise into the floodplain.

26005 – SUCK AT DERRYCAHILL

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952	116.7	N/A	21/10/1954
1953	60.7	N/A	30/01/1956
1954	91.5	N/A	02/01/1957
1955	73.0	N/A	15/02/1958
1956	66.0	N/A	03/01/1959
1957	94.1	N/A	28/12/1959
1958	84.3	N/A	07/12/1960
1959	86.7	N/A	19/01/1962
1960	77.4	N/A	11/12/1962
1961	89.1	N/A	25/11/1963
1962	93.2	N/A	15/01/1965
1963	100.1	N/A	22/11/1965
1964	64.0	N/A	31/01/1967
1965	111.0	N/A	11/10/1967
1966	135.9	N/A	04/11/1968
1967	89.9	N/A	23/12/1969
1968	82.7	N/A	03/11/1970
1969	64.7	N/A	04/04/1972
1970	71.5	N/A	15/12/1972
1971	94.9	N/A	03/12/1973
1972	93.2	N/A	26/01/1975
1973	81.2	N/A	11/01/1976
1974	73.0	N/A	08/02/1977
1975	109.1	N/A	11/11/1977
1976	78.9	N/A	20/11/1978
1977	98.3	N/A	28/11/1979
1978	78.1	N/A	21/12/1980
1979	78.9	N/A	13/03/1982
1980	91.5	N/A	25/11/1982
1981	101.0	N/A	18/01/1984
1982	97.5	N/A	24/09/1985
1983	85.1	N/A	23/12/1985
1984	100.1	N/A	27/11/1986
1985	91.5	N/A	05/02/1988
1986	73.0	N/A	16/01/1989
1987	102.7	N/A	08/02/1990
1988	104.5	N/A	30/12/1990
1989	75.9	N/A	10/01/1992
1990	89.1	N/A	16/06/1993
1991	82.7	N/A	17/12/1993
1992	99.2	N/A	01/02/1995
1993	85.9	N/A	29/10/1995
1994	96.6	N/A	23/02/1997
1995	86.7	N/A	10/01/1998
1996	82.7	N/A	29/10/1998
1997	109.1	N/A	26/12/1999
1998	79.6	N/A	08/11/2000
1999	101.8	N/A	06/02/2002
2000	81.2	N/A	12/11/2002
2001	74.1	N/A	06/02/2004
2002	97.5	N/A	10/01/2005
2003	52.8	N/A	25/09/2006
2004	73.7	N/A	08/12/2006
2005	89.1	N/A	11/12/2007
2006	85.1	N/A	26/08/2009
2007	175.2	N/A	21/11/2009
2008	116.7	N/A	21/10/1954
2009	60.7	N/A	30/01/1956

Gauging Authority: Office of Public Works	
Easting: 182557	**Northing:** 242372
Catchment: Suck	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 1085.4 km^2

QMED (gauged): 87.9 m^3/s	**AREA:** 1085.4 km^2
QMED (synthetic urban): 99.2 m^3/s	**SAAR:** 1054
QMED (CFRAM revised): N/A	**FARL:** 0.98
BFIsoils: 0.56	**S1085:** 0.47
URBEXT: 0.23	**ARTDRAIN2:** 0.00
DRAIND: 0.76	

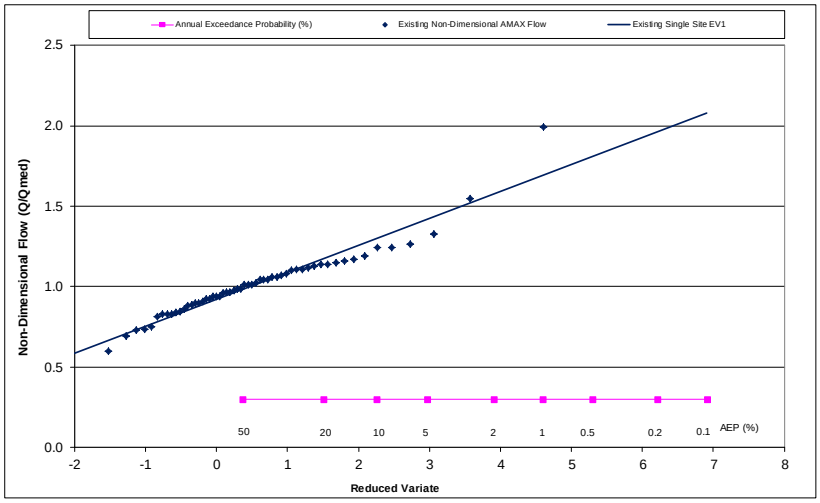
Comments:

Model rating remains unchanged.
Catchment descriptors from FSU data.

Nearby AFAs: Castlerea

Jacobs Rating Review: Yes	**FSU Station Classification:** A2

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 56 years

Jacobs model rating and existing OPW rating showed a good agreement, and therefore the AMAX series remain unchanged.

All of the AMAX flow series from 1952 to date can be used for QMED estimation and flood frequency analysis.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	No control. An old timber bridge with concrete supports, little to no influence on flows
Condition of structure	Good

Gauging Station location description	In turf fields in a remote location outside Ballyforan.
Describe potential for flow bypassing gauging station	There is a high potential for high flows to bypass the station. The station is in the floodplain and it is impossible to say that flood flows would all get picked up by the gauge.
Describe **left** bank **upstream** condition	The banks are grassed with some reeds and vegetation in places, generally well established with gradual slopes.
Describe **right** bank **upstream** condition	The banks are grassed with some reeds and vegetation in places, generally well established with gradual slopes.
Describe **left** bank **downstream** condition	The banks are grassed with some reeds and vegetation in places, generally well established with gradual slopes.
Describe **right** bank **downstream** condition	The banks are grassed with some reeds and vegetation in places, generally well established with gradual slopes.

26006 – SUCK AT WILLSBROOK

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952	16.2	N/A	01/09/1953
1953	30.3	N/A	02/11/1953
1954	70.1	N/A	20/10/1954
1955	14.6	N/A	14/12/1955
1956	22.4	N/A	01/01/1957
1957	34.2	N/A	12/02/1958
1958	24.5	N/A	21/12/1958
1959	22.4	N/A	23/12/1959
1960	21.4	N/A	22/01/1961
1961	26.8	N/A	12/12/1961
1962	17.7	N/A	11/12/1962
1963	23.5	N/A	26/11/1963
1964	30.3	N/A	09/10/1964
1965	41.8	N/A	19/11/1965
1966	18.6	N/A	11/12/1966
1967	31.6	N/A	10/01/1968
1968	68.7	N/A	02/11/1968
1969	24.5	N/A	23/12/1969
1970	23.5	N/A	03/11/1970
1971	18.6	N/A	11/01/1972
1972	18.6	N/A	12/12/1972
1973	26.8	N/A	02/12/1973
1974	21.1	N/A	16/01/1975
1975	18.6	N/A	10/01/1976
1976	17.5	N/A	21/01/1977
1977	24.2	N/A	08/11/1977
1978	26.8	N/A	16/12/1978
1979	27.9	N/A	29/11/1979
1980	31.6	N/A	03/11/1980
1981	21.4	N/A	06/01/1982
1982	22.1	N/A	23/11/1982
1983	22.8	N/A	17/01/1984
1984	26.8	N/A	16/08/1985
1985	34.2	N/A	07/08/1986
1986	27.1	N/A	07/12/1986
1987	26.4	N/A	20/01/1988
1988	24.9	N/A	24/12/1988
1989	32.0	N/A	07/02/1990
1990	37.4	N/A	24/12/1990
1991	42.3	N/A	09/01/1992
1992	32.0	N/A	02/12/1992
1993	30.8	N/A	09/12/1993
1994	32.4	N/A	22/01/1995
1995	54.5	N/A	27/10/1995
1996	24.9	N/A	25/02/1997
1997	25.3	N/A	10/01/1998
1998	29.5	N/A	23/10/1998
1999	44.9	N/A	29/11/1999
2000	26.8	N/A	06/12/2002
2001	31.2	N/A	04/02/2002
2002	29.1	N/A	28/10/2002
2003	34.6	N/A	03/02/2004
2004	35.1	N/A	09/01/2005
2005	22.4	N/A	26/10/2005
2006	43.3	N/A	04/12/2006
2007	41.3	N/A	10/12/2007
2008	31.3	N/A	01/02/2009
2009	65.7	N/A	20/11/2009

Gauging Authority: Office of Public Works	
Easting: 169281	**Northing:** 275594
Catchment: Suck	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 184.8 km^2

QMED (gauged): 26.8 m^3/s	**AREA:** 184.8 km^2
QMED (synthetic urban): 25.5 m^3/s	**SAAR:** 1121
QMED (CFRAM revised): N/A	**FARL:** 0.97
BFIsoils: 0.54	**S1085:** 0.96
URBEXT: 0.55	**ARTDRAIN2:** 0.00
DRAIND: 0.93	

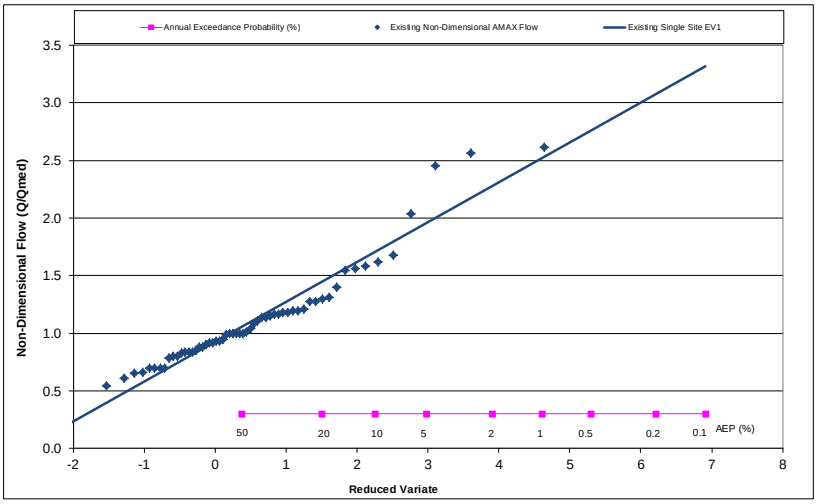
Comments:

Model rating remains unchanged.
Catchment descriptors from FSU data.

Nearby AFAs: Castlerea

Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 58 years

Jacobs model rating and existing OPW rating are very similar, and therefore the AMAX series remain unchanged.

All of the AMAX flow series from 1952 to date can be used for QMED estimation and flood frequency analysis.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	A small masonry house with render, visible from the road. One twin arch old bridge with a flood relief arch and one single span new bridge.
Condition of structure	Good

Gauging Station location description	On the left bank of the River Suck, just upstream of two road bridges and off the main road.
Describe potential for flow bypassing gauging station	Station would not be bypassed as the road level downstream of the station is very high.
Describe **left** bank **upstream** condition	The left bank is a well maintained grassed bank. The bank is steel but not deep. There are some trees growing off the bank but these don't encroach on the river.
Describe **right** bank **upstream** condition	The right bank is a well maintained grassed bank. The bank is steel but not deep.
Describe **left** bank **downstream** condition	The left bank is a well maintained grassed bank. The bank is steel but not deep.
Describe **right** bank **downstream** condition	The left bank is a well maintained grassed bank. The bank is steel but not deep.

26007 – SUCK AT BELLAGILL

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1952	68.3		02/09/1953
1953	76.0		16/11/1953
1954	136.5		20/10/1954
1955	66.9		29/01/1956
1956	112.2		31/12/1956
1957	115.3		15/02/1958
1958	69.0		02/01/1959
1959	98.9		29/12/1959
1960	87.2		06/12/1960
1961	88.2		14/12/1961
1962	82.7		12/12/1962
1963	94.7		26/11/1963
1964	103.3		11/10/1964
1965	110.7		21/11/1965
1966	72.4		28/02/1967
1967	107.7		11/10/1967
1968	147.8		05/11/1968
1969	90.6		23/12/1969
1970	88.6		03/11/1970
1971	61.6		12/01/1972
1972	71.7		15/12/1972
1973	92.1		03/12/1973
1974	93.5		26/01/1975
1975	82.0		11/01/1976
1976	76.8		09/02/1977
1977	109.2		11/11/1977
1978	79.7		14/12/1978
1979	93.5		28/11/1979
1980	79.0		14/12/1980
1981	79.7		14/03/1982
1982	88.2		25/11/1982
1983	104.7		18/01/1984
1984	85.0		24/09/1985
1985	81.2		23/12/1985
1986	97.6		27/11/1986
1987	86.6		07/02/1988
1988	66.2		29/12/1988
1989	120.0		08/02/1990
1990	99.0		07/01/1991
1991	81.2		10/01/1992
1992	88.2		16/06/1993
1993	85.0		16/12/1993
1994	106.2		31/01/1995
1995	83.5		30/10/1995
1996	100.4		22/02/1997
1997	87.3		11/01/1998
1998	84.2		20/01/1999
1999	123.2		29/12/1999
2000	82.0		08/11/2000
2001	115.3		06/02/2002
2002	84.3		31/10/2002
2003	73.3		06/02/2004
2004	104.7		11/01/2005
2005	45.1		24/09/2006
2006	129.7		08/12/2006
2007	97.2		11/12/2007
2008	85.8		02/02/2009
2009	224.3		21/11/2009

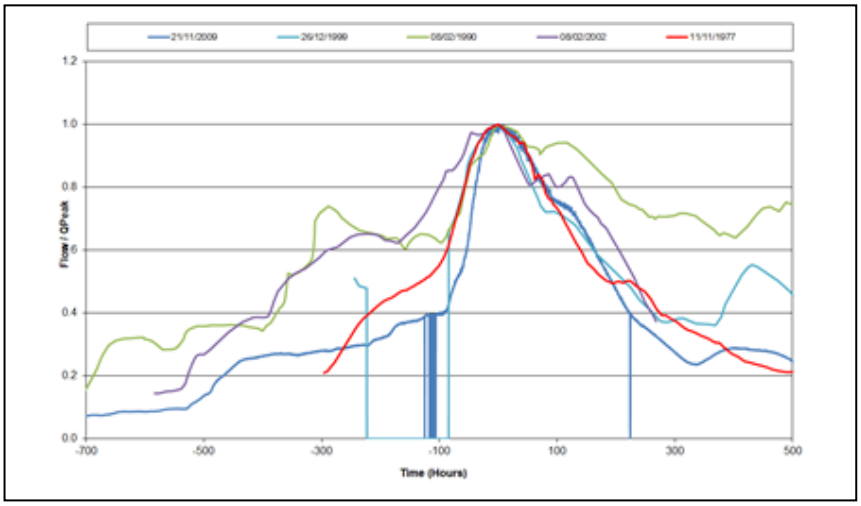
Length of AMAX series: 58 years

The AMAX series based on the OPW rating remains unchanged.

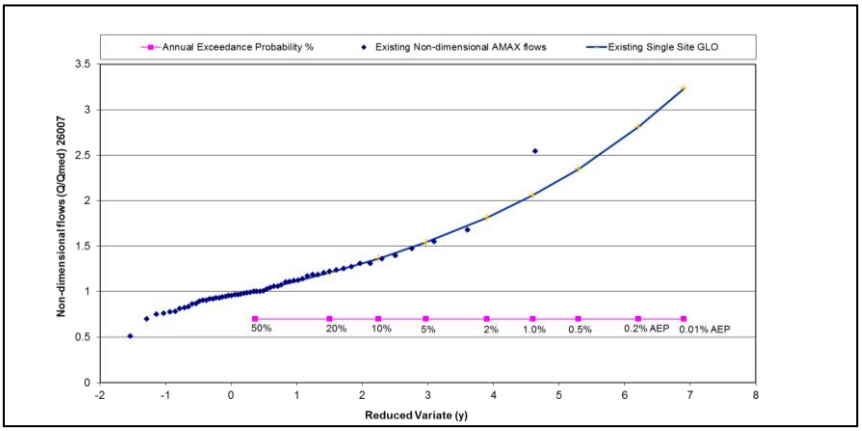
Gauging Authority: Office of Public Works	
Easting: 184175	**Northing:** 234570
Catchment: Suck	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 1207.2 km^2

QMED (gauged): 88.2 m^3/s	**AREA:** 1207.2 km^2
QMED (synthetic urban): 92.5 m^3/s	**SAAR:** 1045.6
QMED (CFRAM revised): 102.9 m^3/s	**FARL:** 1.0
BFIsoils: 0.6	**S1085:** 0.4
URBEXT: 0.2	**ARTDRAIN2:** N/A
DRAIND: 0.8	
Comments: Catchment descriptors from FSU data.	
Nearby AFAs: Ballinasloe	
Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Normalised Hydrographs



Flood Frequency (GLO with Gringorten plotting positions)



Structure control

Channel

Structure Details	
Type of Structure:	Multi arch bridge, 5 in channel arches and 4 relief arches
Condition of structure	Good

Gauging Station location description	Station is located on the right bank downstream of the road bridge.
Describe potential for flow bypassing gauging station	Low, in extreme flood events flooding upstream of the road bridge could come out of bank and move through the floodplain hence bypassing the station, more likely to happen on the right bank
Describe **left** bank **upstream** condition	The banks are grassed with some reeds and vegetation in places. Generally well established with gradual slopes. There is a light line of trees but these do not encroach on the river channel
Describe **right** bank **upstream** condition	The banks are grassed with some reeds and vegetation in places. Generally well established with gradual slopes.
Describe **left** bank **downstream** condition	The banks are grassed with some reeds and vegetation in places. Generally well established with gradual slopes. There is a light line of trees but these do not encroach on the river channel
Describe **right** bank **downstream** condition	The banks are grassed with some reeds and vegetation in places. Generally well established with gradual slopes.

26008 – RINN AT JOHNSTON'S BR.

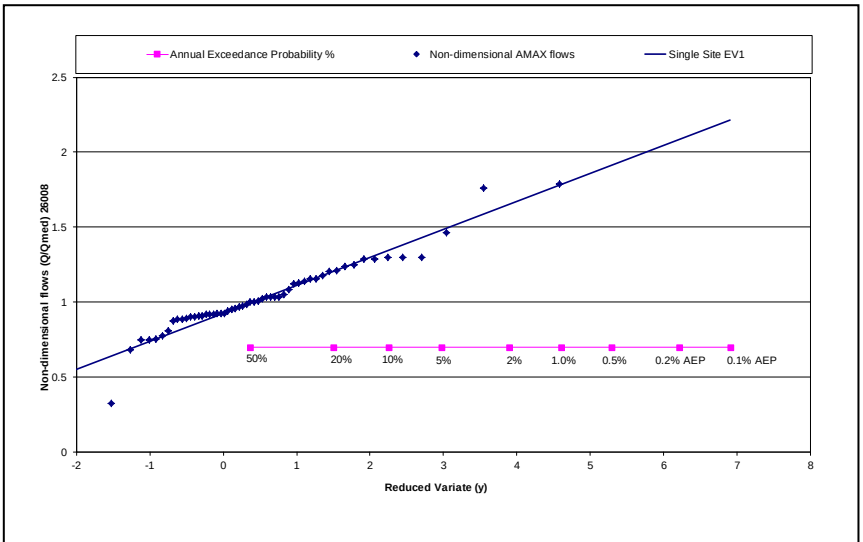
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955	17.3		30/01/1956
1956	26.6		02/01/1957
1957	20.3		14/08/1958
1958	18.5		02/01/1959
1959	17.1		03/02/1960
1960	22.9		22/01/1961
1961	24.1		12/12/1961
1962	20.9		12/12/1962
1963	25.9		25/11/1963
1964	29.5		11/10/1964
1965	**41.0**		**18/11/1965**
1966	17.1		16/12/1966
1967	27.0		10/01/1968
1968	33.5		03/11/1968
1969	23.7		23/12/1969
1970	21.8		04/11/1970
1971	20.1		22/11/1971
1972	15.6		11/12/1972
1973	20.5		08/09/1974
1974	7.5		25/01/1975
1975	21.0		10/01/1976
1976	20.9		22/02/1977
1977	21.2		12/11/1977
1978	22.4		29/12/1978
1979	22.0		28/11/1979
1980	21.0		21/12/1980
1981	21.0		13/03/1982
1982	20.4		25/11/1982
1983	25.7		17/01/1984
1984	23.7		23/09/1985
1985	23.5		08/08/1986
1986	21.6		19/12/1986
1987	28.7		23/10/1987
1988	23.7		27/12/1988
1989	29.7		08/02/1990
1990	29.7		07/01/1991
1991	21.2		10/01/1992
1992	29.5		03/12/1992
1993	20.7		28/02/1994
1994	23.7		11/02/1995
1995	24.9		28/10/1995
1996	23.1		21/02/1997
1997	22.9		04/01/1998
1998	22.2		18/10/1998
1999	29.7		26/12/1999
2000	21.2		10/12/2000
2001	27.6		06/02/2002
2002	26.6		28/10/2002
2003	20.7		04/02/2004
2004	26.1		10/01/2005
2005	17.8		14/03/2006
2006	27.8		09/12/2006
2007	28.4		09/12/2007
2008	22.6		02/02/2009
2009	40.4		21/11/2009

Gauging Authority: Office of Public Works	
Easting: 209006	**Northing: 286138**
Catchment: Upper Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 280.6 km^2

QMED (gauged): 22.9 m3/s	**AREA:** 280.3 km^2
QMED (synthetic urban): 22.7 m^3/s	**SAAR:** 1035.47
QMED (CFRAM revised): N/A	**FARL:** 0.86
BFIsoils: 0.59	**S1085: 1.11**
URBEXT: 0.26	**ARTDRAIN2:**
DRAIND: 1.13	
Comments: *OPW rating not revised. It was not possible to obtain a good fit between model rating and check gaugings most likely as a result of the topographic survey failing to capture a local control. Catchment descriptors from FSU.*	
Nearby AFAs: N/A	
Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 55 years

Slight gradual upward trend in AMAX flow and level series from 1955, cause unknown. Check gaugings fit reasonably well to OPW rating.

26012 – BOYLE AT TINACARRA

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957	18.7		17/02/1958
1958	20.5		06/01/1959
1959	30.7		29/12/1959
1960	22.4		07/02/1961
1961	26.4		15/12/1961
1962	17.8		16/12/1962
1963	27.4		28/11/1963
1964	42.1		20/01/1965
1965	30.7		14/12/1965
1966	24.3		20/12/1966
1967	29.6		19/01/1968
1968	44.7		06/11/1968
1969	26.4		24/02/1970
1970	24.3		08/11/1970
1971	20.5		24/11/1971
1972	29.2		15/12/1972
1973	34.3		15/01/1974
1974	47.8		30/01/1975
1975	30.2		12/01/1976
1976	26.5		13/02/1977
1977	38.9		14/11/1977
1978	31.7		13/12/1978
1979	41.0		13/12/1979
1980	40.5		24/12/1980
1981	35.0		18/03/1982
1982	36.9		29/11/1982
1983	43.5		08/02/1984
1984	35.8		31/08/1985
1985	34.3		25/12/1985
1986	42.2		26/11/1986
1987	45.6		09/02/1988
1988	35.4		03/03/1989
1989	66.6		09/02/1990
1990	53.7		08/01/1991
1991	49.6		10/01/1992
1992	44.3		03/12/1992
1993	41.8	41.8	03/01/1994
1994	50.5	50.5	31/01/1995
1995	43.0	43.0	28/10/1995
1996	46.9	46.9	26/02/1997
1997	48.2	48.2	11/01/1998
1998	49.1	49.1	29/10/1998
1999	61.5	61.5	26/12/1999
2000	46.5	46.5	14/12/2000
2001	62.5	62.5	12/02/2002
2002	47.1	47.1	11/11/2002
2003	47.1	47.1	05/02/2004
2004	59.7	59.7	12/01/2005
2005	26.8	26.8	24/05/2006
2006	65.5	65.5	10/12/2006
2007	60.5	60.5	11/12/2007
2008	52.1	52.1	01/02/2009
2009	109.8	109.8	25/11/2009

Gauging Authority: Office of Public Works	
Easting: 180537	**Northing:** 302625
Catchment: Upper Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 527 km^2

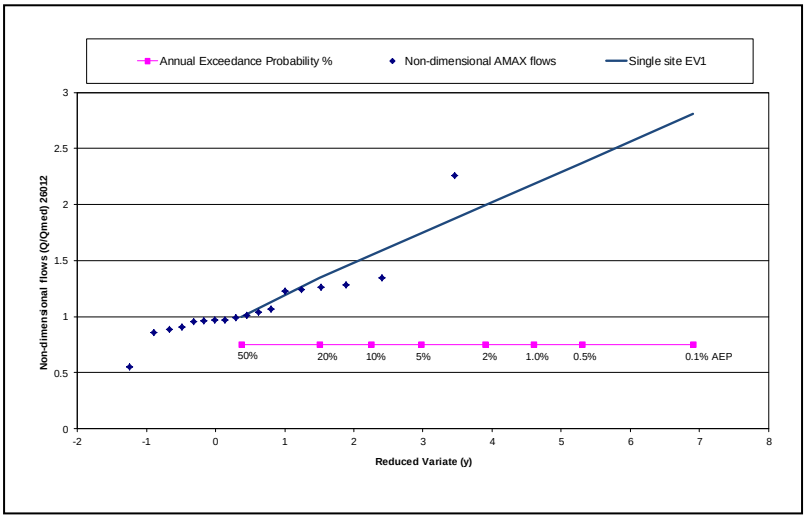
QMED (gauged): 41.0 m^3/s	**AREA:** 527 km^2
QMED (synthetic urban): 57.3 m^3/s	**SAAR:** 1143
QMED (CFRAM revised): 49.1 m^3/s (1993 - 2009)	**FARL:** 0.86
BFIsoils: 0.73	**S1085:** 0.37
URBEXT: 0.42	**ARTDRAIN2:** 53.00
DRAIND: 0.88	

Comments:
Arterial drainage works between 1982 and 1992 and change in datum in 1990, therefore only AMAX from 1993 considered appropriate. Model rating confimed OPW rating, therefore rating not revised. Catchment descriptors from FSU.

Nearby AFAs: Boyle

Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions) - period 1993 to 2009 only



Length of AMAX series: 53 years
Only 17 years (1993 to 2009) used for CFRAMS

Drainage works 1982 to 1992 with a change in datum in 1990. Post drainage works QMED is 49.1 m^3/s (1993+)

26014 – LUNG AT BANADA BRIDGE

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972			
1973			
1974			
1975	13.7		02/01/1976
1976	12.6		10/02/1977
1977	20.3		10/11/1977
1978	21.9		15/11/1978
1979	21.7		26/11/1979
1980	27.7		02/11/1980
1981	19.9		12/03/1982
1982	18.6		23/11/1982
1983	17.5		16/10/1983
1984	12.8		28/11/1984
1985	N/A		N/A
1986	N/A		N/A
1987	N/A		N/A
1988	N/A		N/A
1989	46.7	41.30	06/02/1990
1990	37.0	34.39	06/01/1991
1991	47.9	42.10	08/01/1992
1992	31.3	30.18	01/12/1992
1993	43.6	39.11	08/12/1993
1994	42.0	37.97	21/01/1995
1995	54.8	46.87	26/10/1995
1996	38.3	36.29	21/02/1997
1997	36.8	35.16	10/01/1998
1998	54.0	47.46	24/10/1998
1999	70.9	56.50	28/11/1999
2000	29.8	29.91	12/12/2000
2001	44.1	40.47	10/03/2002
2002	39.9	37.44	27/10/2002
2003	41.0	38.27	01/02/2004
2004	47.5	42.90	08/01/2005
2005	27.1	27.87	21/05/2006
2006	48.0	43.26	04/12/2006
2007	51.6	45.77	08/12/2007
2008	19.3	21.64	11/10/2008
2009	**81.3**	**60.43**	**19/11/2009**

Gauging Authority: Office of Public Works	
Easting: 163444	**Northing:** 294272
Catchment: Boyle	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 215 km^2

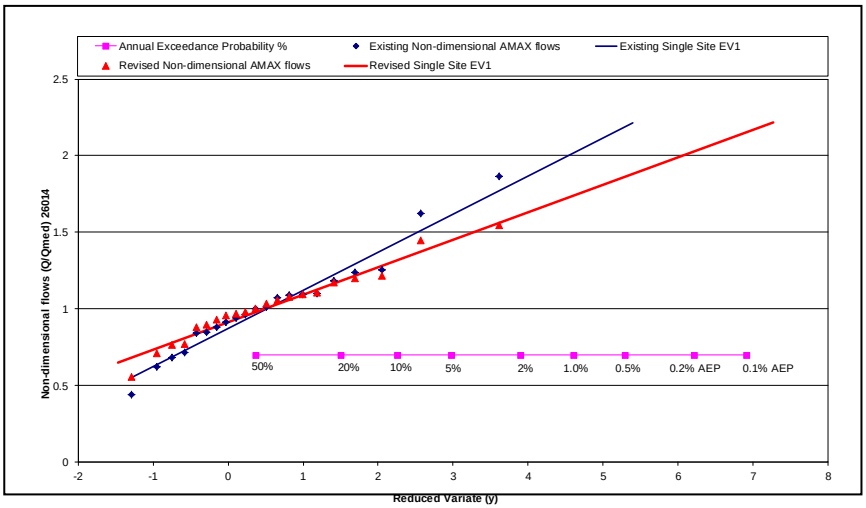
QMED (gauged): 37.0 m^3/s	**AREA:** 215 km^2
QMED (synthetic urban): 42.8 m^3/s	**SAAR:** 1199
QMED (CFRAM revised): 39.1 m^3/s	**FARL:** 0.94
BFIsoils: 0.63	**S1085:** 0.33
URBEXT: 0.32	**ARTDRAIN2:** 50.00
DRAIND: 0.96	

Comments:
Arterial drainage works 1985 to September 1989 therefore only AMAX from 1989 onwards considered. Rating revised from 1989 onwards. Catchment descriptors from FSU.

Nearby AFAs: Boyle

Jacobs Rating Review: Yes	**FSU Station Classification:** B

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 21 years

1985-September 1989 – drainage scheme

Medium to high-flow check gaugings show little scatter, however, highest gauging is only around QMED, further high flow check gaugings required.

26016 – HIND AT BALLYMURRAY

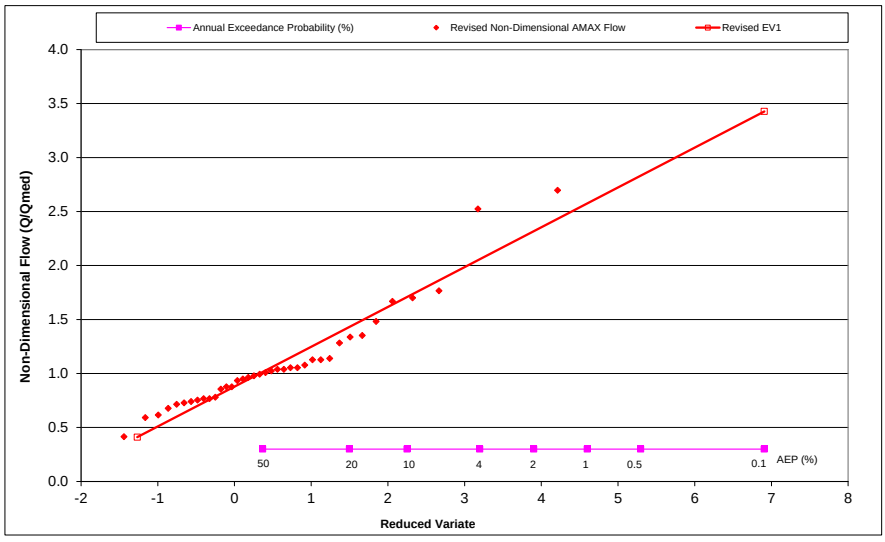
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972	N/A	3.70	11/12/1972
1973	N/A	6.95	08/01/1974
1974	N/A	8.99	13/01/1975
1975	N/A	8.72	09/01/1976
1976	N/A	5.48	17/02/1977
1977	N/A	6.83	10/11/1977
1978	N/A	8.33	28/12/1978
1979	N/A	8.59	27/11/1979
1980	N/A	7.81	09/06/1981
1981	N/A	6.37	12/03/1982
1982	N/A	7.81	24/11/1982
1983	N/A	9.40	17/01/1984
1984	N/A	11.93	16/08/1985
1985	N/A	11.44	01/07/1986
1986	N/A	7.63	25/11/1986
1987	N/A	6.03	19/01/1988
1988	N/A	6.83	05/10/1988
1989	N/A	9.13	07/02/1990
1990	N/A	N/A	N/A
1991	N/A	6.72	12/09/1992
1992	N/A	10.16	02/12/1992
1993	N/A	9.26	16/12/1993
1994	N/A	12.06	28/01/1995
1995	N/A	6.60	27/10/1995
1996	N/A	8.46	20/02/1997
1997	N/A	8.86	09/01/1998
1998	N/A	15.17	22/09/1999
1999	N/A	14.88	25/12/1999
2000	N/A	9.26	30/10/2000
2001	N/A	10.05	04/02/2002
2002	N/A	6.48	10/11/2002
2003	N/A	5.27	03/02/2004
2004	N/A	9.61	09/01/2005
2005	N/A	9.40	22/09/2006
2006	N/A	15.76	05/12/2006
2007	N/A	13.22	11/09/2008
2008	N/A	22.51	24/08/2009
2009	N/A	24.06	20/11/2009
2010	N/A	10.05	16/01/2011

Gauging Authority: Office of Public Works	
Easting: 191635	**Northing:** 261560
Catchment: Hind	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 62.7 km^2

QMED (gauged): N/A	**AREA:** 62.7 km^2
QMED (synthetic urban): 6.7 m^3/s	**SAAR:** 1008 mm
QMED (CFRAM revised): 8.9 m^3/s	**FARL:** 1.00
BFIsoils: 0.65	**S1085:** 1.90 m/km
URBEXT: 4.66%	**ARTDRAIN2:** 0.0
DRAIND: 0.43	
Comments: Natural channel control, bridge location. *Catchment descriptors from FSU data.*	
Nearby AFAs: Roscommon	
Jacobs Rating Review: Yes	**FSU Station Classification:** None

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 38 years
CFRAM Revised: 38 years

Prior to Jacobs' rating review at this site, there was no rating equation and no AMAX flow data available, only AMAX level data.

There is no AMAX level data available prior to 1972.

All of the AMAX flow series from 1972 to date can be used for QMED estimation and flood frequency analysis.

Refer to the rating review summary sheet in Appendix C for more detail.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	N/A
Condition of structure	N/A

Gauging Station location description	On a local road upstream of the road bridge.
Describe potential for flow bypassing gauging station	The likelihood of the station being bypassed is low. The road and railway line act as natural barriers to flows and is raised above the flood plain. The road would flood in the case of bypassing.
Describe **left** bank **upstream** condition	The left bank is a well maintained grassed bank, the bank is steep. There are some trees growing on and near the bank. There is an embankment running along the left bank, with a break in the embankment near the station. The floodplain downstream is generally at a lower level than upstream.
Describe **right** bank **upstream** condition	The right bank is a well maintained grassed bank, the bank is steep but not high. The floodplain downstream is generally at a lower level than upstream.
Describe **left** bank **downstream** condition	The left bank is a well maintained grassed bank, the bank is steep. The floodplain downstream is generally at a lower level than upstream.
Describe **right** bank **downstream** condition	The right bank is a well maintained grassed bank, the bank is steep. The floodplain downstream is generally at a lower level than upstream.

26019 – CAMLIN AT MULLAGH

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1948			
1949			
1950			
1951			
1952			
1953	23.1	23.1	04/12/1953
1954	36.7	36.7	10/12/1954
1955	20.4	20.4	07/09/1956
1956	23.4	23.4	01/01/1957
1957	21.7	21.7	01/11/1957
1958	16.5	16.5	20/12/1958
1959	22.0	22.0	31/01/1960
1960	24.0	24.0	22/01/1961
1961	20.6	20.6	11/12/1961
1962	22.6	22.6	06/11/1962
1963	25.5	25.5	25/11/1963
1964	32.8	32.8	11/01/1965
1965	26.4	26.4	27/11/1965
1966	17.0	17.0	17/08/1967
1967	29.2	29.2	10/01/1968
1968	33.5	33.5	03/11/1968
1969	24.3	24.3	22/12/1969
1970	20.4	20.4	29/11/1970
1971	19.6	19.6	22/11/1971
1972	15.9	15.9	13/11/1972
1973	31.2	31.2	06/11/1973
1974	24.9	24.9	15/01/1975
1975	20.4	20.4	11/01/1976
1976	21.2	21.2	22/02/1977
1977	15.0	15.0	12/11/1977
1978	18.8	18.8	29/12/1978
1979	21.2	21.2	28/11/1979
1980	18.5	18.5	25/12/1980
1981	17.9	17.9	05/01/1982
1982	21.2	21.2	02/02/1983
1983	23.4	23.4	10/12/1983
1984	23.4	23.4	16/08/1985
1985	27.0	27.0	08/08/1986
1986	18.3	18.3	19/12/1986
1987	37.0	37.0	23/10/1987
1988	18.6	18.6	25/12/1988
1989	26.4	26.4	08/02/1990
1990	N/A		N/A
1991	14.6		09/01/1992
1992	18.2		15/06/1993
1993	16.2		09/12/1993
1994	17.3		14/12/1994
1995	17.7		27/10/1995
1996	17.6		20/02/1997
1997	17.1		09/01/1998
1998	17.6		22/09/1999
1999	31.8		25/12/1999
2000	17.1		05/11/2000
2001	22.6		05/02/2002
2002	31.5		23/10/2002
2003	16.9		03/02/2004
2004	28.3		09/01/2005
2005	16.2		14/01/2006
2006	22.6		05/12/2006
2007	26.3		10/12/2007
2008	20.9		01/02/2009
2009	**51.0**		**20/11/2009**

Gauging Authority: Office of Public Works	
Easting: 211674	**Northing:** 275911
Catchment: Camlin	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 253 km^2

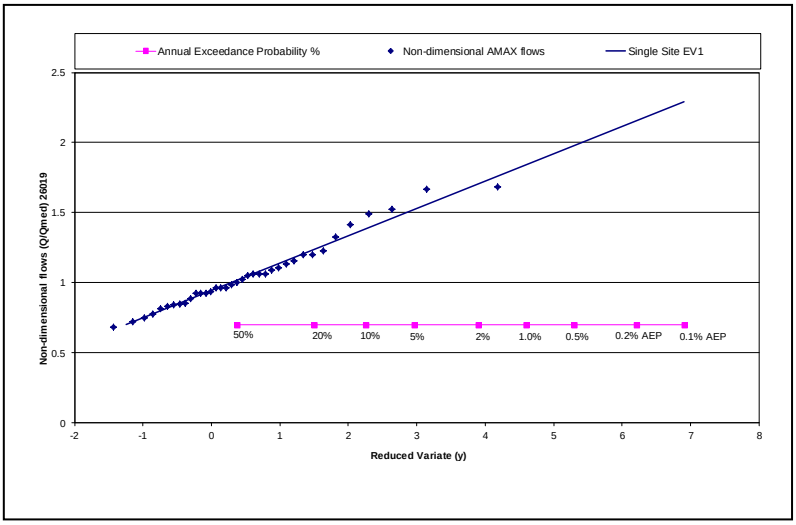
QMED (gauged): 21.2 m^3/s	**AREA:** 253 km^2
QMED (synthetic urban): 23.5 m^3/s	**SAAR:** 979
QMED (CFRAM revised): 23.2 m^3/s (1953 -1989)	**FARL:** 0.99
BFIsoils: 0.60	**S1085:** 0.50
URBEXT: 1.29	**ARTDRAIN2:** N/A
DRAIND: 0.91	

Comments:
Completion of channel works prevents a review of rating pre-October 2010. OPW rating not revised. Check gaugings from 1990s and 2000s indicate that the latest rating is not representative of that 20 year period. Catchment descriptors from FSU.

Nearby AFAs: Longford

Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions) – period 1953 to 1989 only



Length of AMAX series: 53 years
Only 37 years (1953 to 1989 used for CFRAMS)

It is recommended that only data pre-2010 be used due to channel works. A review of the rating indicates that check gaugings from the 1990s and 2000s do not fit well with the latest rating and flows over this period should therefore be used with caution.

26020 – CAMLIN AT ARGAR

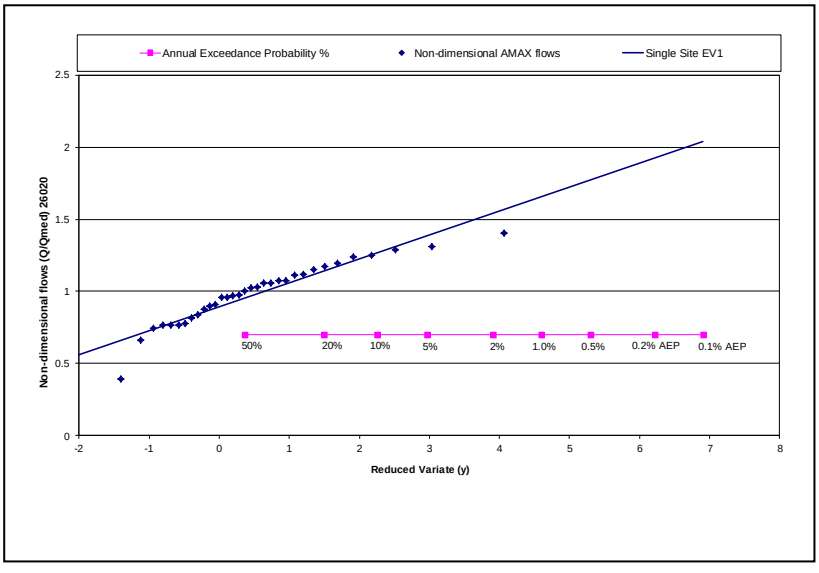
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972	4.4	N/A	14/12/1972
1973	12.8	N/A	09/08/1974
1974	13.8	N/A	15/01/1975
1975	8.5	N/A	01/11/1976
1976	9.1	N/A	21/02/1977
1977	9.3	N/A	13/11/1977
1978	8.7	N/A	28/12/1978
1979	10.8	N/A	27/11/1979
1980	9.8	N/A	23/10/1980
1981	8.3	N/A	01/04/1982
1982	10.0	N/A	02/01/1983
1983	10.7	N/A	12/09/1983
1984	11.1	N/A	20/08/1985
1985	11.9	N/A	08/06/1986
1986	10.1	N/A	16/12/1986
1987	**15.6**	N/A	**22/10/1987**
1988	10.7	N/A	24/12/1988
1989	13.1	N/A	02/08/1990
1990	13.9	N/A	20/03/1991
1991	11.9	N/A	22/12/1991
1992	14.3	N/A	14/06/1993
1993	11.5	N/A	12/09/1993
1994	13.3	N/A	13/12/1994
1995	12.4	N/A	26/10/1995
1996	11.8	N/A	19/02/1997
1997	11.8	N/A	13/10/1997
1998	10.8	N/A	19/01/1999
1999	14.5	N/A	23/12/1999
2000	8.5	N/A	10/11/2000
2001	12.4	N/A	04/02/2002
2002	8.5	N/A	23/10/2002
2003	7.4	N/A	03/02/2004
2004	11.4	N/A	09/01/2005
2005		N/A	
2006		N/A	
2007		N/A	
008		N/A	
2009		N/A	

Gauging Authority: Office of Public Works	
Easting: 218098	**Northing:** 279325
Catchment: Upper Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 122 km^2

QMED (gauged): 11.1 m^3/s	**AREA:** 122 km^2
QMED (synthetic urban): 7.9 m^3/s	**SAAR:** 1003
QMED (CFRAM revised): N/A	**FARL:** 1.00
BFIsoils: 7.94	**S1085:**
URBEXT: 0.07	**ARTDRAIN2:** N/A
DRAIND: 0.04	
Comments: *Catchment descriptors from FSU.*	
Nearby AFAs: Longford	
Jacobs Rating Review: No	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 33 years

26021 – INNY AT BALLYMAHON

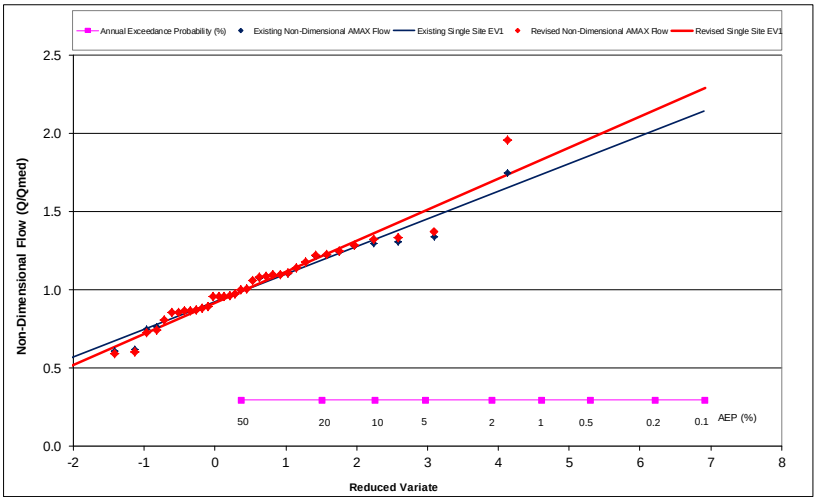
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1946			
1947			
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972			
1973			
1974			
1975	42.2	42.23	09/01/1976
1976	59.8	61.71	20/02/1977
1977	66.2	68.20	04/02/1978
1978	89.9	94.22	27/12/1978
1979	67.4	69.42	15/12/1979
1980	66.5	68.50	09/06/1981
1981	60.9	62.87	03/01/1982
1982	81.5	84.17	31/01/1983
1983	74.6	76.94	16/01/1984
1984	75.9	78.23	15/12/1984
1985	52.0	51.98	06/08/1986
1986	61.8	63.74	18/12/1986
1987	75.3	77.58	22/10/1987
1988	43.0	43.00	23/12/1988
1989	84.1	86.88	06/02/1990
1990	59.2	61.14	21/03/1991
1991	53.1	53.08	08/01/1992
1992	59.8	61.71	09/04/1993
1993	76.5	78.88	27/02/1994
1994	88.6	91.73	31/01/1995
1995	60.4	62.29	25/10/1995
1996	69.8	71.88	18/02/1997
1997	69.2	71.26	09/01/1998
1998	66.2	68.20	16/01/1999
1999	92.5	97.83	25/12/1999
2000	73.4	75.66	06/11/2000
2001	86.0	88.95	11/02/2002
2002	66.2	68.20	22/10/2002
2003	55.8	57.75	15/01/2004
2004	84.7	87.57	08/01/2005
2005	59.2	61.14	01/04/2006
2006	90.5	95.12	11/12/2006
2007	75.9	78.23	29/12/2007
2008	79.0	81.50	31/01/2009
2009	120.9	139.60	20/11/2009

Gauging Authority: Office of Public Works	
Easting: 216107	**Northing:** 256987
Catchment: Inny	**Telemetry:** No
Station Type: Recorder	**Catchment Area:** 1098.8 km^2

QMED (gauged): m^3/s	**AREA:** 1098.8 km^2
QMED (synthetic urban): 25.5 m^3/s	**SAAR:** 946
QMED (CFRAM revised): 71.3 m^3/s	**FARL:** 0.80
BFIsoils: 0.77	**S1085:** 0.20
URBEXT: 0.41	**ARTDRAIN2:** 63.32
DRAIND: 0.76	
Comments: *Catchment descriptors from FSU data.*	
Nearby AFAs: Ballymahon	
Jacobs Rating Review: Yes	**FSU Station Classification:** A2

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 35 years

This site is confirmed to be stable, with the first year of the record (1975) exceptionally dry and the last year (2009) exceptionally wet.

Revised AMAX series are recommended for QMED estimation and flood frequency analysis.

Gauging Hut

Channel looking upstream

Channel looking downstream

Structure Details	
Type of Structure:	No control at this location, masonry hut on the left bank. There is a bridge (1 large arch) about 0.5km downstream
Condition of structure	Good

Gauging Station location description	On the right bank about 500m upstream of the bridge in Ballymahon.
Describe potential for flow bypassing gauging station	Low. Ground is high on the left bank and right bank. Right bank may be slightly lower, no reason to think that flows would bypass the gauge.
Describe **left** bank **upstream** condition	The bank is steep and 2 to 3 m above bed level. There is vegetation and trees growing on the banks that encroach on the channel. These do not appear to be significant. But could potentially get out of hand and cause problems if not monitored.
Describe **right** bank **upstream** condition	The bank is steep and 2 to 3 m above bed level. There is vegetation and trees growing on the banks that encroach on the channel. These do not appear to be significant. But could potentially get out of hand and cause problems if not monitored.
Describe **left** bank **downstream** condition	The bank is steep and 2 to 3 m above bed level. There is vegetation and trees growing on the banks that encroach on the channel. These do not appear to be significant. But could potentially get out of hand and cause problems if not monitored.
Describe **right** bank **downstream** condition	The bank is steep and 2 to 3 m above bed level. There is vegetation and trees growing on the banks that encroach on the channel. These do not appear to be significant. But could potentially get out of hand and cause problems if not monitored.

26022 – FALLAN AT KILMORE

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date

26027 – SHANNON AT ATHLONE

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1952	156.97		08/11/1952
1953	185.41		27/02/1954
1954	312.12		14/12/1954
1955	156.97		31/01/1956
1956	254.47		05/01/1957
1957	177.69		27/02/1958
1958	193.41		08/01/1959
1959	275.16		29/12/1959
1960	239.13		06/02/1961
1961	220.95		15/12/1961
1962	175.58		15/12/1962
1963	243.22		27/11/1963
1964	284.50		23/01/1965
1965	271.44		28/11/1965
1966	188.99		19/12/1966
1967	258.69		18/01/1968
1968	269.82		24/01/1969
1969	203.95		25/02/1970
1970	202.98		30/11/1970
1971	167.68		10/04/1972
1972	160.52		17/12/1972
1973	225.76		18/01/1974
1974	275.16		30/01/1975
1975	178.62		12/01/1976
1976	219.94		25/02/1977
1977	192.06		14/11/1977
1978	207.15		17/12/1978
1979	262.32		17/12/1979
1980	225.76		29/12/1980
1981	230.17		16/03/1982
1982	242.16		08/01/1983
1983	252.91		08/02/1984
1984	194.76		28/12/1984
1985	196.12		10/10/1985
1986	254.47		20/12/1986
1987	265.50		09/02/1988
1988	192.06		23/03/1989
1989	296.70		13/02/1990
1990	289.98		05/01/1991
1991	189.39		13/01/1992
1992	225.76		23/01/1993
1993	256.03		04/01/1994
1994	300.09		02/02/1995
1995	174.12		17/02/1996
1996	251.36		01/03/1997
1997	240.64		11/01/1998
1998	243.68		23/01/1999
1999	303.50		30/12/1999
2000	265.66		15/12/2000
2001	300.26		11/02/2002
2002	267.26		16/11/2002
2003	197.62		07/02/2004
2004	270.47		10/01/2005
2005	153.55		18/01/2006
2006	305.39		13/12/2006
2007	267.26		25/01/2007
2008	234.03		06/02/2009
2009	396.39		25/11/2009

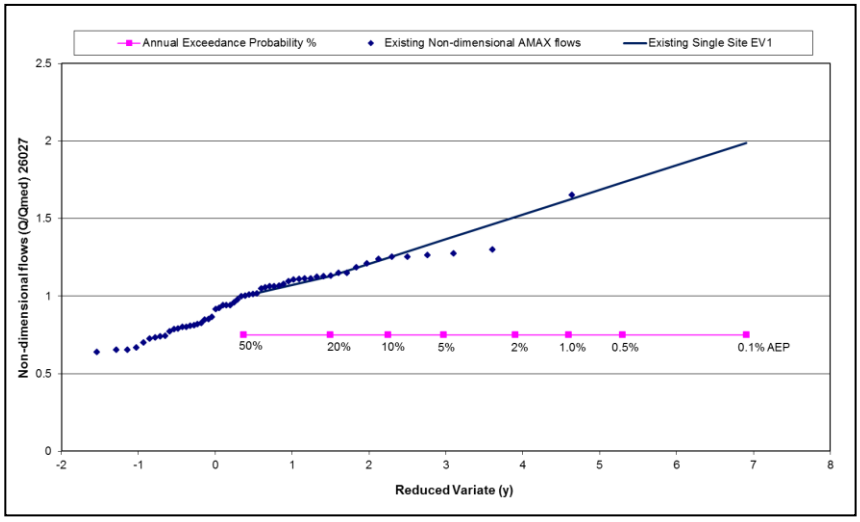
Length of AMAX series: 58

No changes made to existing OPW AMAX series.

Gauging Authority: Office of Public Works	
Easting: 204042	**Northing:** 241293
Catchment: Mid/Lower Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 4601 km^2

QMED (gauged): 240 m^3/s	**AREA:** 4601 km^2
QMED (synthetic urban): 145 m^3/s	**SAAR:** 1058
QMED (CFRAM revised): not revised	**FARL:** 0.67
BFIsoils: 0.69	**S1085:** 0.31
URBEXT: 0.61	**ARTDRAIN2:** 22.8
DRAIND: 0.86	
Comments: *Catchment descriptors from FSU data.*	
Nearby AFAs: Athlone	
Jacobs Rating Review: No	**FSU Station Classification:** None

Flood Frequency (EV1 with Gringorten plotting positions)



Structure control

Photos not available

Channel looking upstream

Photos not available

Channel looking downstream

Photos not available

Structure Details	
Type of Structure:	Information not available.
Condition of structure	Information not available

Gauging Station location description	Information not available.
Describe potential for flow bypassing gauging station	Information not available.
Describe **left** bank **upstream** condition	Information not available.
Describe **right** bank **upstream** condition	Information not available.
Describe **left** bank **downstream** condition	Information not available.
Describe **right** bank **downstream** condition	Information not available.

26108 – BOYLE AT BOYLE ABBEY BR.

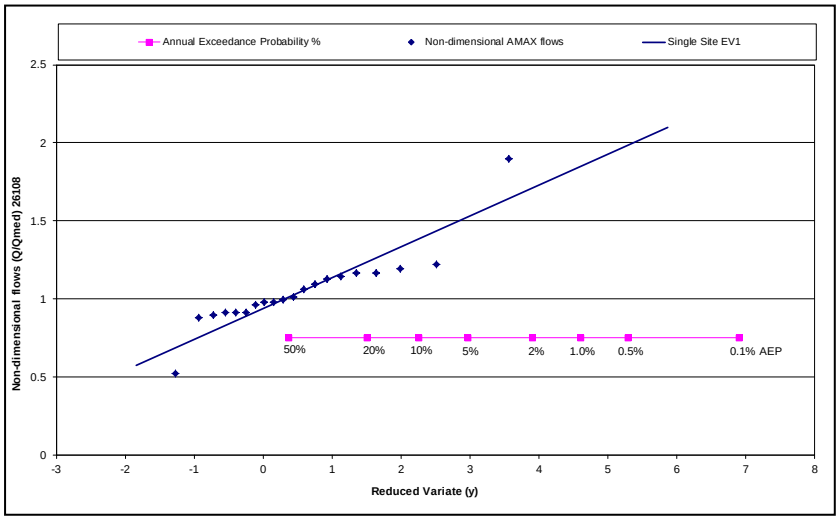
Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
1948			
1949			
1950			
1951			
1952			
1953			
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972			
1973			
1974			
1975			
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985			
1986			
1987			
1988			
1989			
1990	45.5		05/01/1991
1991	48.4		10/01/1992
1992	41.3		03/12/1992
1993	40.6		19/12/1993
1994	47.0		01/01/1995
1995	36.7		28/10/1995
1996	40.6		26/02/1997
1997	39.9		12/01/1998
1998	42.0		29/12/1998
1999	48.4		27/12/1999
2000	38.0		08/12/2000
2001	50.7		12/02/2001
2002	38.0		11/11/2002
2003	37.3		04/02/2004
2004	47.7		11/01/2005
2005	21.6		24/05/2006
2006	49.5		12/12/2006
2007	44.1		11/12/2007
2008	38.0		02/02/2009
2009	**79.0**		**25/11/2009**

Gauging Authority: Office of Public Works	
Easting: 180537	**Northing:** 302625
Catchment: Upper Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 527.3 km^2

QMED (gauged): 41.6 m^3/s	**AREA:** 527.3 km^2
QMED (synthetic urban): 57.3 m^3/s	**SAAR:** 1143
QMED (CFRAM revised): N/A	**FARL:** 0.86
BFIsoils: 0.73	**S1085:** 0.37
URBEXT: 0.42	**ARTDRAIN2:** 53
DRAIND: 0.88	
Comments: *Model rating confimed OPW rating, therefore rating not revised.* *Catchment descriptors from FSU.*	
Nearby AFAs: Boyle	
Jacobs Rating Review: Yes	**FSU Station Classification:** A1

Flood Frequency (EV1 with Gringorten plotting positions)



Length of AMAX series: 20 years

Entire AMAX appropriate for QMED estimation and flood frequency analysis.

26221 – CROSS AT SUMMER HILL

Annual Maxima Series

Hydrological Year	Existing Flow (m^3/s)	Revised Flow (m^3/s)	Date
2002		9.70	11/02/2002
2003		10.52	30/10/2002
2004		5.89	31/01/2004
2005		12.53	08/01/2005
2006		4.63	13/01/2006
2007		6.38	18/01/2007
2008		7.93	28/12/2007
2009		6.85	31/01/2009
2010		9.08	06/04/2010
2011		7.74	06/02/2011
2012		7.48	29/11/2011
2013		7.41	18/01/2013

Length of AMAX series: 12 years

The OPW rating based AMAX series remain unchanged.

Gauging Authority: Office of Public Works	
Easting: 201044	**Northing:** 240198
Catchment: Lower Shannon	**Telemetry:** Yes
Station Type: Recorder	**Catchment Area:** 103.30 km^2

QMED (gauged): 7.6m^3/s	**AREA:** 103.3 km^2
QMED (synthetic urban): 8.2m^3/s	**SAAR:** 933.3
QMED (CFRAM revised): N/A m^3/s	**FARL:** 0.99
BFIsoils: 0.79	**S1085:** 1.81
URBEXT: 0.26	**ARTDRAIN2:** 0.0
DRAIND: 0.55	
Comments: Catchment descriptor from FSU data	
Nearby AFAs: Athlone	
Jacobs Rating Review: Yes	**FSU Station Classification:** None

Flood Frequency (EV1 with Gringorten plotting positions)

Chart not available

Structure control

Photo not available

Channel looking upstream

Photo not available

Channel looking downstream

Photos not available

Structure Details	
Type of Structure:	Information not available
Condition of structure	Information not available

Gauging Station location description	Information not available
Describe potential for flow bypassing gauging station	Information not available
Describe **left** bank **upstream** condition	Information not available
Describe **right** bank **upstream** condition	Information not available
Describe **left** bank **downstream** condition	Information not available
Describe **right** bank **downstream** condition	Information not available

Appendix E Flood Frequency Curves

Table of Content

25006 Ferbane

25014 Millbrook

25016 Rahan

25017 Banagher

25022 Syngefield

25023 Milltown

25025 Ballyhooney

25027 Gourdeen

25029 Clarianna

25038 Tyone

25040 Roscrea

25075 Parteen Weir

26002 Rookwood

26005 Derrycahill

26006 Willsbrook

26007 Bellagill

26008 Johnston's Bridge

26012 Tinacarra

26016 Ballymurray

26019 Mullagh

26020 Argar

26021 Ballymahon

26027 Athlone

26108 Boyle Abbey Bridge

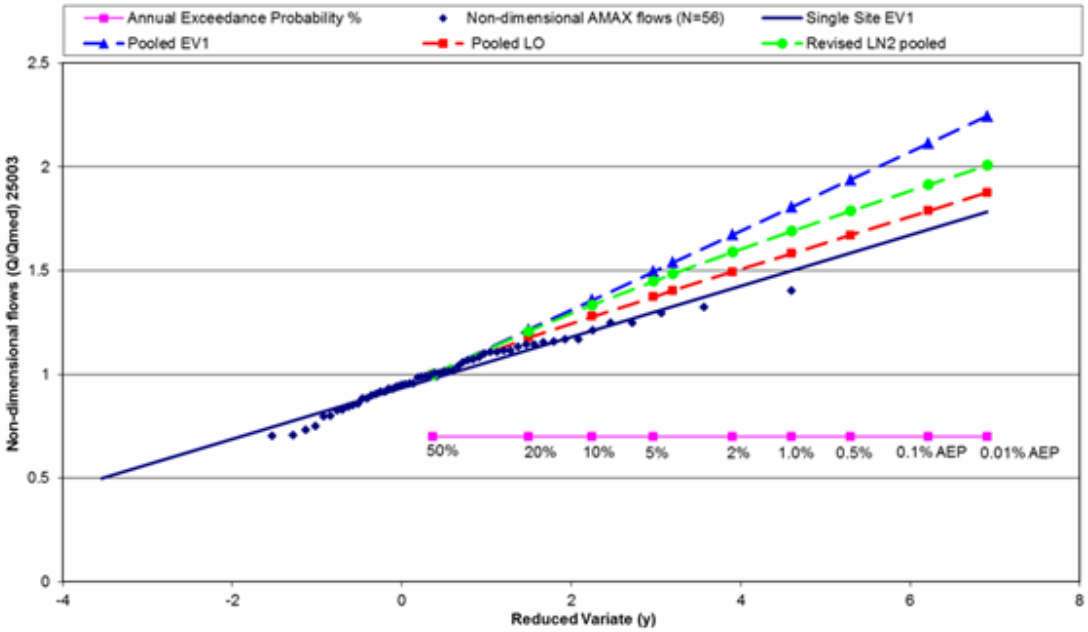


Figure E.1 Abington (25003) Flood Frequency Curves

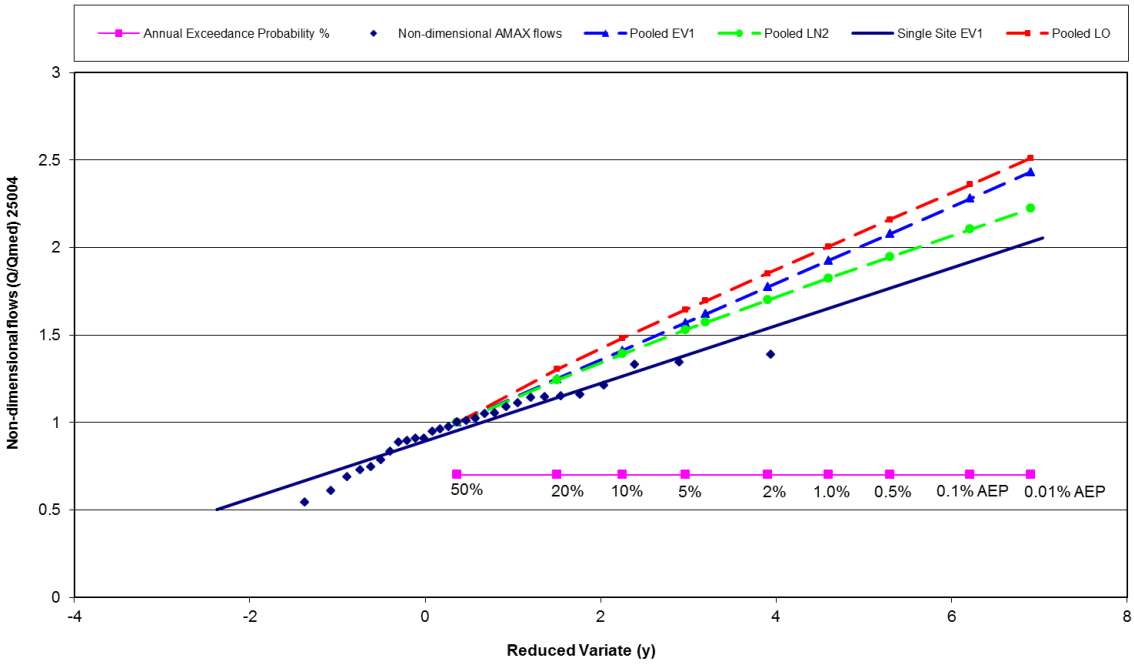


Figure E.2 Newbridge (25004) Flood Frequency Curves

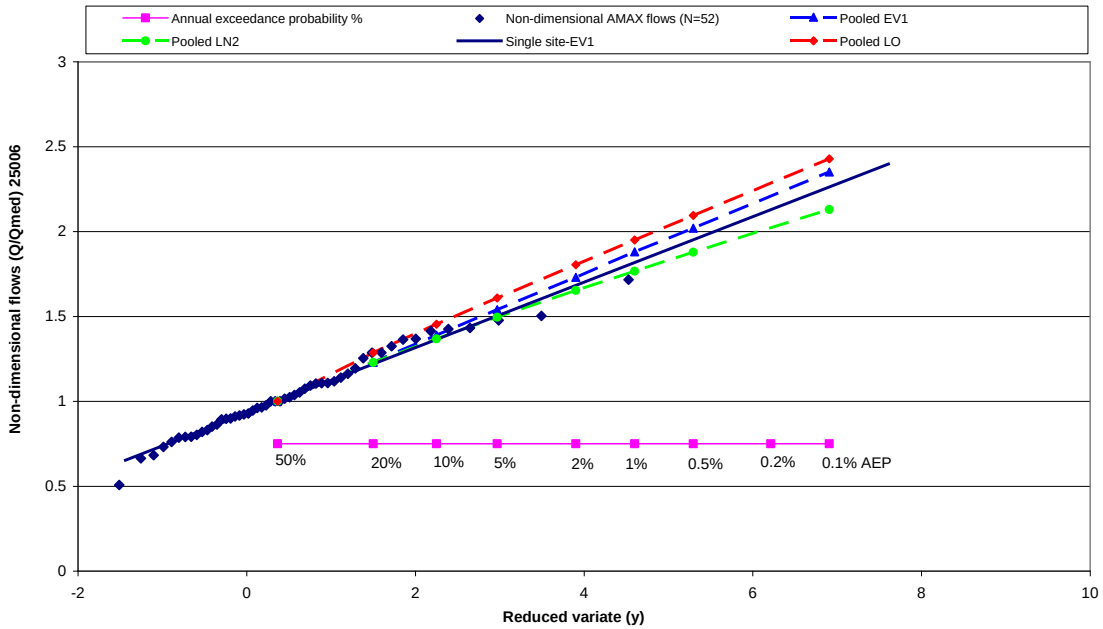


Figure E.3 Ferbane (25006) Flood Frequency Curves

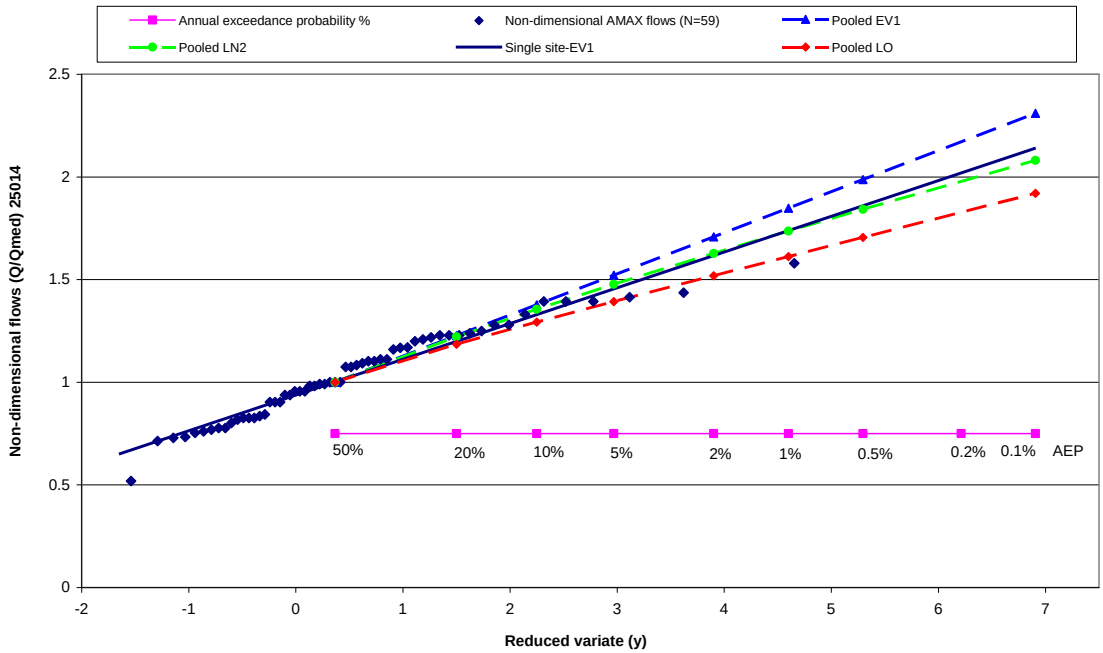


Figure E.4 Millbrook (25014) Flood Frequency Curves

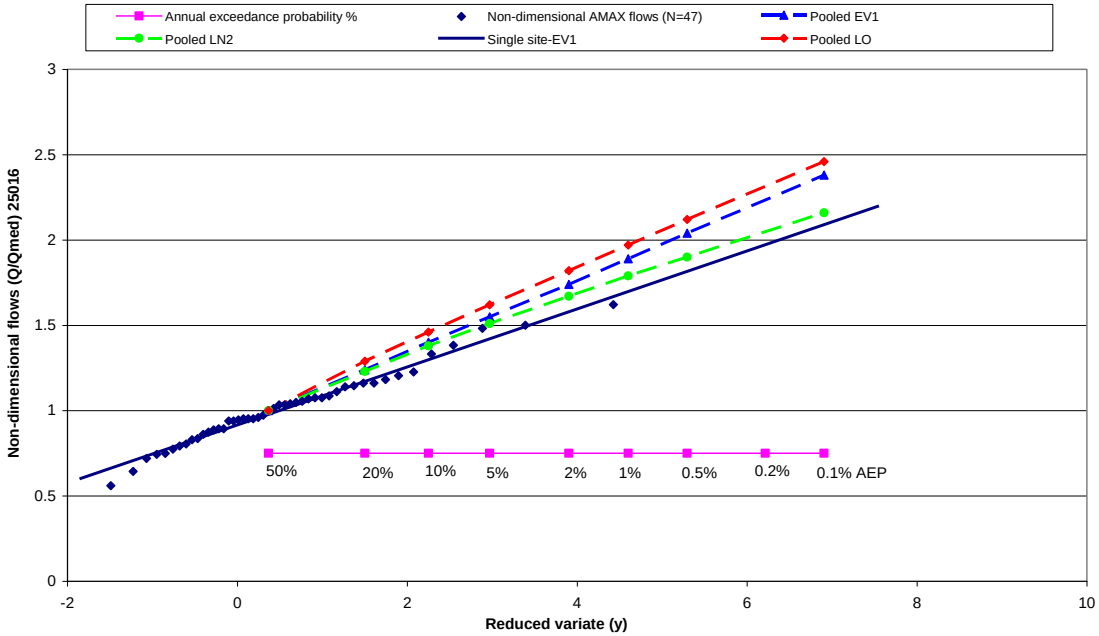


Figure E.5 Rahan (25016) Flood Frequency Curves

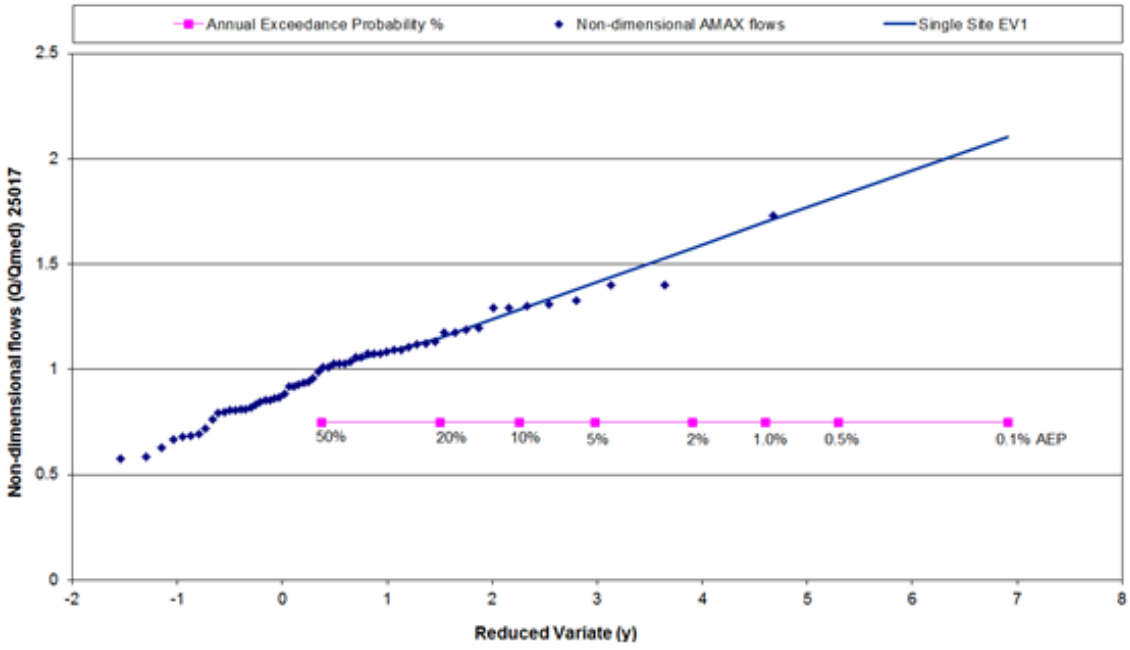


Figure E.6 Banagher (25017) Flood Frequency Curves

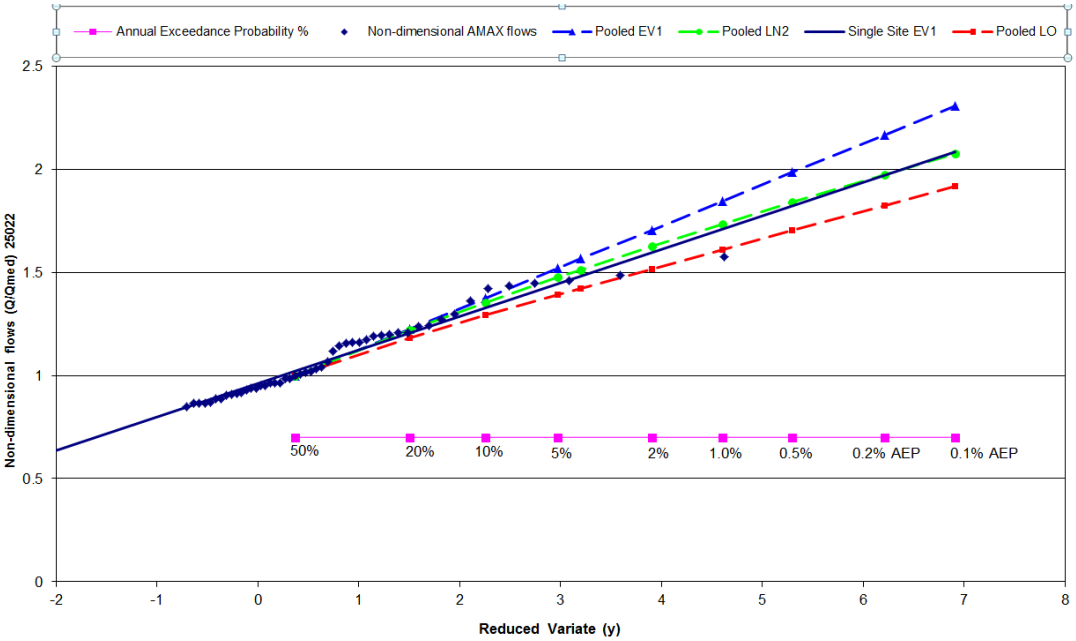


Figure E.7 Syngefield (25022) Flood Frequency Curves

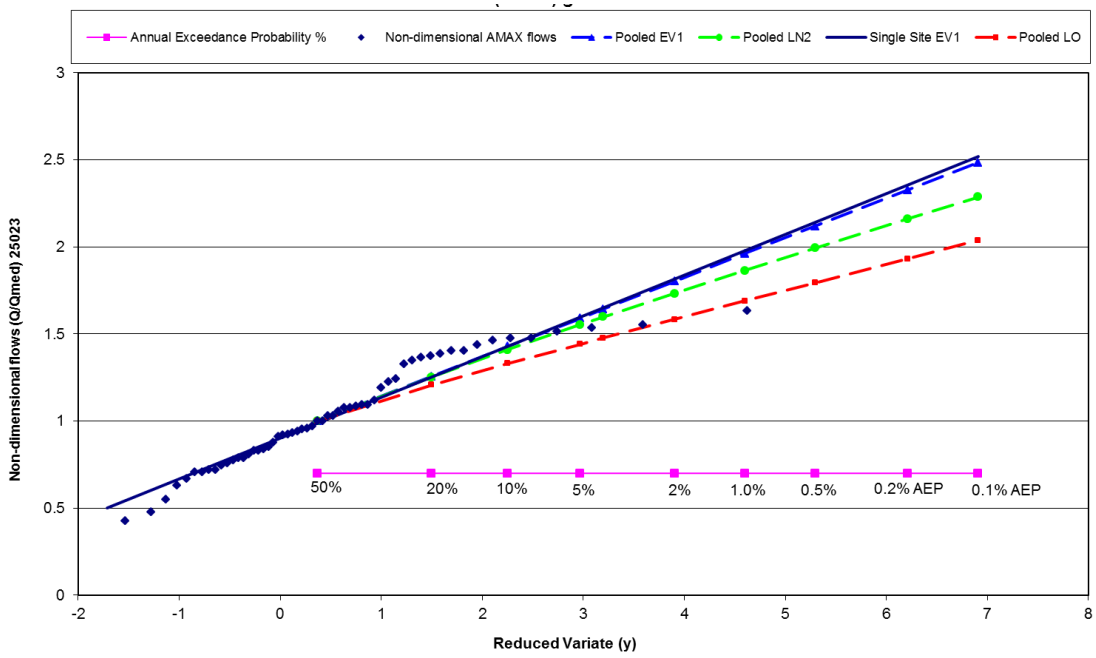


Figure E.8 Milltown (25023) Flood Frequency Curves

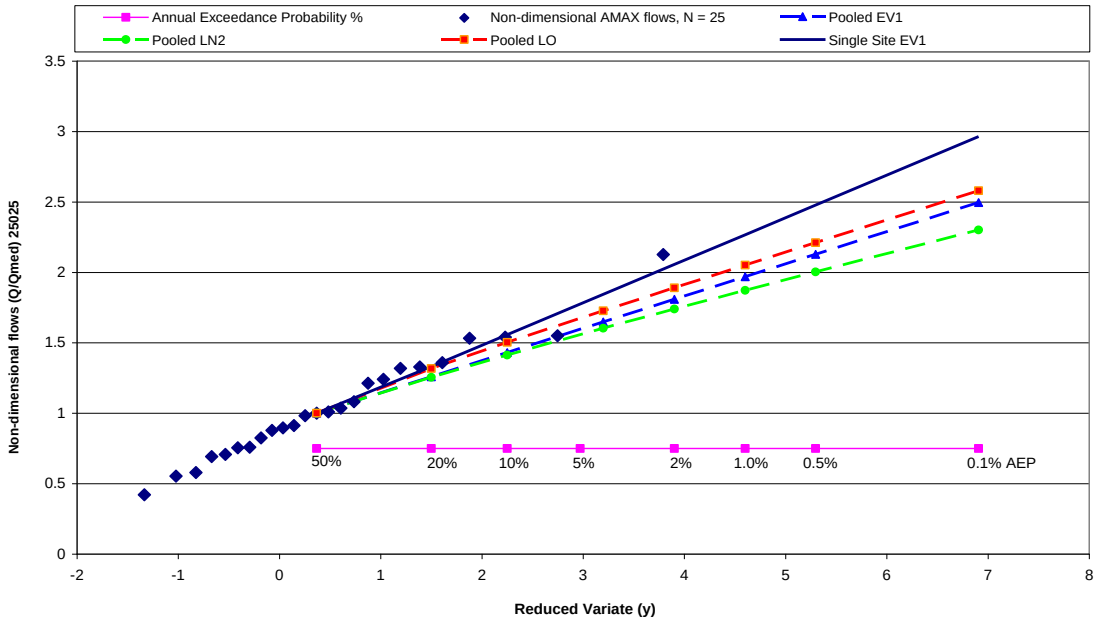


Figure E.9 Ballyhooney (25025) Flood Frequency Curves

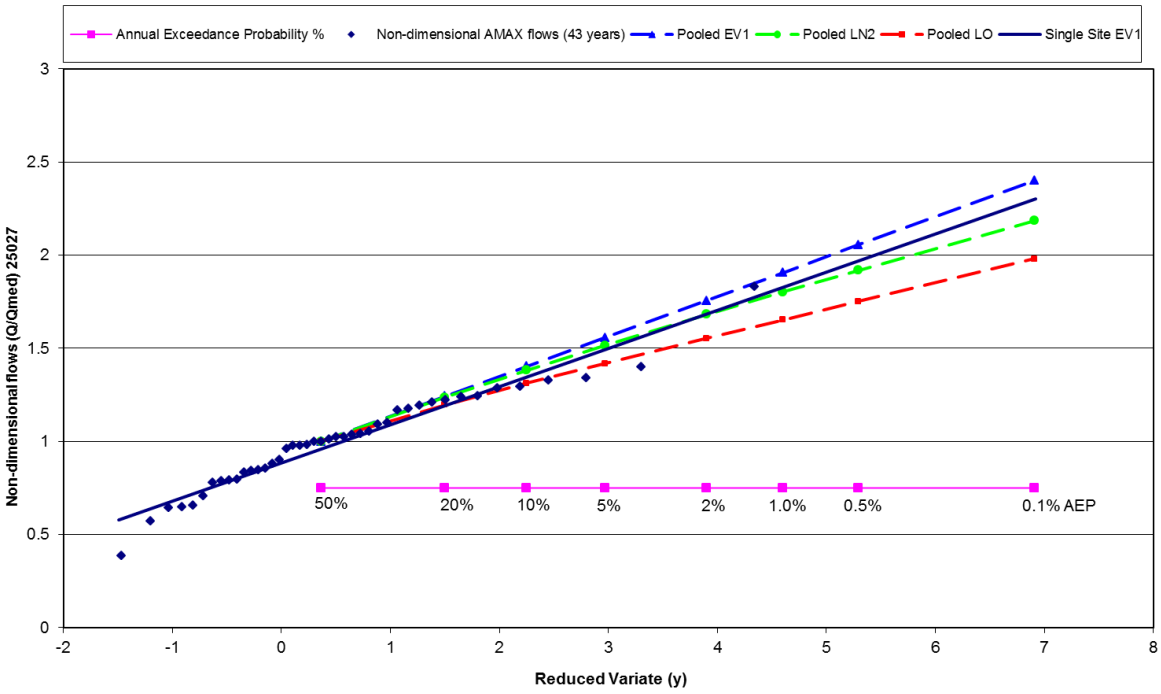


Figure E.10 Gourdeen (25027) Flood Frequency Curves

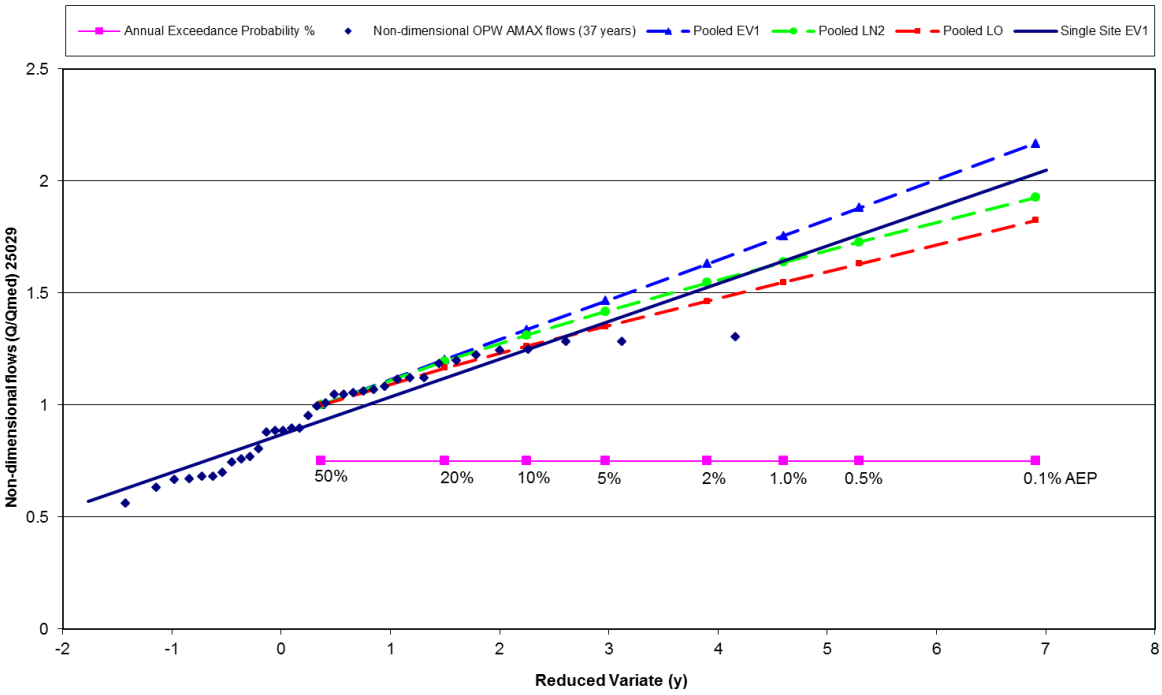


Figure E.11 Clarianna (25029) Flood Frequency Curves

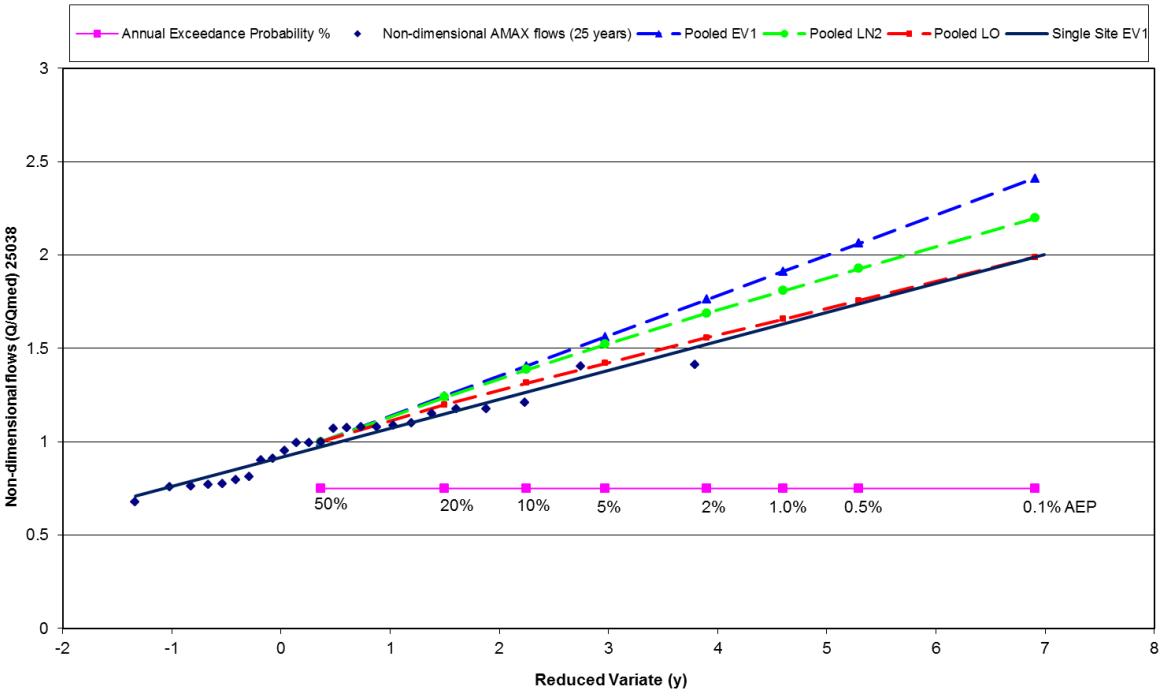


Figure E.12 Tyone (25038) Flood Frequency Curves

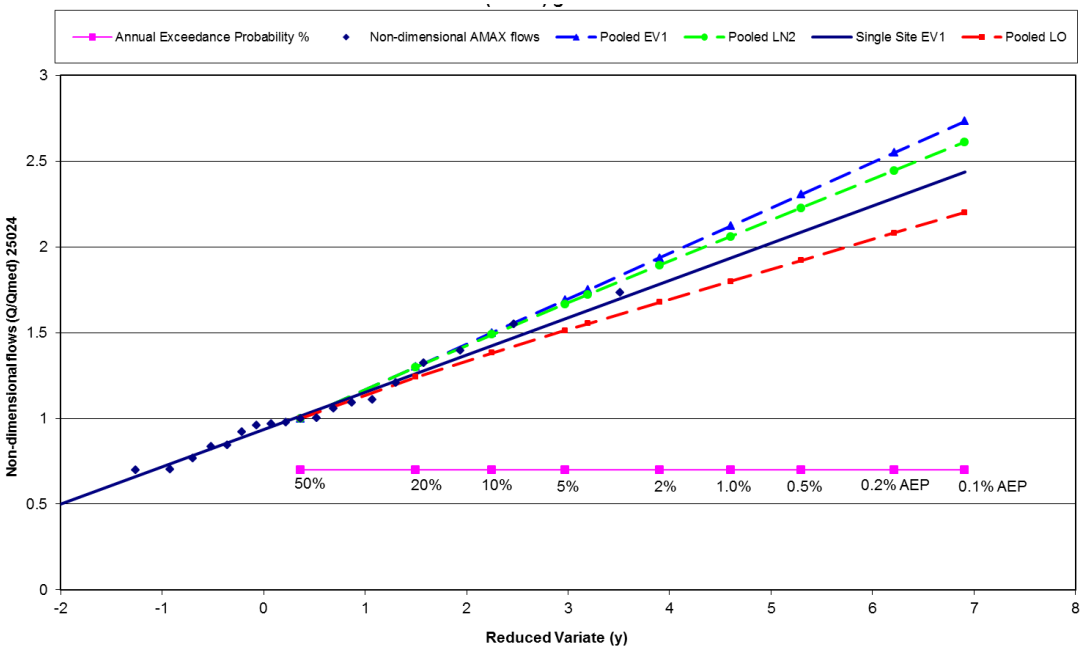


Figure E.13 Roscrea (25040) Flood Frequency Curves

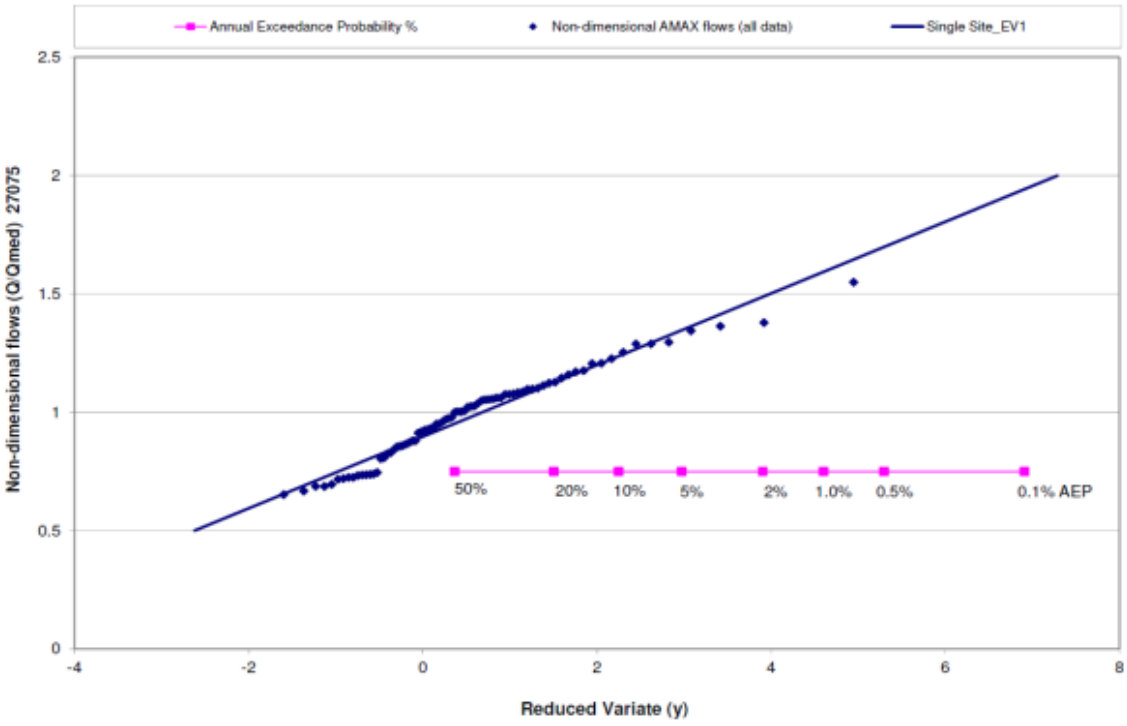


Figure E.14 Parteen Weir (25075) Flood Frequency Curves

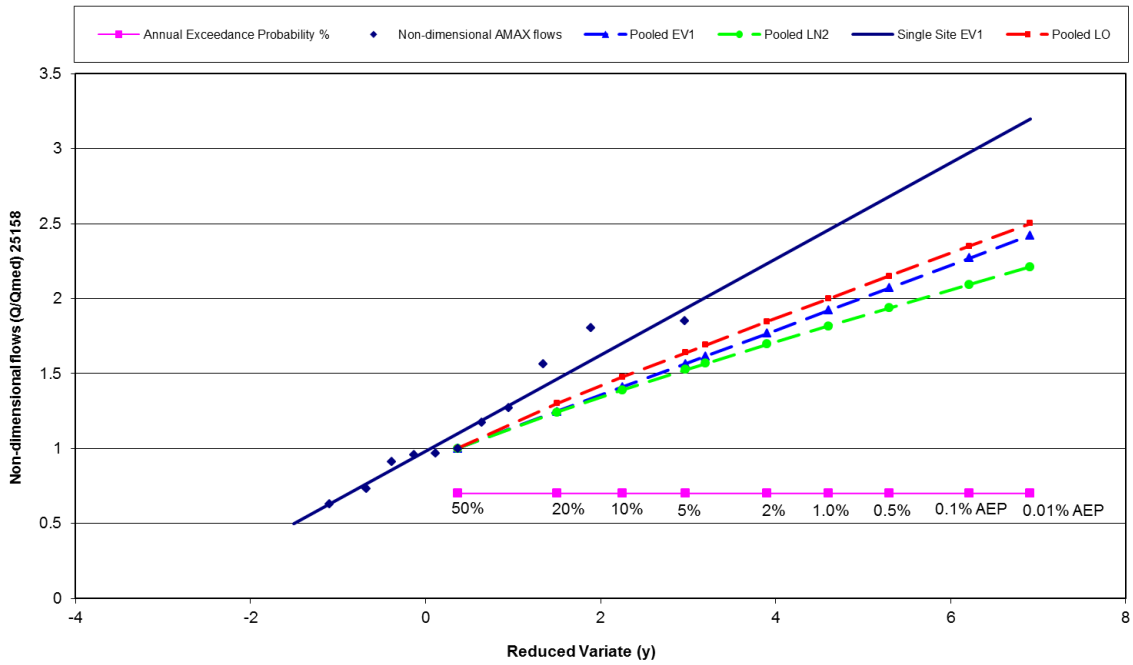


Figure E.15 Waterpark Bridge (25308) Flood Frequency Curves

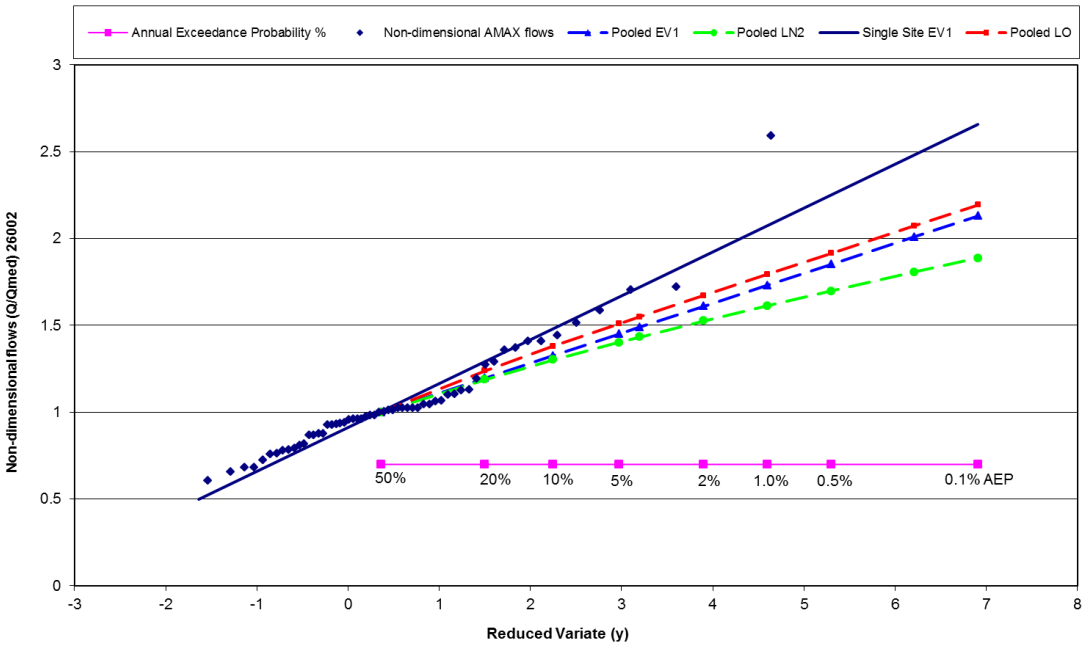


Figure E.16 Rookwood (26002) Flood Frequency Curves

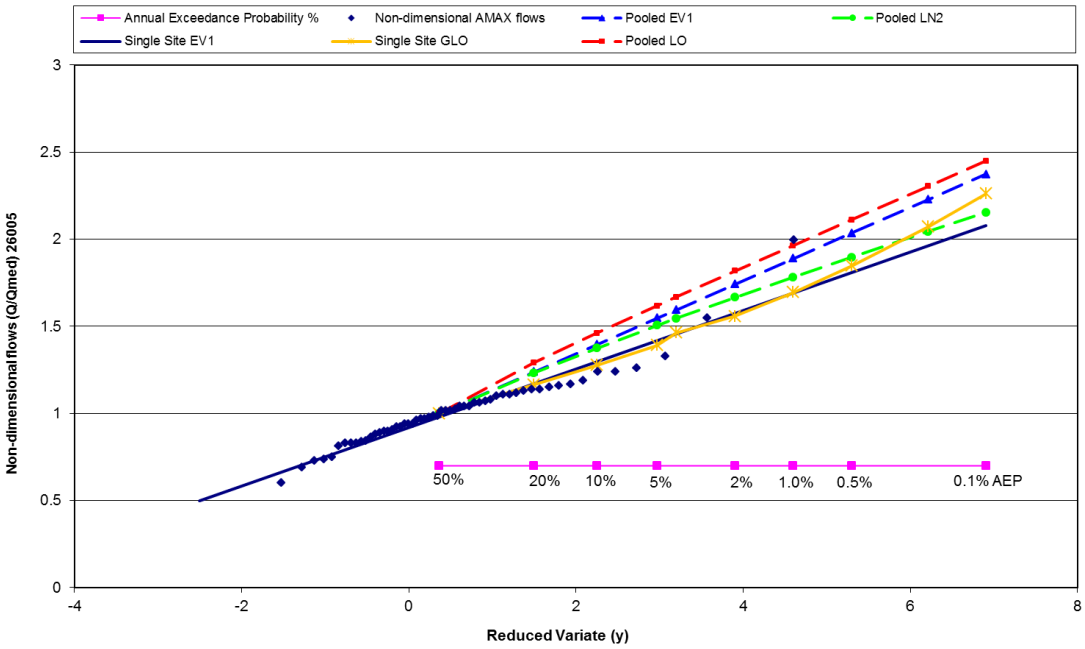


Figure E.17 Derrycahill (26005) Flood Frequency Curves

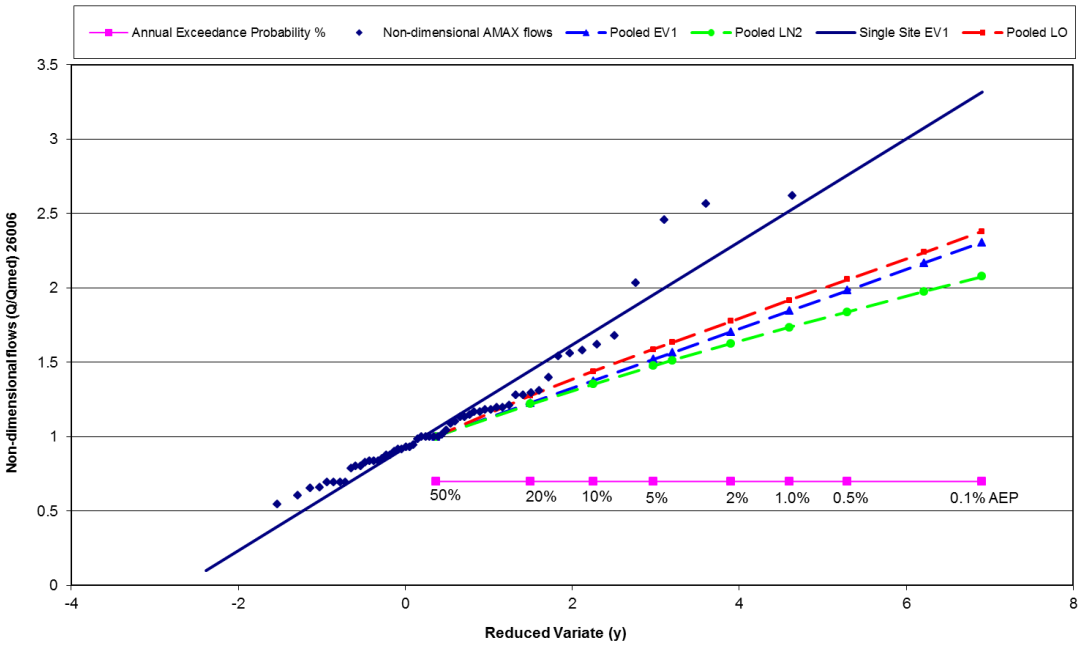


Figure E.18 Willsbrook (26006) Flood Frequency Curves

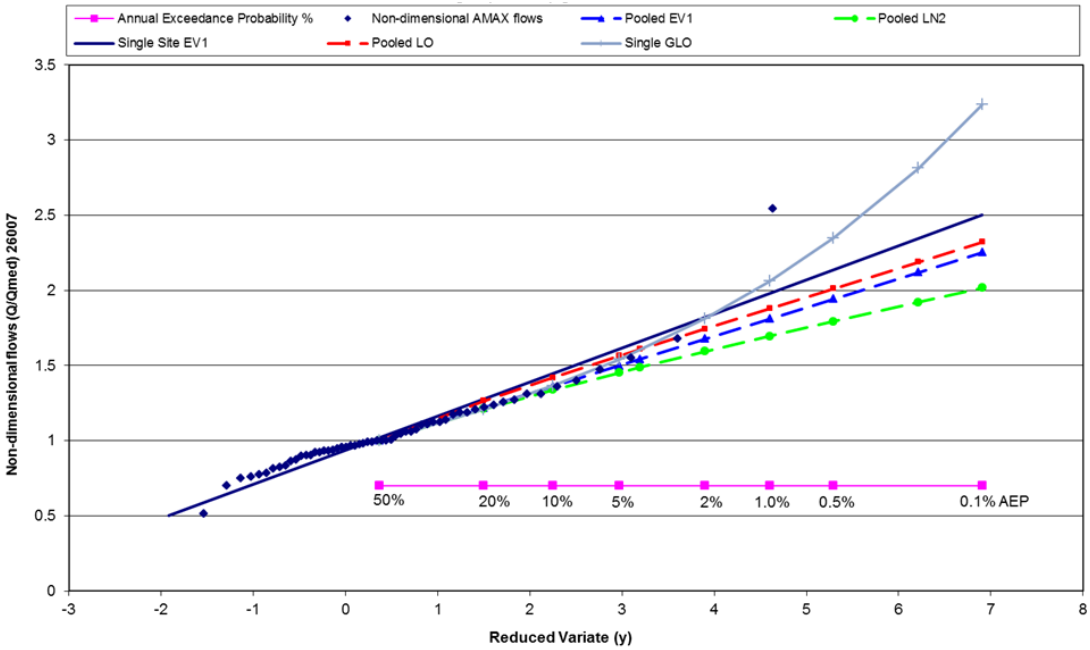


Figure E.19 Bellagill (26007) Flood Frequency Curves

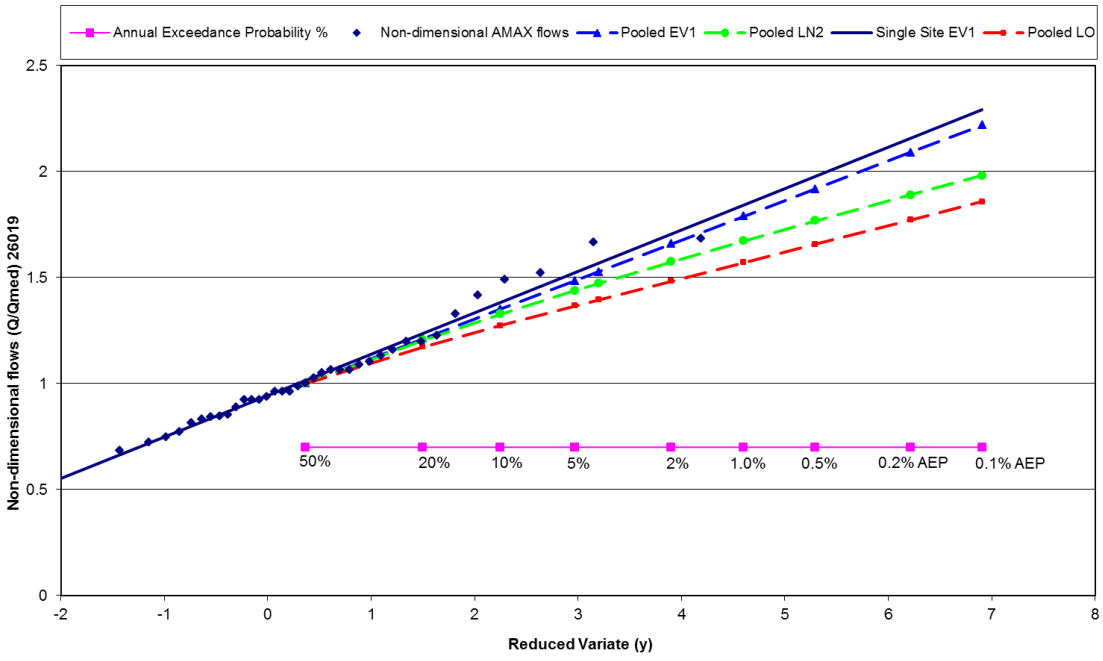


Figure E.20 Johnston's Bridge (26008) Flood Frequency Curves

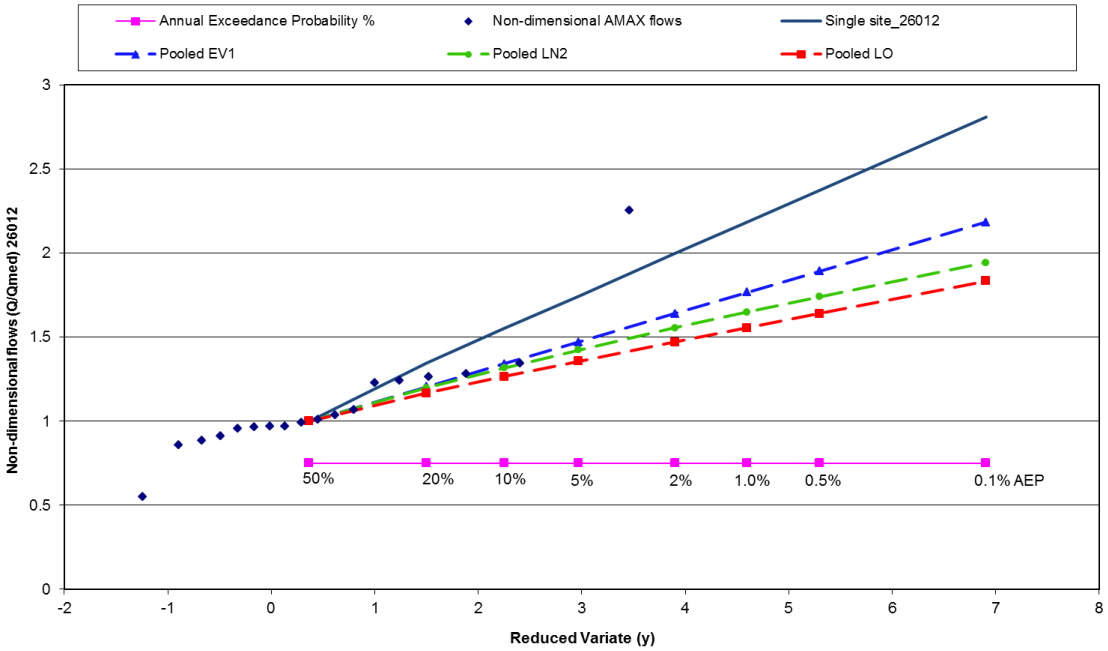


Figure E.21 Tinacarra (26012) Flood Frequency Curves

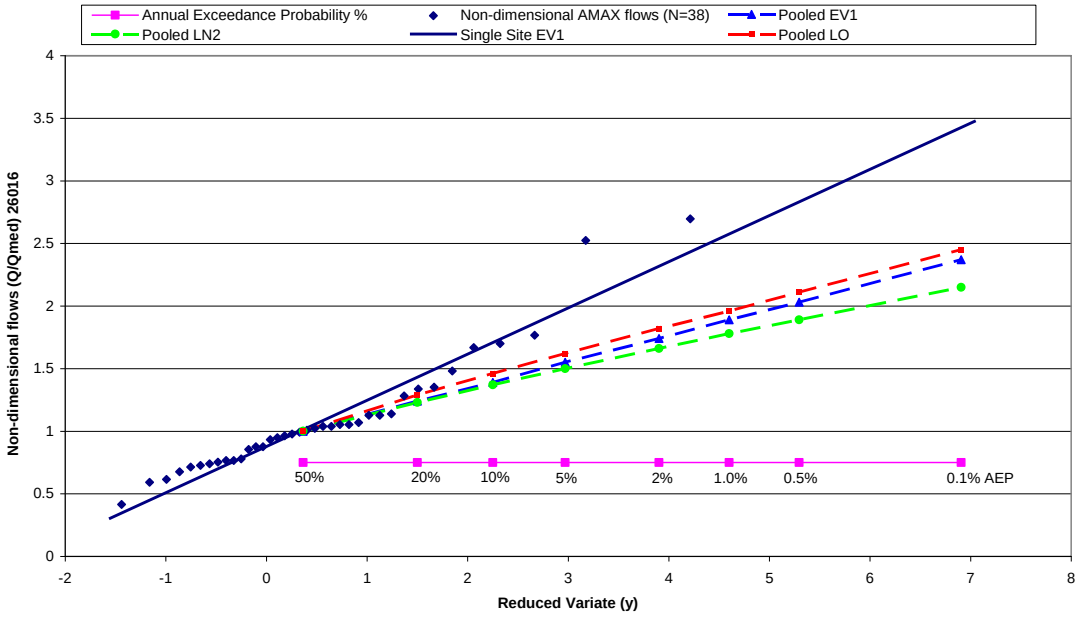


Figure E.22 Ballymurray (26016) Flood Frequency Curves

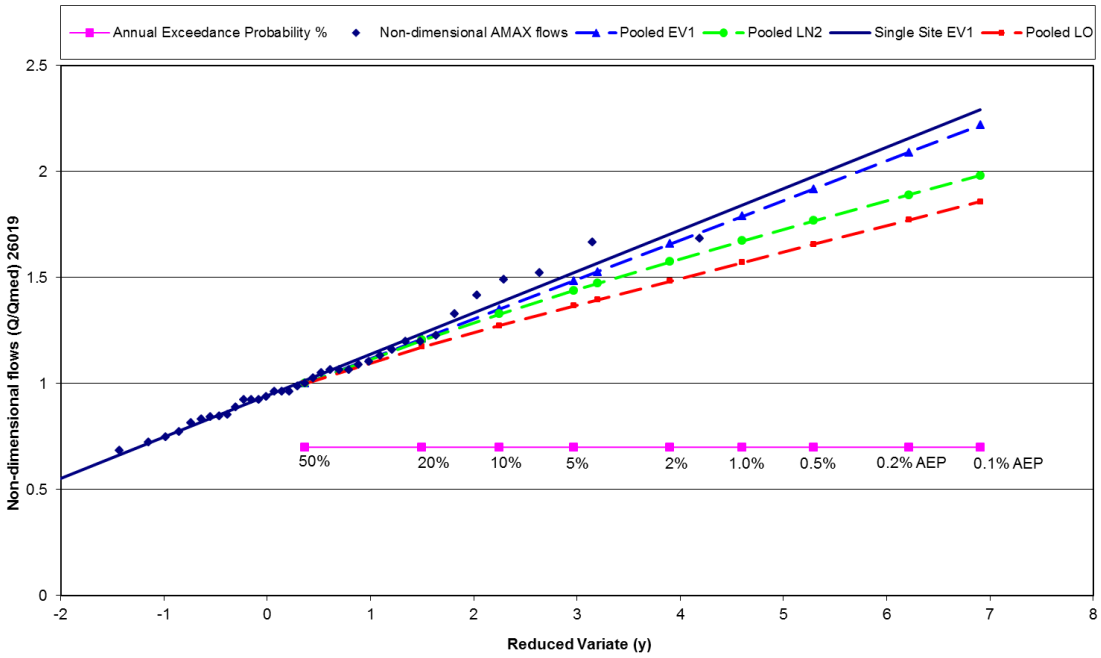


Figure E.23 Mullagh (26019) Flood Frequency Curves

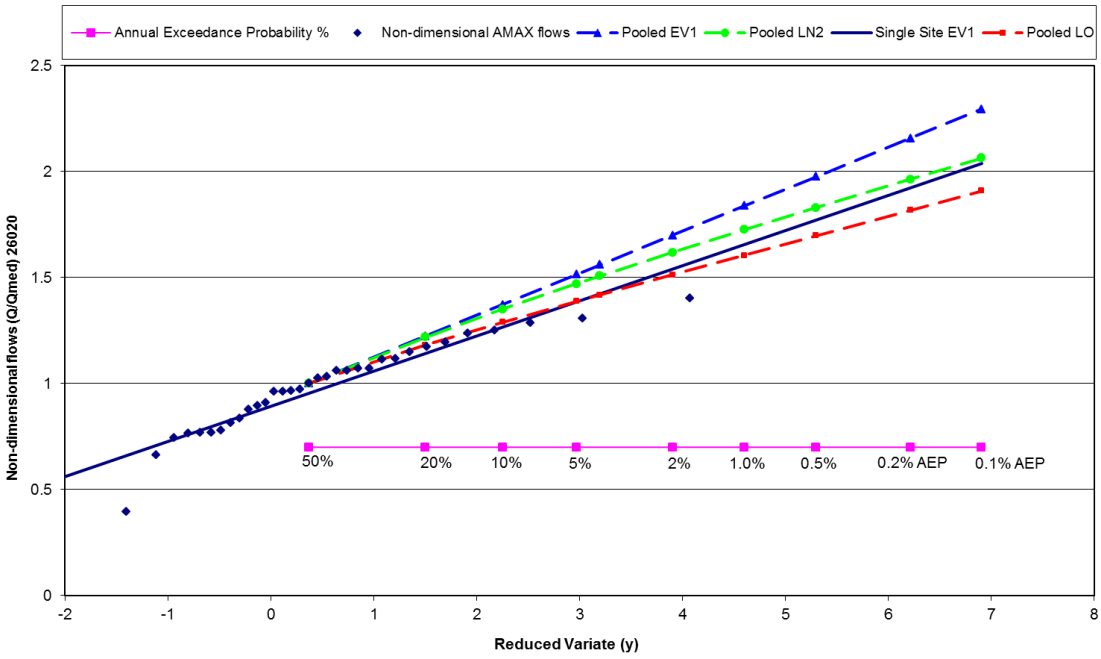


Figure E.24 Argar (26020) Flood Frequency Curves

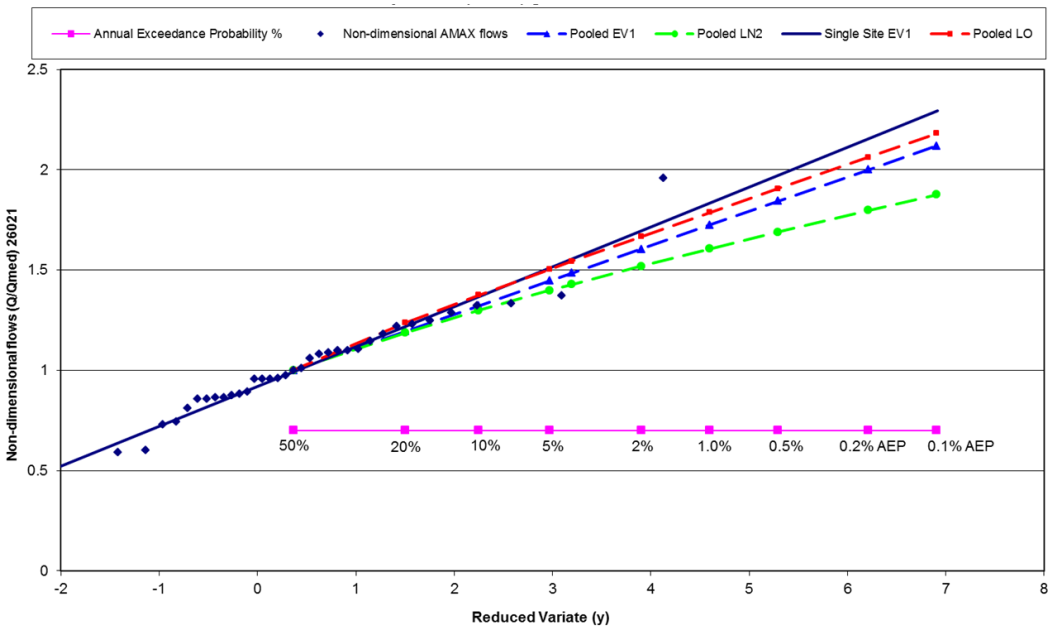


Figure E.25 Ballymahon (26021) Flood Frequency Curves

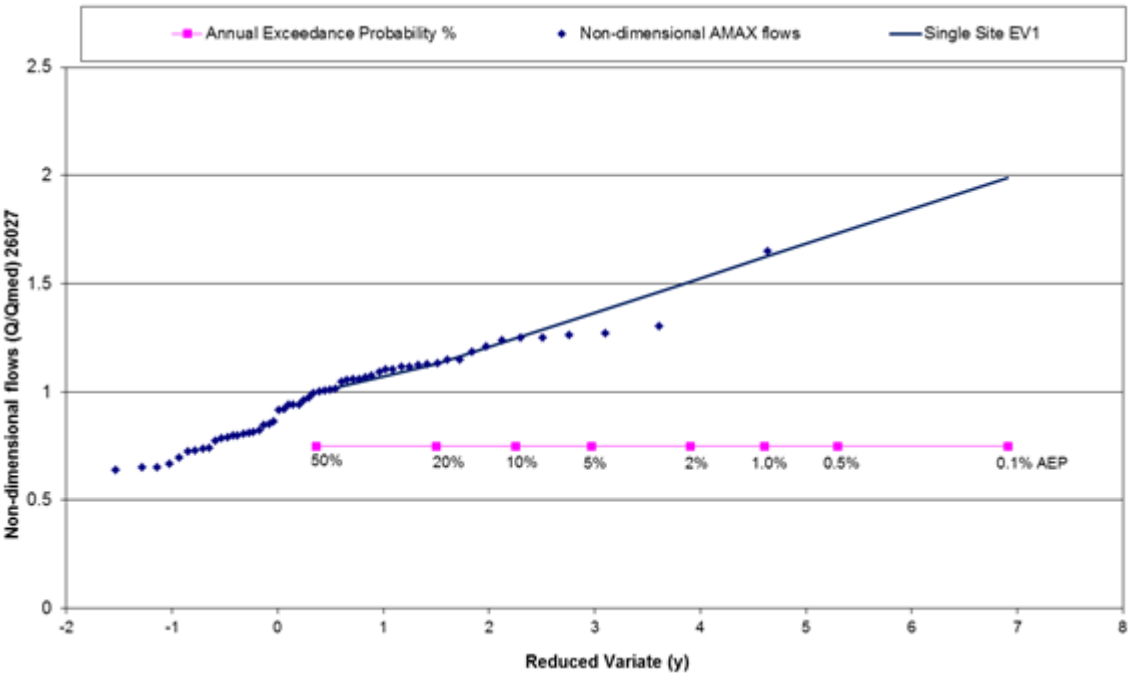


Figure E.26 Athlone (26027) Flood Frequency Curves

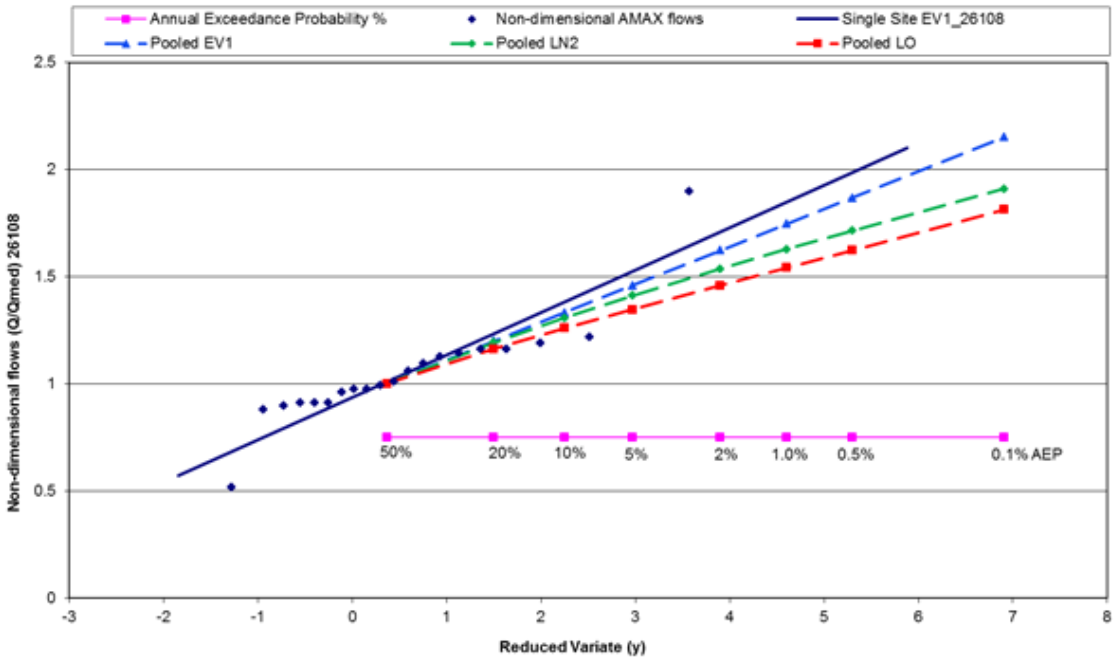


Figure E.27 Boyle Abbey Bridge (26108) Flood Frequency Curves

Appendix F Calibration Strategy Sheets

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Model N16

For the event categories and scoring system adopted in the Calibration Strategy Sheets in this appendix the reader is referred to Guidance Note 23 in Appendix D of the hydraulics report.

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N01**	Length	70 km
Unit of Management		25/26	
AFAs	Drumshanbo, Leitrim Villlage, Boyle, Carrick-on-Shannon		
IRRs	None		
River / Sub-Catchment / Catchment	River Shannon / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model extent N01 is comprised of the River Shannon and a number of major and minor tributaries of the Shannon. The major tributary into the River Shannon within N01 is the Boyle River (including its tributary the Easkey River). The minor tributaries include the River Aghagrania, Ballinamore River & Ballyconnell Canal, Guiltyconeen & Mullaghmore River in addition to the Lisnabrack, Drummagh and Keenaghban tributaries within Carrick-on-Shannon AFA. There are a number of Loughs within model N01. Lough Allen is found near the head of the River Shannon with Lough Corry found further downstream. Lough Gara is situated at the head of the Boyle River. Along the flow path of the Boyle River can be found Lough Key, Lough Oakport and Lough Eidin. There are 4 AFAs located within the model known as Drumshanbo, Leitrim Village, Boyle and Carrick-on-Shannon. There are 8 gauging stations within this model which measure level and/or flow.		

Completed by	Kieran Daly	James Cullinane	
Date	13/02/13	15/04/2014	

Potential Flood Events to consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	20-26/11/2009 – Jacobs data collection for GIS digitisation of Nov. 2009 flood event, some flood levels within Carrick-on-Shannon Basin, flood levels at Jamestown weir, aerial and ground photographs of flooding extent from 2009 event.	1	2+2+0+3+3 = 10	Verification
2	Winter 1999/2000 – Series of peak flood levels recorded during Dec. 1999 flood event in Carrick-on-Shannon, meeting minutes mentioning N4 road liable to flooding near Lough Eidin.	1	2+2+0+2+2 = 8	Verification

3	01/12/ 1954 – Approximate flood outline of the 1954 flood event. Irish MET Office weather bulletin (no specific levels/flows mentioned). River Shannon Flood problem Report by Corps of Engineers U.S. Army (no specific flood data).	1	0+0+0+1+1 = 2	Not suitable for Calibration/Verification
4	29/7/1996 – Ground photographs of flooding at Boyle Railway station, Church View Housing Estate and Hanley Avenue. All areas located within Boyle AFA.	1	2+2+0+1+2 = 7	Verification
5	Gauge data only – In-bank events	1	To be identified in phase 2	calibration/verification
6	Gauge data only – Out-of-bank events	1	To be identified in phase 2	calibration/verification

The flood event data above and in Appendix B are taken from www.floodmaps.ie database.

* See Appendix B for Event Details of events 1-4, ** See Appendix C for Quality Category and Quality Score
Scoring - 0 (Not suitable for calibration) to 15 (Suitable for calibration)

Gauging Station Information within Model Extent (or close to)					
Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification	Comment
26012 – Tinacarra	1993 - present	Level and flow	61.79	A1	Jacobs rating review completed. Very little difference observed between the Jacobs model rating and OPW rating so AMAX series was not re-worked. OPW rating verified up to 0.74xQMED (post Drainage Works – 1993 onwards).
26108 – Boyle Abbey bridge	1990 - present	Level and flow	48.62	A2	Jacobs rating review completed. Very little difference observed between the Jacobs model rating and OPW rating so AMAX series was not re-worked. OPW rating verified up to 1.90xQMED.
26085 – Jamestown	1957 - present	Level only	38.39	Not FSU Classified	Gauge datum to be confirmed from survey data by hydraulic modellers.
26030 – L. Allen D/S	2001 - present	Level and flow	40.21	Not FSU Classified	No Jacobs rating review undertaken. EPA gauging station, rating verified up to 1.80xQMED. Gauge datum to be confirmed from survey data by hydraulic modellers.
26074 – Blackrock Lock	1994 - present	Level only	43.69	Not FSU Classified	Gauge datum to be confirmed from survey data by hydraulic modellers.
26075 – Cuppanagh	1980 - present	Level and flow	62.40	Not FSU Classified	No data held on 26075 by Jacobs. Consultation of the OPW Hydro Data website confirmed that there are no flows or AMAX flow records available for the site and that digitised water level records only exist from 2007 to 2009.
26073 – L. Allen U/S	1932 - present	Level only	42.92	Not FSU Classified	Level gauging station under the authority of the ESB. Gauge datum to be confirmed from survey data by hydraulic modellers.
26324 – Carrick – on - Shannon	2004 - present	Level only	38.83	Not FSU Classified	Gauge datum to be confirmed from survey data by hydraulic modellers.
* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor)					

Control structures		
Reference	Type	Description
River Shannon	Sluice Gates	Bellantra Sluices – Control the water level on Lough Allen.
River Shannon	Sluice Gate & Weir	Jamestown Sluice & Weir.
Boyle River	Lock & Weir	Knockvicar lock and weir – Control the water level on Lough Key.

Conclusions from Phase 1

Phase 1 suggested:

- Observational data available for events 1, 2, 3 and 4.
- Event 1 observational data consists of a Jacobs GIS digitisation of the November 2009 flood event. This GIS data was compiled using a substantial series of aerial photographs. This could be used for verification. There are also some flood levels recorded between the 16/11/2009 and 29/11/2009 within Carrick-on-Shannon Basin (i.e. at Maxol station – Leitrim Village, Carrick Bridge US and DS, US of Knockvicar Bridge near Lough Key, Bellantra Bridge US and DS, and at Jamestown weir). Co-ordinates are provided for each of the locations where flood levels are measured. These water levels cannot be used for calibration for reasons stated in bullet point two of the "Discussion and Strategy" within Phase 2. A series of aerial and ground photographs of the flooding extent from the 2009 event are also available with photographs at specific locations available (i.e. Keadue Road within Leitrim Village AFA and Park Lane & R280 in Carrick-on-Shannon AFA).
- Event 2 observational data comprises of a map with the locations within Carrick-on-Shannon where a series of peak flood levels were recorded during the Winter 1999/2000 flood event (water levels also provided). Locations where the spot flood levels were taken include Priests Lane, US and DS of Carrick-on-Shannon Bridge and Dublin Road. The minutes of a meeting with the Area Engineer for Boyle on 17/12/2004 make reference to frequent flooding around Lough Eidin.
- Event 3 observational data is a map with the outline of the 1954 flood event sketched on which may be used for verification. There is also a report entitled "River Shannon Flood Problem" by the Corps of Engineers U.S. Army circa 1956. This report contains no specific water level or flow data.
- Event 4 observational data is a series of ground level photographs of the 27/09/1996 flood event in Boyle at Boyle Railway Station, Church View Housing Estate and Hanley Avenue. There is no indication of a return period for this flood.
- Gauging station 26012 had a rating review completed by Jacobs. There was very little difference observed between the Jacobs' model rating and OPW rating and so the AMAX series was not re-worked. The rating is reliable up to $0.74 \times QMED_{obs}$ (post drainage works – 1993 onwards).
- Gauging station 26108 had a rating review completed by Jacobs. There was very little difference observed between the Jacobs' model rating and OPW rating and so the AMAX series was not re-worked. The rating is reliable up to $1.90 \times QMED_{obs}$. This gauge is located within Boyle AFA.
- Gauging station 26030 has a rating verified up to $1.80 \times QMED_{obs}$.
- Jacobs had no flow or water level data for gauging station 26075. Investigation of the OPW Hydro Data website revealed that there are no flows or AMAX flow records available for the site and that digitised water level records only exist from 2007 to 2009.
- Gauging station 26085, 26073, 26074 and 26324 are level gauges.

Phase 2					
Gauging Station Information Used – Out of Bank*					
Run	Main Stem	Tributary	Main Stem	Tributary	
Type	Calibration		Verification		
Flood Event	6a – 21/01/2005	6b - 25/11/2009	6c – 20/11/2009	6d - 12/02/2002	
GS Number	26073	26012	26073	26012	
Station Name	Lough Allen US	Tinacarra	Lough Allen US	Tinacarra	
Recorded Start of peak level	10/12/2004	N/A***	15/10/2009	N/A	
Recorded Finish of peak level	10/02/2005	N/A	13/01/2010	N/A	
Peak level **(mAOD Malin)	47.30	N/A	47.98	N/A	
Peak flow (m^3/sec)	N/A (Level gauge)	110.09	N/A (Level gauge)	61.47	
Other gauging stations for same event	Lough Allen DS (26030)	Boyle Abbey Bridge (26108)	Lough Allen DS (26030)	Boyle Abbey Bridge (26108)	
Gauging Station Information Used – In Bank*					
Run	Main Stem	Tributary	Main Stem	Tributary	
Type	Calibration		Verification		
Flood Event	5a – 28/05/2002	5b – 11/12/2007	5c – 10/12/2011		
GS Number	26073	26012	26073		
Station Name	Lough Allen US	Tinacarra	Lough Allen US		
Recorded Start of peak level	03/05/2002	N/A	16/11/2011		
Recorded Finish of peak level	04/07/2002	N/A	25/12/2011		
Peak level **(mAOD Malin)	47.32	N/A	47.29		
Peak flow (m^3/sec)	N/A (Level gauge)	61.82	N/A (Level gauge)		
Other gauging stations for same event	Lough Allen DS (26030)	Boyle Abbey Bridge (26108)	Lough Allen DS (26030)		

*Calibration events may include more than one gauging station but the table above indicates the details for the most upstream gauging station which will provide the level and flow data for the calibration/verification.

**Stage plus datum (see Phase 1) from topographical survey (Stage in brackets). This stage value should be confirmed as correct by the modeller concerned as this stage estimate has been converted from Poolbeg to Malin datum using the “PtoM Conversion Map.pdf”.

***N/A – Only flows are provided for 26012 (Tinacarra) and not water levels. This is because 26012 is the most upstream gauging station where the calibration flows will be input and so water levels need not be checked at 26012. Water levels and flows will be checked at the downstream gauging station 26108 (Boyle Abbey Bridge).

Discussion and Strategy

Discussion:

- There is some observational data for verification. Refer to Events 1, 2 and 3 outlined in Phase 1 for full details.
- Event 4 does not have an associated return period and cannot be used for verification.
- Observed flood level are available for the November 2009 flood event between the 16/11/2009 and 29/11/2009 at locations including US and DS of Bellantra Bridge, DS of Jamestown weir, US and DS of Carrick bridge, US of Knockvicar Bridge, Park Lane football pitch and at the Maxol Station in Leitrim Village. However, these cannot be used for calibration because:
    - No gauges are available to attempt to reproduce the flows for this event.
    - The water level recorded US of Knockvicar Bridge is immediately downstream of Lough Key which has no recorder gauging station and therefore an initial water level cannot be established for the November 2009 event on this lake.
    - The other flood water levels outlined above were primarily all recorded at weir structures and are not considered suitable for verification due to the limitation associated with the model in accurately representing the water levels in the immediate vicinity of a weir.
- There are four gauging stations which can be used for calibration and verification of the N01 model. These include 26012 (Tinacarra) and 26108 (Boyle Abbey Bridge) on the Boyle River in addition to 26073 (Lough Allen US) and 26030 (Lough Allen DS) found immediately downstream of the transition from Lough Allen outlet to the main River Shannon.
- Two out-of-bank events have been identified from the gauged data which cover the Boyle River (tributary) found between gauging station 26012 and 26108. Two out-of bank events have also been identified from gauged data which cover the outflow from Lough Allen (Main stem). In both cases, the Main Stem and tributary, one event will be used for calibration and the other used for verification.
- One in-bank event has been identified from gauged data which cover the Boyle River (tributary) found between gauging station 26012 and 26108. This event will be used for calibration. Two in-bank events have been identified from gauged data which cover the outflow from Lough Allen (Main stem). One event will be used for calibration and the other used for verification.
- Calibration and verification will not be attempted along the river reach between Lough Gara and immediately upstream of gauging station 26012 as there is no gauged or observational data for this portion of the Boyle River.
- Calibration and verification may be completed on the N01 model extent along the Boyle River reach found between gauging stations 26012 and 26108 using gauged data.
- Calibration and verification will not be attempted on the Boyle River immediately upstream of gauging station 26108 to the confluence between the Boyle and Shannon River using **gauged data** given that no such data exists along this river reach. However, verification may be completed along this reach using observational data from Events 1 and 4 previously described in Phase 1.
- Calibration and verification may be completed on the N01 model extent in the region of Lough Allen outlet where gauging stations 26073 and 26030 are found immediately downstream of the transition from Lough Allen outlet to the main River Shannon.

Calibration/Verification Strategy:

- N01 Main Stem:
  Out-of-bank and in-bank main stem calibration and verification is to be undertaken at the outflow from Lough Allen between gauging station 26073 and 26030. This will be done by fixing the lake levels in Lough Allen at those water levels recorded at gauging station 26073 for this event and then checking the resulting modelled flows and water levels over the weir at Lough Allen outflow with the gauged flows and water levels from 26030 for the event concerned. To be completed for 4 events:

    - 21/01/2005 (Out-of-bank) - Calibration
    - 20/11/2009(Out-of-bank) - Verification
    - 28/05/2002 (In-bank) - Calibration
    - 10/12/2011 (In-bank) - Verification

- River Boyle:
  Out-of-bank and in-bank tributary calibration and verification is to be completed between gauging station 26012 and 26108. This will be done by inputting the gauged flows at gauging station 26012 and then comparing the resulting modelled flows and water levels downstream at gauging station 26108 with the gauged flows and water levels from gauging station 26108 for the event concerned. To be completed for 3 events:

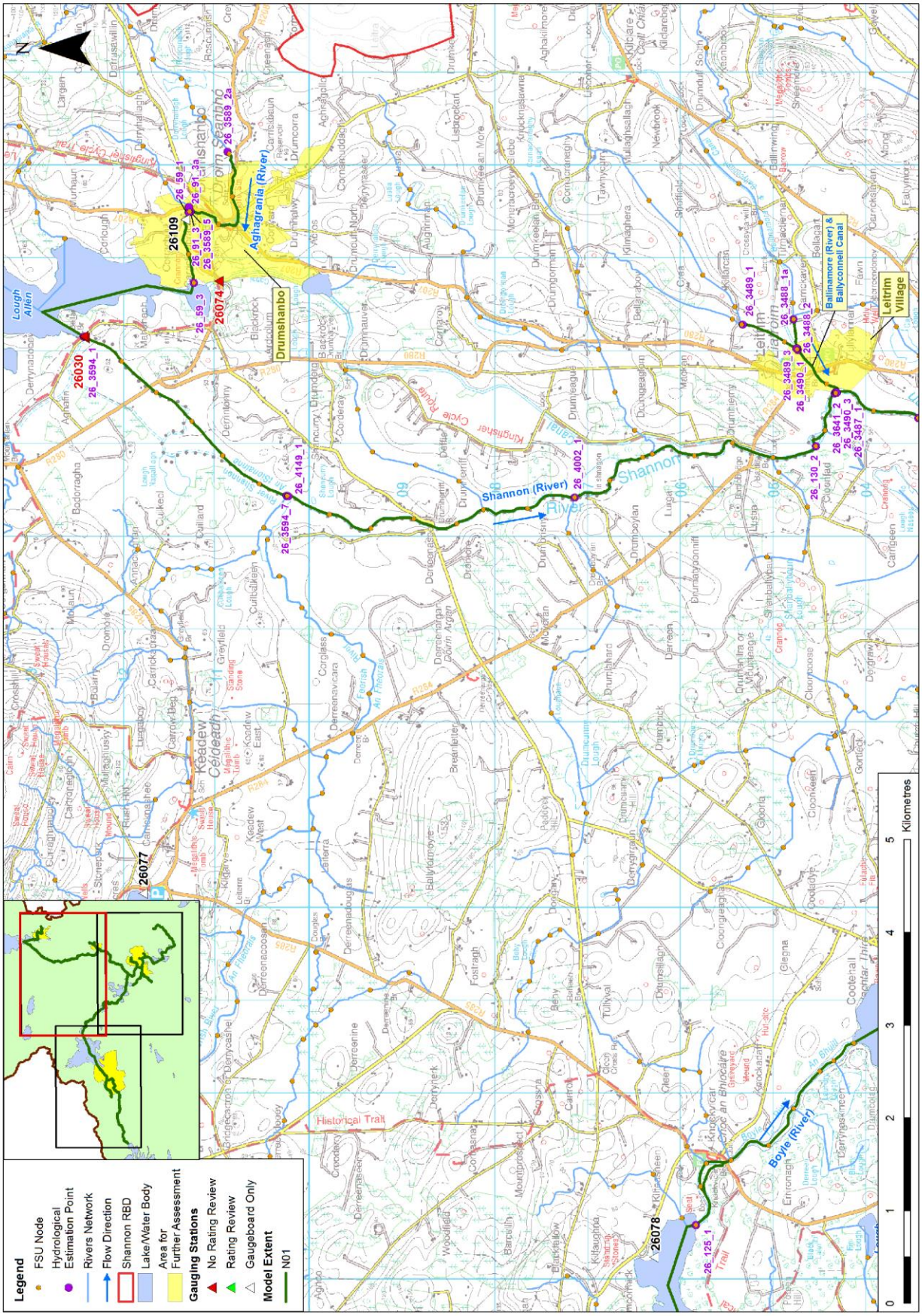
  - 25/11/2009 (Out-of-bank) - Calibration
  - 12/02/2002 (Out-of-bank) - Verification
  - 11/12/2007 (In-bank) – Calibration

  As the distance between the upstream and downstream gauges is small (about 4 km) no intermediate flows needs to be added between them.

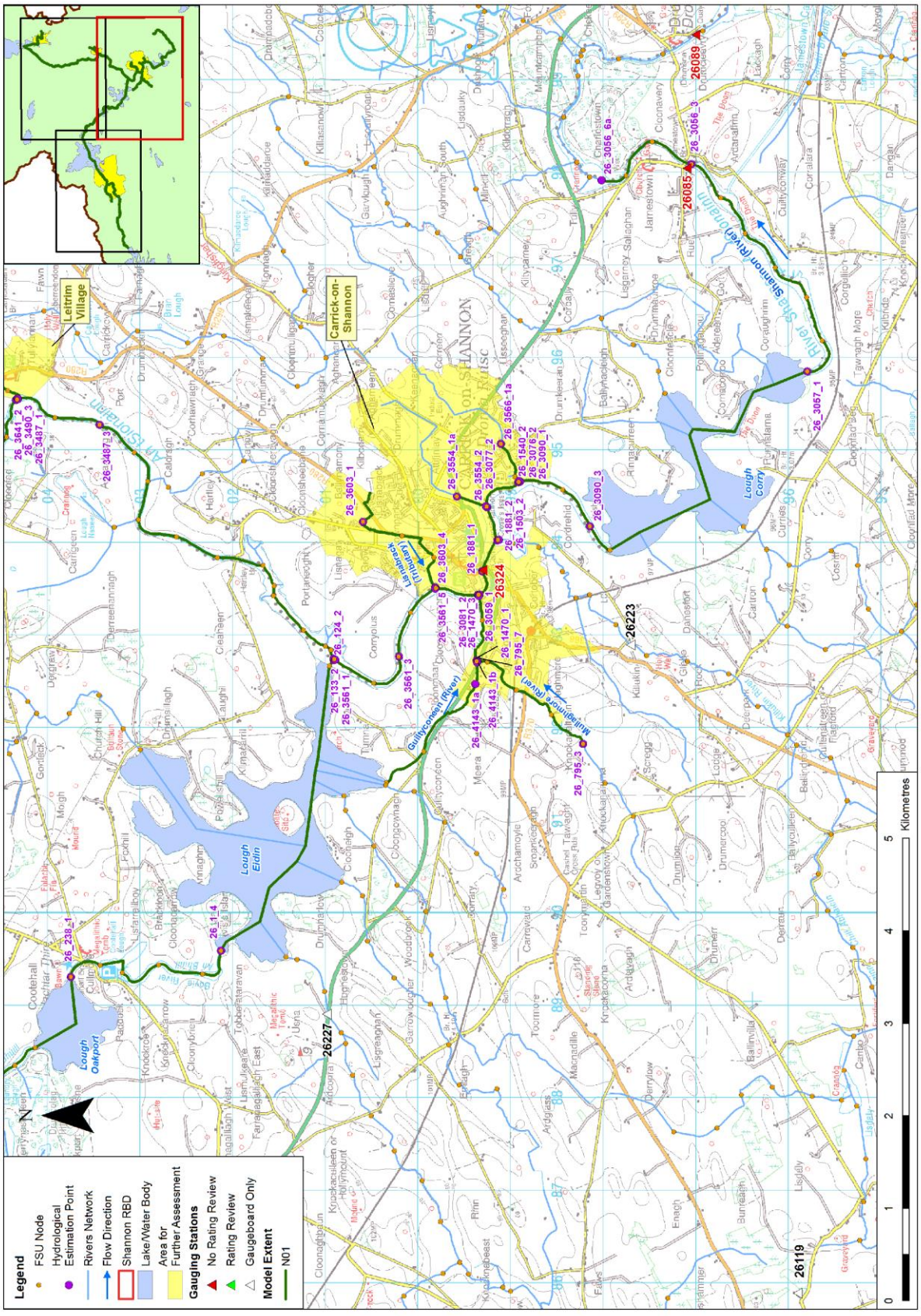
Post-Design Event Modelling Verification:

- Some high level verification will be attempted using the Jacobs GIS digitisation of the November 2009 flood event in areas where an estimate of the event rarity is available. Single site analysis at Boyle Abbey GS (with an EV1 distribution) gives a return period between 100 and 200+ years. It is believed that the return period at Carrick-on-Shannon may have been in excess of 100 years. This GIS flood extent dataset was compiled using a substantial series of aerial photographs. This data is located within folder B-0054. For this verification, the modelled flood extents for the100, 200 and 1000-year design events will be broadly compared with digitised flood extents for the November 2009 event. A series of aerial and ground photographs of the flooding extent from the 2009 event are also available with photographs at specific locations available (i.e. Keadue Road within Leitrim Village AFA and Park Lane & R280 in Carrick-on-Shannon AFA).
- A series of flood levels recorded during the Christmas 1999 flood event are available at Priests Lane, Dublin Road and Carrick-on-Shannon Bridge. These locations are all within Carrick-on-Shannon AFA. These recorded flood levels could be used to verify that the model results consistent with these observed levels. These flood levels are found within folder B-0063, within “16-3a lei_re_mf_0000003094.pdf”. The Christmas 1999 event is predicted to be just lower than a 5 year return period event based on single site analysis using the EV1 distribution at gauging station 26108 on the Boyle River (where the catchment is considerably smaller than at Carrick-on-Shannon). No flow gauge is located on the River Shannon near Carrick-on-Shannon. It may be expected that the event rarity at Carrick-on-Shannon is between 1 in 2 AEP and 1 in 10 AEP.
- The median of annual maximum water levels (which is equal to the 1 in 2 AEP design peak level) at 26085 (Jamestown) for the most recent 15 years of water levels is 41.33 mAOD Malin. The modelled 2 year return period water level for the main stem N01 model at 26085 is to be verified against this water level estimate.

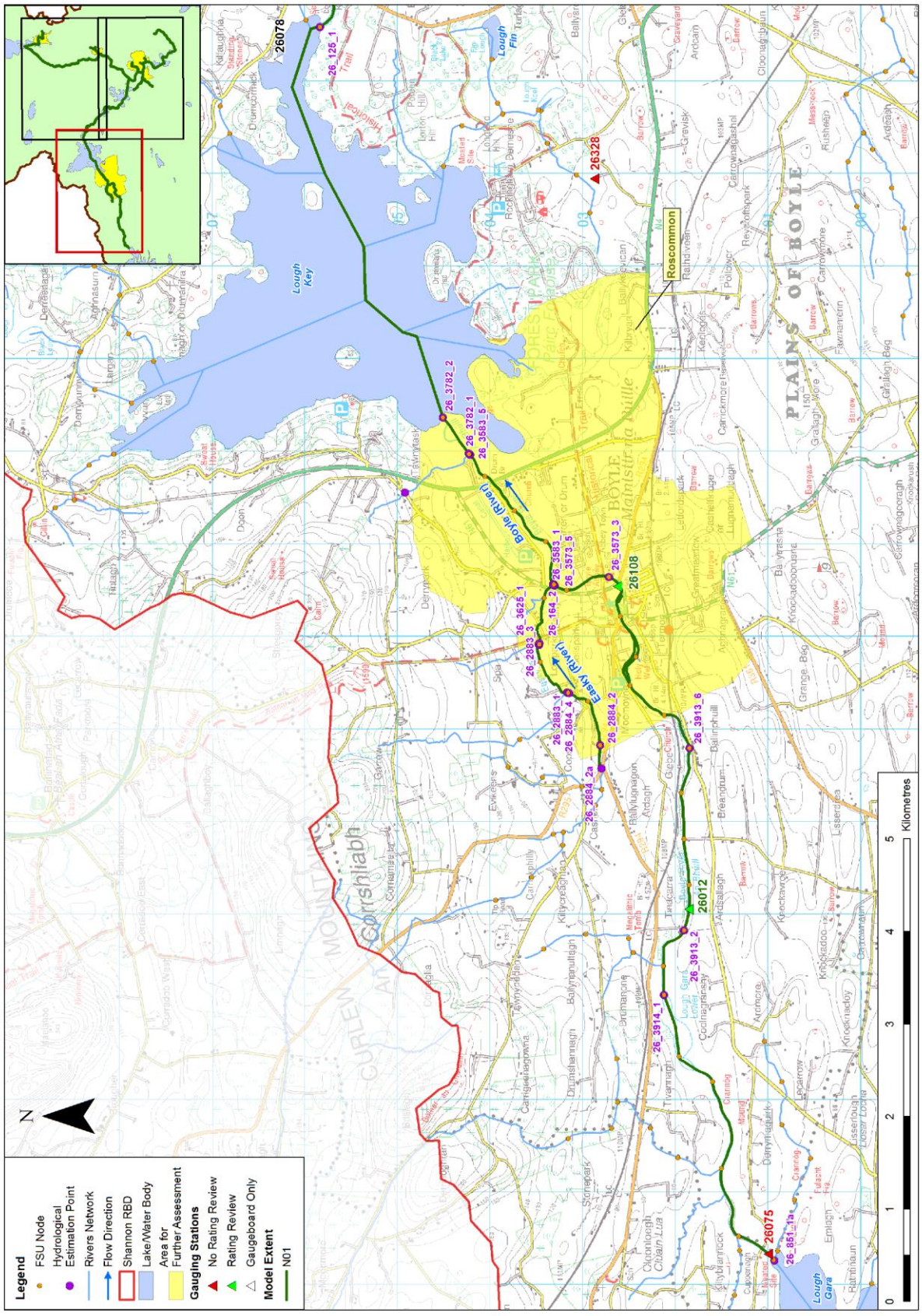
Appendix A - Plan of Model N07 (Lough Allen Outflow to Shannon River/Boyle River Confluence)



Appendix A - Plan of Model N01 (Shannon River/Boyle River confluence to N01 model end)



Appendix A - Plan of Model N01 (Boyle River tributary)



Appendix B – Details Flood Event Records			
Flood Event	Material type	Data location	Contains
	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☐ *No coverage: ☒
All/ General Verification	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☒ *No coverage: ☐
1	GIS layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☒ *No coverage: ☐
All/ General Verification	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☒ **No coverage: ☐
1	Photographs and videos	B-0007, B-0013, B-0014, B-0015, B-0025, B-0028, B-0029 & B-0035	A collection of photographs and videos of the November 2009 event. This imagery was used to create the Jacobs 2009 digitisation of the November flooding event.
1	Letter	B-0032	Letter 16/6/2011 to Nicky Leggatt (Jacobs) from Brian Kenny (Leitrim CoCo) referring to PGM05 meeting minutes and providing November 2009 flood levels at Athlone, Tarmonbarry, Rooskey, Jamestown and Clarendon and raising key issues that he considers need resolving
1	Excel	B-0042	Calibration information from November 2009 flood event in Leitrim.
1	Consultants Report	B-0063	16-0a Flood Study report indicating flood level of; -65.6mOD @ Mc Dormatt's House -72.84mOD @ timber fence post at edge of Derraun Road Also contains 2no. Photographs of flood level at Mrs Mc Dermott's house.
1	GPS Coordinates	B-0049	Water flood extent positions along the River Shannon in November/December 2009. Water levels were recorded by OPW.
1	Letter	B-0032	Letter from Brian Kenny (Leitrim CoCo) referring to PGM05 meeting minutes and providing November 2009 flood levels at Athlone, Tarmonbarry, Rooskey, Jamestown and Clarendon and raising key issues that he considers need resolving.
1 & All	Report	B-0047	Letter and supporting data of 31/5/2011 including 2009 and 2010 calibration data / photos including Jamestown, Clarendon Weir, Dromod, Mohill, Termonbarry, Rooskey, Carrick-on-Shannon. Evapotranspiration data also provided.
2	Photographs	B-0063	16-1c – 16-1z 24 no. ground level photographs of 2000 flood extent. Grid ref 972 644

			Locations: Golden Island
2	GIS Layer	B-0020	Source of mapped flood extent polygon. Extent of 1999 /2000 Shannon flood based on aerial photos. Includes Shannon River within Leitrim, Roscommon.
2	Consultants Report	B-0063	16-1a ESB International Report: River Shannon Flood of Winter 1999/00
2	Map	B-0063	16-3a Maps & photographs showing flooding & levels 40.199 (nr Gortinity Lake), 41.940 (Dublin Rd), 42.365 (Priests Lane), 42.090 & 41.995 (nr Carrick on Shannon Bridge).
3	Weather	B-0063	16-2b Met Éireann Monthly Weather Bulletin - special article with photos and rainfall data on December 1954 flood in Dublin. Refers to flooding on Shannon
3	Consultants Report	A-0006	1956 River Shannon Flood Problem Report
3	GIS Layer	B-0020	Flood extent polygon during 1954 event.
4	Photographs	B-0063	13-2a, 3a, 4a (1) Photos of flooding at the Railway Station, Boyle Co Roscommon. (2) Photos of flooding in the Church View Housing Estate, Boyle Co Roscommon (3) Photos of flood damage in Hanley Avenue, Boyle Roscommon July 1996
All	Report	B-0021	Lough Allen Inundation study and results reports.
All	Meeting minutes	B-0063	13-4b Minutes of meeting identifying areas subject to flooding Roscommon. This letter does not contain any specific flood information.
All	Report	B-0023	Tesco – Carrick-on-Shannnon flood risk study (confidential)
All	.pdf document	C-0106	Cill levels on weirs and locks affecting Carrick-on Shannon. Claredon Weir – water height above cill levels.
All	Report	B-0063	13-7a OPW report Section of Boyle River d/s of Boyle town – flooding of Road & land has occurred a number of times over the past few winters. No house flooding to date but a number of residential properties are at risk.
All	Notepad	B-0063	13-1a Note identifying areas subject to flooding.
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of “benefiting lands” does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		Likely accuracy of Flow estimate	Likely accuracy of Gauged Level estimate	Known hydraulic conditions (1)	Supplementary known, useful flood levels(2)	Reliable flood history (levels, locations, dates) (3)	Indicative calibration score (sum of columns 2-6)	Calibration comment
Category 1	Large gauged river within an AFA (HPW)	1 (2) , 2 (2) , 3 (0), 4 (2)	1 (2) , 2 (2) , 3 (0), 4 (2)	1 (0) , 2 (0) , 3 (0), 4 (0)	1 (3) , 2 (2) , 3 (1), 4 (1)	1 (3) , 2 (2) , 3 (1), 4 (1)	1 (10) , 2 (8) , 3 (2), 4 (6)	Storms 2, 3 and 4 are not appropriate for use as calibration events. Storms 2 and 4 are suitable for verification though. Reasons: 2-Flood levels from the Christmas 1999 event. No specific dated though. 3-Approximate flood outline for the 1954 flood event and general report on the River Shannon. No specific flood levels or flows. 4-Series of ground level photographs. No specific information on dates, levels or flows.
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely. Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2).

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table D.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 FSU Gauging station classification (from hydrologic 2006)

Appendix E – Further notes on Events

Minutes of Meeting with Boyle Area Engineer – 17/12/2004, compiled by Search Manager ESBI (B-0063/13-3b)

- Minutes of meeting between Boyle Area Engineer, Supervisor and ESBI Search Manager identifying areas subject to flooding Roscommon (i.e. Boyle, Lough Eidin, Killukin River at Derraun, etc.). This letter does not contain any specific flood information.

River Shannon Flood Problem – 20/08/1956, written by Corps of Engineers U.S. Army (A-0006)

- This report broadly reviews the physical, hydraulic and flood characteristics of the River Shannon and its tributaries, the potential for increased utilisation of its water resources and how the problem of flooding can be combatted through flood control and drainage.
- This report contains no specific flow or water level information.

Killukin River Flooding Report – June 2010, written by Ryan Hanley Consulting Engineers (B-0063/16-0a)

- This report was developed in light of a study undertaken by Ryan Hanley Consulting Engineers into the ongoing problem of flooding at the Killukin River near the R368, Cortober/Carrick-on-Shannon, County Roscommon.
- This report contains 2 flood levels resulting from the November 2009 event. One flood mark level of 65.5m OD was recorded at Mrs. Paula McDermotts house. Another flood mark level of 72.84m OD was taken from a timber fence post erected by Roscommon County Council at the edge of the Derraun Road.

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N02**	Length	189 km
Unit of Management		25/26	
AFAs	Cloondara, Dromod, Longford, Mohill		
IRRs	none		
River / Catchment / Sub-catchment	River Eslin, Rinn, Camlin / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model extent N02 comprises of the River Shannon and a few tributaries: 1) River Eslin; 2) River Rinn and its tributaries (Cappagh and Shannagh into Cappagh); 3) River Camlin and its tributaries (Knockmartin, Carrickglass Demesne, Clookeen, Ardnacassagh, and Ballyminion into Ardnacassagh); 4) Camlin South and its tributary (Fallan). There are five lakes within the model extent: Lough Tap (1 km^2), Lough Boderg (4 km^2), Lough Bofin (5 km^2), Lough Forbes (3 km^2), and Lough Rinn (2 km^2). The former three lakes are along the River Shannon, Lough Rinn is along the River Rinn, and Lough Forbes forms the confluence of the Rivers Shannon and Rinn. There are four AFAs within the model extent: Cloondara, Dromod, Longford and Mohill.		
Completed by	Clodagh Fitzgerald	Yiwen Zhao	
Date	04/02/13	07/01/2014	

Potential flood events to consider for calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	12/1954 – 01/1955 – Digital flood map	1	1+1+0+2+2=6	Post-design run verification
2	11/1999 – 12/1999 – No specific data	1	1+1+0+0+1=3	Not possible
3	12/1999 – 01/2000 – Digital flood extent	1	1+1+0+0+2=4	Verification
4	11/2009 – Jacobs delineated flood extent and reported flood levels in Jamestown, Drumsna, Dromod, Roosky, Newtown Forbes, Longford and Cloondara. 30/11/2009 – SERTIT flood outline	1	1+1+0+3+3=8	Verification
5	12/2004 – Photos at Longford	1	1+1+0+1+1=4	Verification
6	04/02/2002 – Indicative flood map at Longford	1	1+1+0+1+1=4	Verification
7	Winter 1994/1995 – No specific data	1	1+1+0+0+2=4	Not possible

* See Appendix B for Event Details of events 1-2, ** See Appendix C for Quality Category and Quality Score
(Scoring - 0 (Not suitable for calibration) to 15(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
26008 Johnston's Br.	01/09/1955 - present	Level and Flow	37.24	A1	Acceptable model fit cannot be achieved; OPW data remains unchanged.
26015 Corrascoffy	01/10/1956 - present	Level and Flow	Missing	Not FSU Classified	No rating review; on tributary outside of model extent
26019 Mullagh	01/09/1953 - present	Level and Flow	38.24	A1	Drainage works completed in Oct 2010. OPW rating adopted for pre-2010 data. Scatter in check gaugings
26020 Argar	01/10/1957 - present	Level and Flow	44.589	A1	No rating review. Scatter in check gaugings
26022 Kilmore	01/10/1957 - present	Level and Flow	39.05	A2	Rating review; on tributary outside of model extent
26079 Lough Rinn	01/08/1997 - present	Level and Flow	Missing	Not FSU Classified	No rating review; lakeside
26085 Jamestown	01/10/1957 - present	Level	Missing	Not FSU Classified	No rating review
26089 Drumsna	01/10/1984 - present	Level	Missing	Not FSU Classified	No rating review
26326 Roosky Br.	Unknown (reported unreliable)	Level and Flow	Missing	Not FSU Classified	No rating review
26331 Kilnagarrow Br.	10/07/2008- present	Level and Flow	Missing	Not FSU Classified	No rating review

* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor))

Control structures

Reference	Type	Description
River Shannon	Weir	Weir and sluices at Jamestown
River Shannon	Weir	Roosky lock, weir and sluices (control level and Lough Bofin).
River Shannon	Weir	Termonbarry weir and lock
River Camlin	Weir	Weir in Longford town

Conclusions from Phase 1

Phase 1 suggested:

- Station 26015 on the River Eslin upstream of Dromod is considered reasonably reliable for flows up to the highest check gauging of 6.1 m^3/s for recorded data from February 1987. Such data can be used for calibration or verification at the downstream Dromod AFA. Flows that are much higher than 6.1 m^3/s are subject to too much uncertainty to be of use.
- Station 26019 (Mullagh) has been reviewed as part of the CFRAM rating reviews. There is a concern about recent flow estimates (1990 to present) which show a large scatter and do not align with the adopted rating for that period. Considerable scatter in the few available check gaugings prevents the creation of an improved rating. It is downstream of and close to Longford, but a large tributary between it and Longford would make the estimation of flows in Longford uncertain even

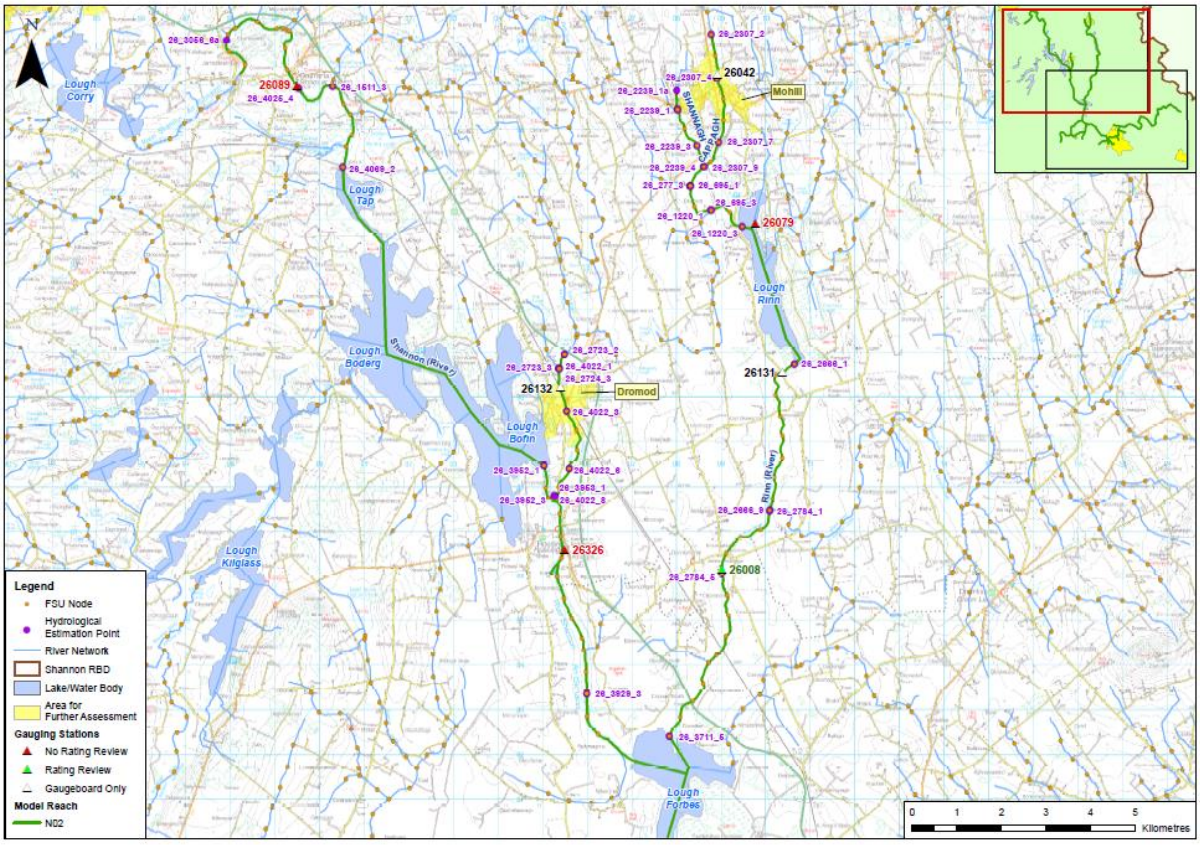
with a reliable rating.

- Station 26020 upstream of Longford has FSU classification A1 but check gaugings from the early 1980s onwards are too scattered and too far removed from the latest rating curve to be reliable enough for calibration or verification.
- Station 26008 is located on the River Rinn, between Lough Rinn (upstream of the station) and Lough Forbes downstream of the station on the River Shannon. This station is not near a town (or another location where flood observations have been recorded) and there are no other recorder gauging stations nearby.
- Station 26022 is on the Fallan tributary and has no data available for calibration.
- Station 26079 is a lake level gauge (Lough Rinn).
- Station 26085 and station 26089 at the upper reach of the River Shannon, have only level data, and cannot be used for calibration.
- Station 26326 (Waterways Ireland site) – confirmed by WWI and Leitrim County Council that level data at this station is not reliable.
- Station 26331 (Longford County Council site) is a low flow station and is not suitable for flood flow estimation.

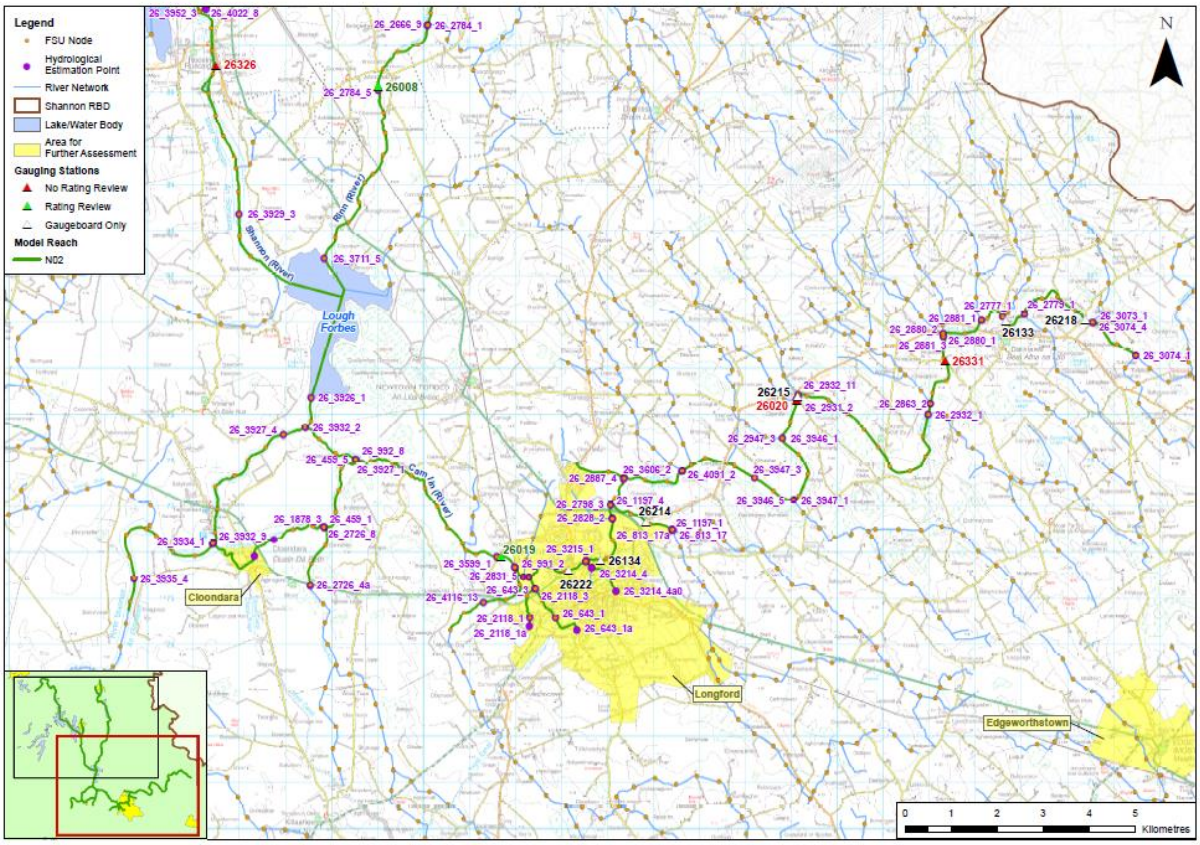
- There is a digitised flood extent map based on observed information available along the River Shannon and a few tributaries for Event 1. However, no gauged data is available for calibration or verification.
- There is no reliable gauged or ungauged flood data available for Event 2.
- There are photos indicating the extent of flooding along the River Camlin and a flood extent map of the River Shannon and a few tributaries for Event 3. Due to a lack of reliable flow estimates on the larger rivers Shannon and Camlin and a lack of resolution (detail) on a small gauged tributary (Dromod on the Eslin) this cannot be used for calibration/verification of the model.
- There are photos, observed data and a digitized flood extent map available along River Shannon, Eslin and Camlin for Event 4. Flows for this event cannot be estimated with sufficient accuracy for Dromod and Longford (see the comments in the first three bullet points above) and calibration and verification will therefore not be feasible for this event.
- Photos and indicative flood maps available at Longford AFA for Events 5 and 6 may be used for broad-brush verification.
- There is no observed data or reliable gauged data available for Event 7.

Phase 2						
Gauging Station Information Used – Out of Bank						
Location	AFA Dromod					
Type	Verification					
Flood Event	3 (26/12/1999)					
GS Number	26015					
Station Name	Corrascoffy					
Approximate Start of peak level	20/12/1999 16:15:00					
Approximate Finish of peak level	11/01/2000 13:45:00					
Peak level* (mAOD Malin)	7.05m (43.97mAOD -Poolbeg or 42.21mAOD Malin)					
Peak flow (m^3/sec)	7.05m^3/s					
Other gauging stations for same event	N/A					
Gauging Station Information Used – In Bank - Not possible due to insufficient data available						
• Modellers to check gauge datum on survey. Malin peak level is estimated by subtracting 2.76m from Poolbeg level in accordance with Poolbeg to Malin conversion map.						
Discussion and Strategy						
Discussion • There are four AFAs within the model extent, but due to a lack of good quality gauged data and detail of the observations no calibration can be undertaken. • None of the observational information can be used to undertake event-based verification, because of a lack of good quality gauged data on the larger rivers (Shannon and Camlin) and a lack of resolution or detail in the observations for the gauged Eslin (Dromod AFA). • Broad-brush verification may be undertaken for the entire model extent by comparing modelled extents with historical flood maps, photos and indicative records for Events 1, 3, 4, 5 and 6. Calibration/Verification Strategy • No calibration/verification can be undertaken within the N02 model domain. Post-Design Event Modelling Verification: • Broad-brush verification may be undertaken throughout the model extent by comparing modelled extents with historical flood maps, photos and indicative records of re-occurring flooding for Events 1, 3, 4, 5 and 6.						

Appendix A - Plan of model N02



North



South

Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
4	GIS Layer	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 Relevant: ☒ Not relevant: ☐
1	GIS layer	B-0020	Digitisation of 1954 flood event. Relevant: ☒ Not relevant: ☐
4	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. Relevant: ☒ Not relevant: ☐
All	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☒ **No coverage: ☐
All/ General Verification	FRR site visit	A-0072, A-0073, A-0076, A-0078	Cloondara, Longford, Dromod, Mohill - Notes, marked up plans, photographs and videos during UoM 25/26 Site Visit
4	Photographs and videos	B-0007, B-0013, B-0015, B-0025, B-0028, B-0029, B-0035	A collection of photographs and videos of the November 2009 event. This imagery was used to create the Jacobs 2009 digitisation of the November 09 event.
1	Rydell Report	A-0006	This report reviews the physical, hydraulic and flood characteristics of Shannon River and its tributaries including various means of flood control, drainage and flood data. Flow recorded: River Eslin 1000 ft^3/s River Rinn 1000 ft^3/s River Camlin 1400 ft^3/s
2	Cork Examiner Newspaper “Region hit by deluge after river bursts banks”	B-0063	06-2qq "Highest in almost 50 yrs". Worse than 1954 flood. Affected private house, farms and businesses in counties Leitrim, Longford, Roscommon and etc.
2	Longford Leader Newspaper	B-0063	07-3c Residents of Lough Rynn Avenue were cut off from the rest of the world for a week and farmers lands were flooded.
3	GIS	B-0012	Flood polygons of the 2000 flood event, River Shannon.
4	Ground Photographs	B-0051	Ground level photographs identifying flood extents for various locations in Longford during November 2009. Data includes maps identifying location date and time photograph was taken.
4	Report of Special Meeting on Flooding	B-0049	Intense rainfall on the 18th to 19th November 2009 on already saturated land and high river levels led to severe flooding in Longford town and throughout the country.
4	Flood map	B-0022	Lough Rinn flood map showing height 209,519 (X) 395,11 (Y) in 11/2009.
4	Aerial Photographs	B-0025	Aerial photographs of Longford Bypass on 20/11/2009.

4	Ground Photographs	B-0026	Photographs of Longford November 2009 flood event by Paul Newell (Leitrim Co Co). Includes areas Camlin & Cloonart Br.
4	Flood Map	B-0027	Flood map showing extent of flooding on N5 Longford Town Bypass during 11/2009.
4	Aerial Photograph	B-0035	Photograph of Termonbarry Hydro Station (sheet piles) 26th November 2009 showing hydraulic influence of the sheet piles/weir structure.
4	Letter & Supporting Data	B-0047	Letter and supporting data of 31/5/2011 including 2009 and 2010 calibration data / photos including Jamestown, Clarendon Weir, Dromod, Mohill, Termonbarry, Rooskey, Carrick-on-Shannon. Evapotranspiration data also provided.
4	GIS	C-0075	Shannon profile data - November 2009
5	Ground Photographs	B-0063	40-2a, 40-2 Photographs of flooding at Mullagh Longford on 11/01/2005. Good quality but difficult to determine specific location
5	Ground Photographs	B-0063	40-3a, 40-3 Photographs of flooding at Camlin Great Water Street Longford on 10/01/2005. Good quality Upstream of bridge in town centre (and park upstream of bridge)
3 & 6	Consultant report	A-0172	April 2002, 39 pages, flood study of the Camlin in Longford Town. Section 2.5 refers to video footage taken of a flood event date 4/2/2002. Figure 2.3 is the flood outline produced based on the video footage. Brief includes a 1d hydraulic model.
7	Consultants ESB Report	B-0019	ESB International Report: River Shannon Flood of Winter 1994/95. The report • Analyses the extent and severity of the rainfall which fell on the Shannon catchment during the winter months. • Compares the rainfall that occurred with the design rainstorms • Examines the extent of flooding. • Models the flood using the 'Shannon Flood Forecasting Model'. • Estimates the return period. • Makes recommendations.
General Verification	Summary Report	A-0173	Information supplied by the IFA at meeting of 20/04/2011: - Measures proposed by IFA for the management of flood risk along Shannon (from Michael Silk, IFA) - Drawings showing flood problems in the Cloondara area of Longford (from IFA member for Longford).
General Verification	Minutes of Meeting Longford CoCo	B-0063	40-5d List of areas in Longford County which are prone to flooding. No specific or detailed information provided.
General Verification	OPW Flood Hazard Mapping Phase 1	B-0063	41-1a List of areas in the Mohill Area which are prone to flooding. No specific or detailed

			information provided.
All	Excel	A-0027	Existing models for the River Shannon study area particularly those used in design of existing defences (as listed in Tables 4, 6 and 7 of the Stage II Brief), including models themselves and associated reports.
All	Excel	C-0105	Daily water levels and sluice operations data
All	Pdf report	A-0192	River Camlin Flood Study - summary integrated report: findings to date regarding the Camlin Drainage system which has been investigated in a series of flood study and drainage channel studies carried out by Nicholas O'Dwyer since 1999. Includes pdf cross sections & long sections, drainage artery details, Nov 09 flood map and predictive flood maps, key map for bridges and bridge section drawings.
General Verification	Consultants reports	A-0192	6 Nicolas O Dwyer reports into flood risk on the Camlin and Longford Town. These reports are summarised in a single report under A-0192
4	Flood map	A-0197	Additional flood outlines for the November 2009 event

*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question.
**The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment (with event number)**
Category 1	Large gauged river within an AFA (HPW)	1(1) 2(1) 3(1) 4(1) 5(1) 6(1) 7(1)	1(1) 2(1) 3(1) 4(1) 5(1) 6(1) 7(1)	1(0) 2(0) 3(0) 4(0) 5(0) 6(0) 7(0)	1(2) 2(0) 3(0) 4(3) 5(1) 6(1) 7(0)	1(2) 2(1) 3(2) 4(3) 5(1) 6(1) 7(2)	1(6) 2(3) 3(4) 4(8) 5(4) 6(4) 7(4)	
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table B.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 - FSU Gauging station classification (from Hydro-Logic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N03**	Length	32km
Unit of Management		25/26	
AFAs	Abbeyshrule, Ballymahon, Edgeworthstown		
IRRs	none		
River / Sub-catchment / Catchment	River Inny / Inny / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model extent N03 comprises of the River Inny and its tributaries: the Rivers Black, Tipper, and Keelbaun. The Ballindadny is a tributary of the River Black. The River Inny catchment upstream of the model extents features several large and small lakes. There are four gauging stations along the River Inny and two along the River Black within the model extent. There are three AFAs within the model extent: Abbeyshrule, Ballymahon on the Inny and Edgeworthstown on the Black.		
Completed by	James Murray	Yiwen Zhao	
Date	09/ 05/ 13	01/08/2013	

Potential Flood Events to Consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	20/11/2009 – Out of bank event – Unknown location of observed data	1	0+2+0+0+0=2	Calibration
2	01/12/1954 – Out of bank event –Map showing outline of extent.	1	0+2+0+0+0=2	Verification

* See Appendix B for Event Details of events 1-2, ** See Appendix C for Quality Category and Quality Score
(Scoring - 0 (Not suitable for calibration) to 15(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)					
Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
26104 Ballinalack	1981 - present	Level	Not found	Not FSU Classified	No rating review; 1km upsteam of the model extent
26081 Iron	1952 - 1964	Level	Not found	Not FSU Classified	Inactive; Downstream of Lough Iron; No rating
26023 Ballycorkey	1952 - 1958	Level	52.890	Not FSU Classified	Inactive; No rating
26021 Ballymahon	1965 - present	Level and Flow	41.470	A2	CFRAM rating up to 3xQMED
26220 Shrule Bridge	2009 - present	Level and Flow	34.340	Not FSU Classified	No high flow rating
26323 Edgeworthstown	2004 - 2007	Level and Flow	Not found	Not FSU Classified	Inactive; No rating review; short record with suspect flows
26330 Barne	2008 - present	Level	Not found	Not FSU Classified	No rating
* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor))					

Control structures

Reference	Type	Description
None		

Conclusions from Phase 1

Phase 1 suggested:

- Observational data for event 1 has insufficient data to be of use for calibration or verification. However, there is gauged data for this event downstream of Ballymahon AFA which may be of use for calibration or verification.
- Observational data for event 2 shows a very crude flood extent, but there is no gauged flow data and no estimate of the return period.
- Station 26021 has data with an FSU classification of A2 and has had a CFRAM rating review completed, producing a rating up to 3xQMED.
- Station 26220 is at the downstream end of the N03 model extent and only has level data since 2009. The flow data at this station from the same date is not reliable for high flows, as the rating was developed for low flows only.
- Other stations (listed in the table above) upstream of Station 26021 only have level data.
- Stations 26021 and 26220 have a short period of overlap in their gaugings.
- There are no observed or gauged flood event data available at AFA Abbeyshrule or AFA Edgeworthstown.

Phase 2

Gauging Station Information Used – Out of Bank*

**Location	AFA Ballymahon
Type	Calibration
Flood Event	1 (20/11/2009)
GS Number	26021
Station Name	Ballymahon
Approximate Start of peak level	19/11/2009 03:15:00
Approximate Finish of peak level	22/11/2009 15:45:00
Peak level*** (mAOD Malin)	44.58 (3.11m)
Peak flow (m^3/sec)	139.60
Other gauging stations for same event	Shrule Bridge (26220)

Gauging Station Information Used – In Bank* - Not possible due to insufficient data available

*Calibration events may include more than one gauging station but the table above indicates the details for the most upstream gauging station which will provide the level and flow data for the calibration/verification.
**The calibration will only be possible between stations 26021 and 26220.
***Stage plus datum (see Phase 1) from topographical survey (Stage in brackets).

Discussion and Strategy

Discussion

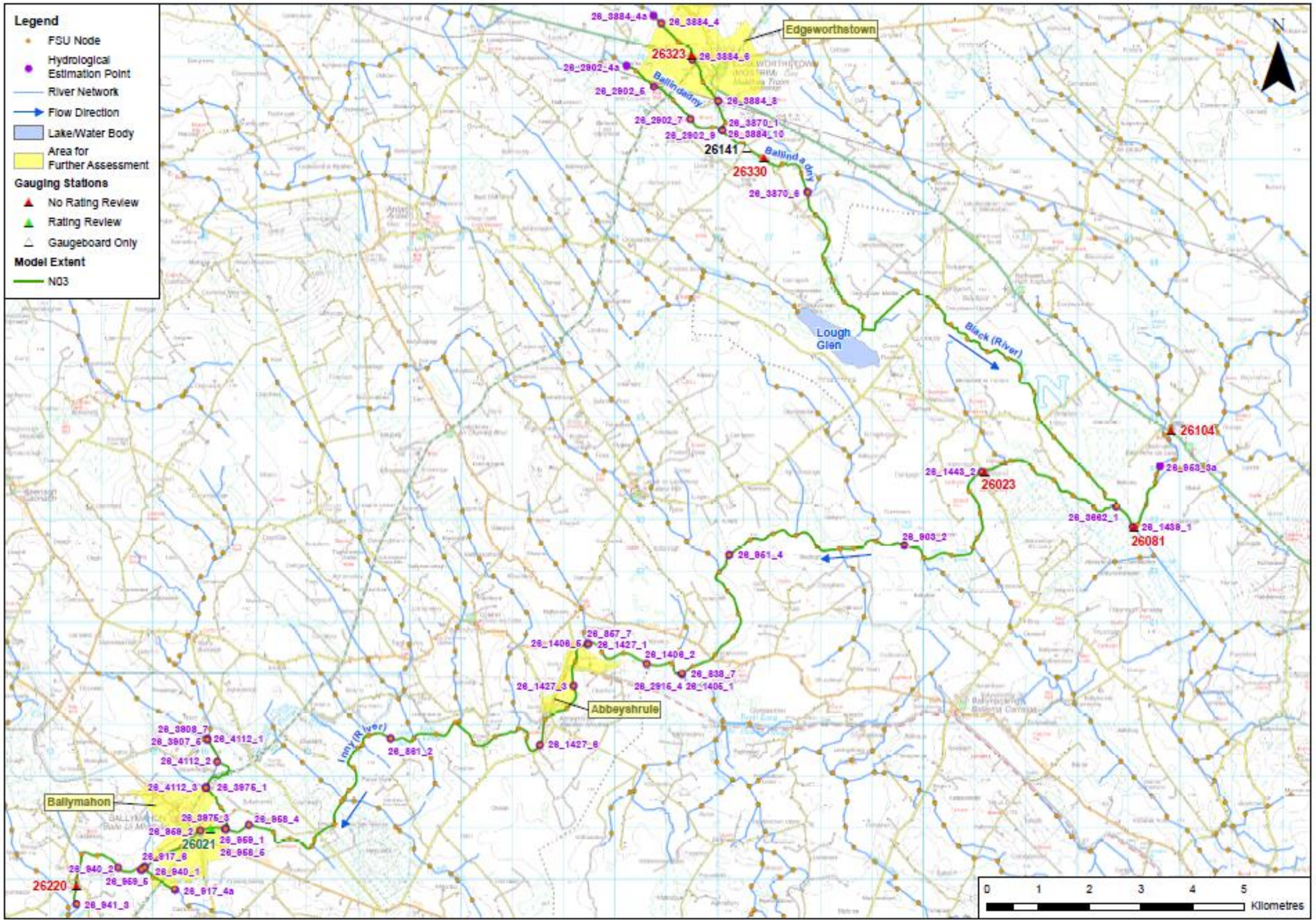
- Flood observational data for Events 1 (Nov 2009) and 2 (Dec 1954) cannot be used for calibration or verification. The Event 1 data is not specific enough to identify the locations, and the Event 2 data is from before the gauged flow records, and does not come with an estimated return period.
- Event 1 (Nov 2009) has gauged data at Stations 26021 and 26220.
- There are a number of stations within the model extent but most only have level. Station 26021 and station 26220 are located within a short distance of one another with the upstream station having flow and the downstream station having level. The data series at the two stations overlap since 2009 so calibration can be attempted here for the short overlapping period. The calibration between these stations may allow the model at Ballymahon AFA to be calibrated.
- There are three AFAs within the model extent, calibration/verification is only feasible at Ballymahon AFA as there is no observed or gauged data available for the other two AFAs.
- Major inflows between Station 26021 and Station 26220 need to be taken into consideration. These inflows can be estimated based on a 'historic event growth factor' (gauged event peak flow / synthetic QMED) and a hydrograph shape which is adjusted based on the HEP location and event.
- Event 1 (an out-of-bank event) is the only flood event that was recorded in the period of overlapping record at Stations 26021 and 26220. In-bank calibration or verification is not possible as no events were recorded in the short overlapping period from Feb 2009 to Jan 2011 that would be large enough to approach a bank-full event (~QMED). Water levels or flows significantly below QMED are below the range of events considered appropriate for the hydraulic model (which is built to mimic flood events and not low-flow conditions).

Calibration/Verification Strategy

- Out-of-bank calibration is possible between Stations 26021 and 26220 by applying gauged flow data from Station 26021 to a section at the station and comparing the modelled water levels with the gauged 15min water levels at station 26220. Major lateral inflows between Stations 26021 and 26220 need to be taken into consideration. These inflows can be estimated based on a 'historic event growth factor'

	(gauged event peak flow / synthetic QMED) and a hydrograph shape which is adjusted based on the HEP location and event.

Appendix A - Plan of model N03



Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
2	GIS Layer	B-0020	Digitisation of 1954 flood event. Relevant: ☒ Not relevant: ☐
All/ General Verification	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. Relevant: ☒ Not relevant: ☐
All/ General Verification	GIS layer	B-0006	Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 and SPOT 5 data acquired the 15th of May 2005 and derived for the SAFER ERCS022 # Relevant: ☐ Not relevant: ☒
All/ General Verification	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. Relevant: ☐ Not relevant: ☒
1	Report	B-0049	Statement on road and land flooding and possible danger to 3no houses in Ballymahon. No flood levels or times given.
All/ General Verification	Report	B-0049	ESBi report on Water level control on Lough Ree.
All/ General Verification	Report	B-0049	Areas that experience flooding during heavy rainfall in Model.
All/ General Verification	Meeting Minutes	B-0063	04-2a No flood levels. Ballymahon: “Low lying area floods after heavy rain every year”
All/ General Verification	Flood Risk Review notes	A-0077	Notes taken during flood risk review at Abbeyshrule, indicating potential areas at risk and flood flow paths.
All/ General Verification	Flood Risk Review notes	A-0104	Notes taken during flood risk review at Edgeworthstown, indicating potential areas at risk and flood flow paths.
All/ General Verification	Flood Risk Review notes	A-0106	Notes taken during flood risk review at Ballymahonn, indicating potential areas at risk and flood flow paths.

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment (with event number)**
Category 1	Large gauged river within an AFA (HPW)	**1(0) 2(0)**	**1(2) 2(2)**	**1(0) 2(0)**	**1(0) 2(0)**	**1(0) 2(0)**	**1(2) 2(2)**	**1)**
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table B.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 - FSU Gauging station classification (from Hydro-Logic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N04**	Length	19 km
Unit of Management		25/26	
AFAs	Roscommon		
IRRs	None		
River / Catchment / Sub-catchment	River Jiggy / Hind / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Tidal ☐		
Comments	There are multiple ungauged tributaries at the top of the catchment. There are three gauging stations with recorders and six gaugeboards. There is some observed flood event data available for the town of Roscommon (See Appendix A).		
Completed by	Kieran Daly	Alice Wiggins	
Date	28/03/13	20/06/2013	

Potential Flood Events to consider for Calibration

Event No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	01/10/2009 - 30/11/2009	1	2+2+0+0+1=5	Verification Only
2	13/01/1965 - Uncertain details and location.	1	0+2+0+1+0=3	Not Suitable
3	11/01/1969 - 12 /01/1969- Uncertain details and location.	1	0+0+0+1+0=1	Not Suitable
4	Gauge Data only - In-bank events	1	To be identified in Phase 2	Possibly Calibration
5	Gauge Data only - Out-of-bank events	1	To be identified in Phase 2	Possibly Calibration

The flood event data above and in Appendix B are taken from www.floodmaps.ie.database.

* See Appendix B for Event Details of events 1-3, ** See Appendix C for Quality Category and Quality Score
(Scoring - 0 (Not suitable for calibration) to 18(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
26016 Ballymurray	01/06/1958 to Present	Level	37.32	Not FSU Classified	Rating review completed. Some data missing.

26204 Ballymartin	15/04/2004 to Present	Flow and Level	N/A	Not FSU Classified	Low flow site. low-flow stage-discharge relationship
26312 Ballinagard	09/11/2001 to 12/2/2008	Level Only	N/A	Not FSU Classified	Very poor data. A lot of missing data, flat lining of data. This OPW gauging site was removed as it was deemed unsuitable for flow monitoring.

* See Appendix D for Key to FSU Station Classification (A1 (Good) to C (Poor))

Control Structures

Reference	Type	Description
No Control Structures	N/A	N/A

Conclusions from Phase 1

Phase 1 Suggested:

- Station 26204 has an unreliable (low flow) rating which should be used with caution if at all.
- Station 26312 has no rating and was removed in February 2008.
- Station 26016 has good quality data and has had a Jacobs rating review.
- Observational data available for events 2 and 3.
- For event 1 the River Jiggy Flood Study specifies locations that are known to have flooded in the event, which were used to verify their model. It does not provide flood depths.

Phase 2 – Gauging station event table omitted as the gauge data cannot be used for (hydrological and hydraulic) calibration within this model extent.

Discussion and Strategy

Discussion:

- For event 1 the River Jiggy Flood Study specifies locations that are known to have flooded in the event, which were used to verify the model within the River Jiggy Flood Study. It does not provide flood depths. It may be possible to use this map for verification in this local area.
- Calibration or verification based on level and flow gaugings only (e.g. for in-bank calibration/verification) is not feasible due to the distance between gauging stations
- Station 26016 is the only reliable flow gauge in the Hind catchment. As 26016 is situated on the River Hind at considerable distance downstream of the Roscommon AFA, it cannot be used for hydrological or hydraulic calibration within Roscommon.

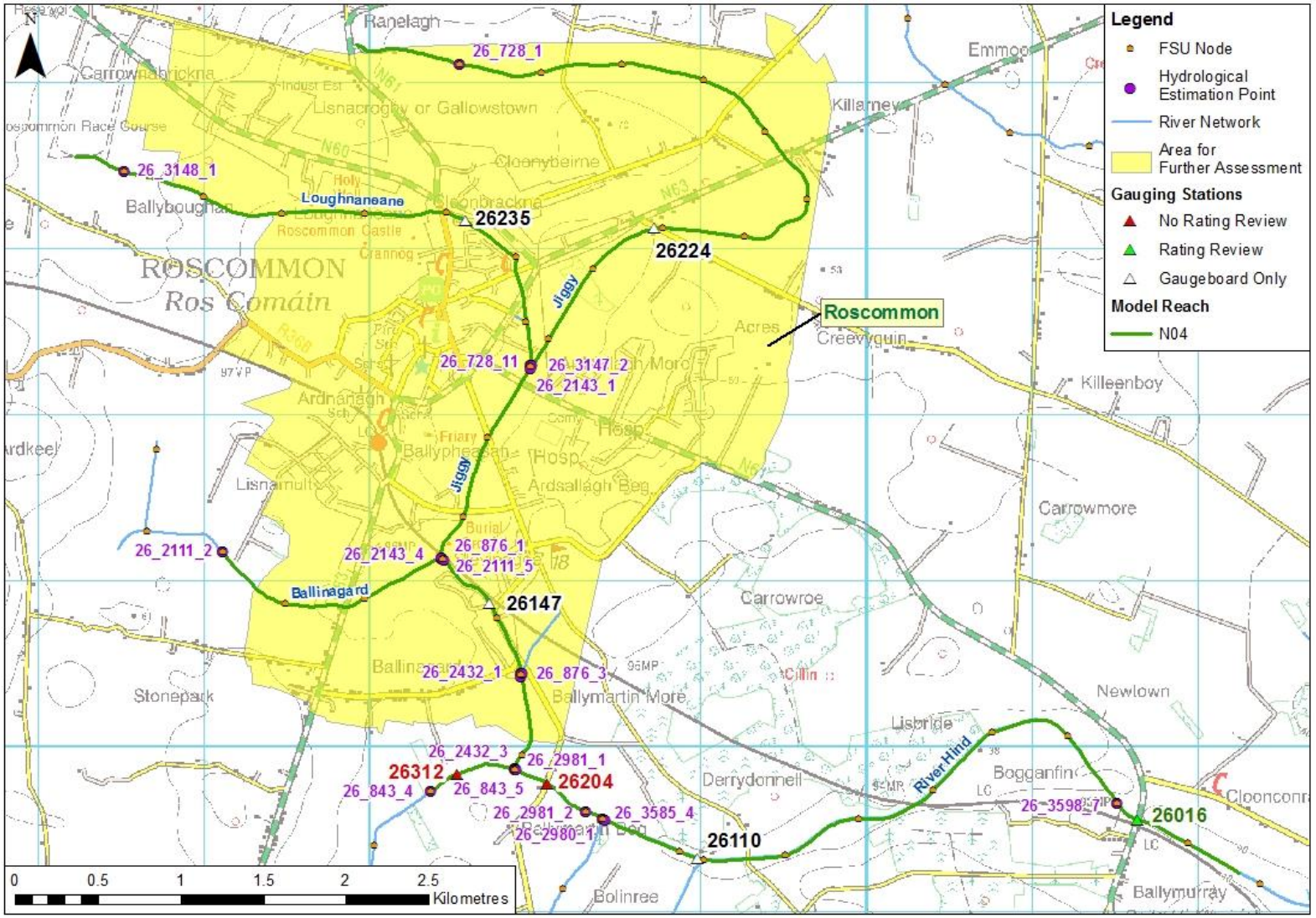
Calibration/Verification Strategy:

- No calibration can be undertaken as no gauged data is available near the locations of flood event observations (in Roscommon),

Post-Design Event Modelling Verification Strategy:

- The modelled flood outlines will be compared to the November 2009 event known flood locations (see above), to verify that the model results seem consistent with the observed data and to verify the estimated return period of the 2009 event (estimated between 50 years based on single site analysis with the EV1 distribution at gauging station 26016 and 200 years in the River Jiggy Flood Study Report. In the River Jiggy Flood Study Report the estimated 200 year return period is based on analysis of rainfall data and a broad-brush scaled hydrometric analysis at station 26204).

Appendix A – Plan of Model N04



Appendix B – Details Flood Event Records			
Flood Event	Material type	Data location	Contains
1/ General Verification	GIS file	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☒ ** No Coverage: ☐
All/ General Verification	FRR site visit	A-0066	Roscommon (CAR 51) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 11/05/2011.
1	Response	A-0180	Roscommon CoCo- Response to Jacobs Flood Risk Review. Report references Strokestown and Tulsk which are not in Roscommon Town and outside the model extent.
1	Report	B-0063	51-1a River Jiggy floods adjacent to Lanesboro Road. Flooding North of Creevy Road. Flooding at the rear of Centrepoint Retail Park, rear of fire station at Circular Road. Extensive flooding on Golf Links Road. Tributary of the Jiggy floods at Glenview. Flooding at culvert on access road at WwTP Ballinagard. Low lying area flooded at Ballinagard. Flooding downstream at Ballymartin. Extensive flooding throughout at Derrydonnell. Extensive flooding north of railway at Bogganfin. Extensive flooding downstream of Athlone Road. *Various flood alleviation options have been proposed in the report. Detailed and comprehensive consultant report assessing the hydraulic performance of the existing surface water drainage system and outline proposals to improve flood protection within Roscommon Town and environs. Refers to flow estimates and an ISIS model
2	Newspaper article	B-0063	51-4 Irish Times identifying Roscommon Town having experienced flooding
3	Newspaper article	B-0063	51-4 Indicates minor flooding in and around Roscommon town after the heavy rain on Sunday. Much of the low lying land in the direction of Athleague severely flooded.
All/ General Verification	Report	B-0049	CC Meeting minutes outlining which areas have flooded previously.
All/ General Verification	GIS Layer	B-0049	Mapinfo file indicating areas that experience repeated flooding within Roscommon and surroundings. Also includes contact details for originators (ESB International)
	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands.

			*Coverage: ☐ *No Coverage: ☒
	Excel file	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☐ *No Coverage: ☒
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		Likely accuracy of Flow estimate	Likely accuracy of Gauged Level estimate	Known hydraulic conditions (1)	Supplementary known, useful flood levels(2)	Reliable flood history (levels, locations, dates) (3)	Indicative calibration score (sum of columns 2-6)	Calibration comment (with event number):
Category 1	Large gauged river within an AFA (HPW)	1(2) 2(0) 3(0)	1(2) 2(2) 3(0)	1(0) 2(0) 3(0)	1(0) 2(1) 3(1)	1(1) 2(0) 3(0)	1(5) 2(3) 3(1)	1-some information on the flood event. 2- no specific dates of location of event 3- no specific dates of location of event
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely. Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2).

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (See Table D.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1: FSU Gauging station classification (from Hydro-Logic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N05**	Length	32km
Unit of Management		25/26	
AFA	Mullingar		
IRRs	None		
River / Catchment / Sub-catchment	River Brosna / Brosna / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	The catchment has a large lake (Lough Ennell) within the model extent. With many ungauged inflows into the lake, model calibration will be completed in two separate stages, one upstream of (and including) the lake and one downstream. There is only observed flood event data available for the town of Mullingar (See Appendix B) upstream of the lake.		
Completed by	James Murray	Alice Wiggins	
Date	19/12/2012	20/06/2013	

Potential Flood Events to consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	16/08/2008 – Uncertain location, on small ungauged tributary	1	0+0+0+1+1=2	Not suitable
2	10/1987 - Localised storm with small peak, no flood level details	1	1+1+0+0+0=2	Not suitable
3	11/1965 – No continuous flow or level data before 1978.	1	0+0+0+1+1=2	Not suitable
4	01/1995 – Uncertain location	1	1+1+0+0+0=2	Not suitable
5	Gauge Data Only - In-bank event – Qmed	1	To be identified in Phase 2	Calibration/verification
6	Gauge Data Only - Out of bank event – Highest recorded flow	1	To be identified in Phase 2	Calibration/verification

The flood event data above and in Appendix B are taken from www.floodmaps.ie.database.

* See Appendix B for Event Details of events 1-4, ** See Appendix C for Quality Category and Quality Score (Scoring - 0 (Not suitable for calibration) to 18(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
25213 Culleen Fish Farm	1957 to Date	Level and Flow	95.25	Not FSU Classified	No rating review. Rating verified up to less than 0.3XQmed, flow

					appears regulated.
25050 Mullingar Pump House	1978 to Date	Level and Flow	88.24	Not FSU Classified	No rating review, model rating considered for design hydrology.
25032 Mullingar	1975 to 1985	Level Only	Not found within the survey data	Not FSU Classified	Level only.
25085 Clonsingle	1954 to Date	Level Only	77.96	Not FSU Classified	Lake outflow control, sluice, no rating
25124 Ballynagore	1986 to Date	Level and Flow	76.17	Not FSU Classified	No rating review, but rating verified up to Qmed
25013 Newell's Bridge	1974 to Date	Level and Flow	77.67	Not FSU Classified	Jacobs rating review completed up to 3xQmed; considerable scatter in check gaugings

* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor))

Control Structures

Reference	Type	Description
D/S Lough Ennell	Sluice	There is a sluice downstream of Lough Ennell that controls the water level in the Lough.

Conclusions from Phase 1

Phase 1 suggested:

- Observation data available for events 1 to 4 cannot be used for calibration or verification as the data is not specific in date or location.
- Station 25013 has had a rating review completed by Jacobs.
- Station 25124 has a reliable high flow rating up to Qmed.
- Station 25050 has a low flow rating only.
- Stations 25085, 25032 and 25213 are level only, with the exception of 25213 that has low flow gaugings.
- Station 25213 has been discarded for calibration and verification as the flows at this location are very small and the rating is unreliable. The level and flow data indicates that the river at this location immediately downstream of a lake is regulated.
- Station 25085 is a gauging station at the lake outflow (Lough Ennell).
- Cross lake calibration can be carried out with a flood event for which gauging stations upstream and downstream of the lake have overlapping data availability. This calibration will aid the estimation of flows into the lake, to get water levels in the lake with sufficient accuracy to reproduce backwater effects upstream of the lake. This calibration event will not contribute to the calibration of model parameters like the Manning's n.

Phase 2

Gauging Station Information Used – Out of Bank* - Not possible as no out-of-bank flooding occurred

Gauging Station Information Used – In Bank*

**Location	Upstream of the Lough Ennell		Downstream Lough Ennell	
Type	Calibration	Verification	Calibration	Verification
Flood Event	6 (16/01/1984)	5 (31/01/1983)	8 (20/11/2009)	7 (17/08/2008)
GS Number	25050	25050	25013	25013
Station Name	Mullingar Pump House	Mullingar Pump House	Newell's Bridge	Newell's Bridge
Approximate Start of peak level	16/01/1984 02:15	30/01/1983 00:00	16/11/2009 00:00	15/08/2008 14:45
Approximate Finish of peak level	21/01/1984 09:45	03/02/1983 15:00	24/11/2009 01:30	23/08/2008 09:45
Peak level*** (mAOD Malin)	88.987 (0.747m)	89.066 (0.826m)	79.668 (1.998m)	79.602 (1.932m)
Peak flow (m^3/sec)	3.31	5.88	17.42	15.81
Other gauging stations for same event	Mullingar (25032)	Mullingar (25032)	Ballynagore (25124), Clonsingle (25085)	Ballynagore (25124), Clonsingle (25085)

*Calibration events may include more than one gauging station but the table above indicates the details for the most upstream gauging station which will provide the level and flow data for the calibration/verification.
**The calibration will be split into upstream and downstream of Lough Ennell.
***Stage plus datum (see Phase 1) from topographical survey (Stage in brackets).

Discussion and Strategy

Discussion

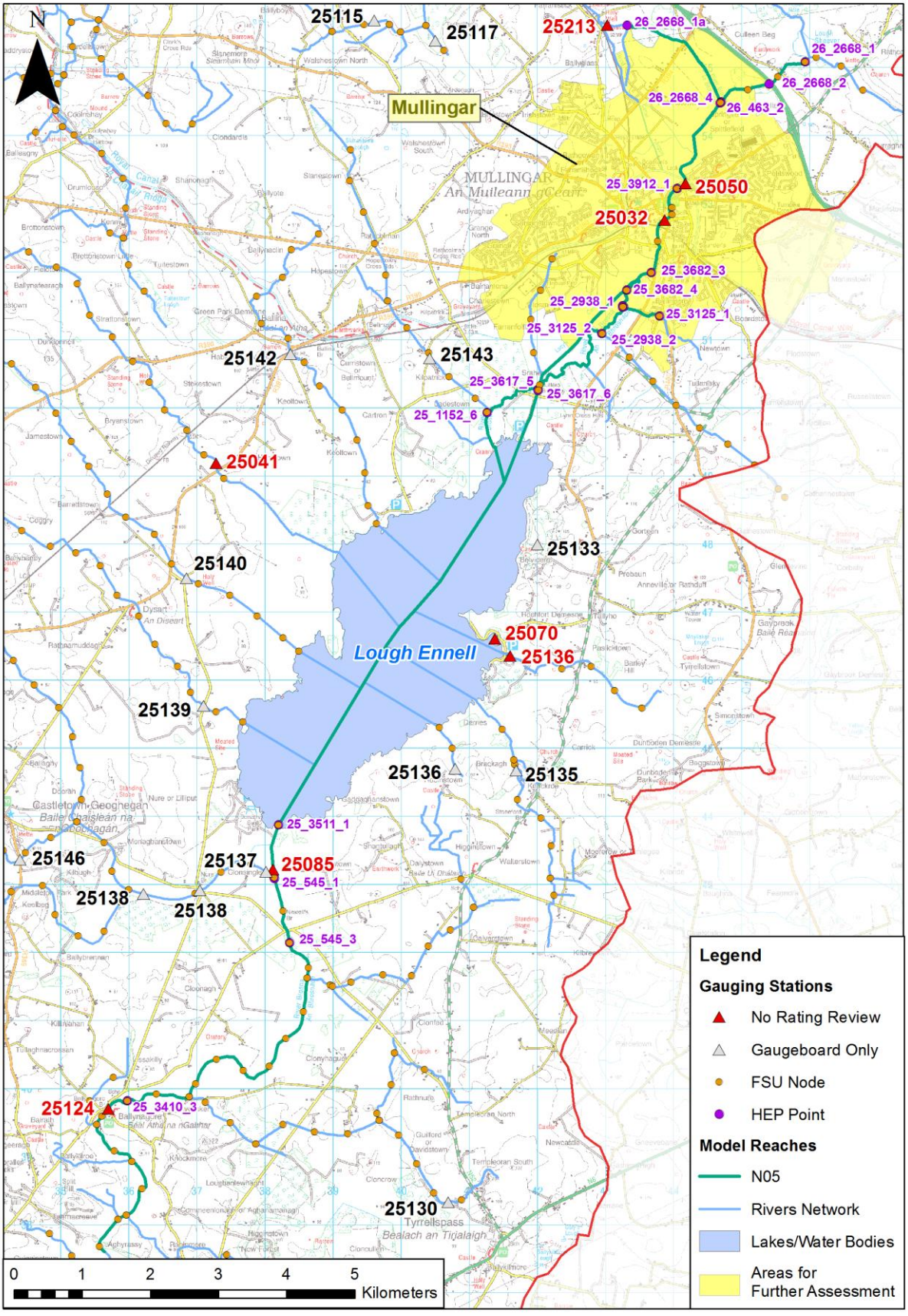
- Flood events 1 to 4 cannot be used as detailed at the end of Phase 1.
- There are no AFAs in the model extent N05 downstream of Lough Ennell. The Brosna in this reach is a MPW.
- There are a number of gauging stations which can be used for calibration such as stations 25050, 25032, 25124 and 25013. The flow data derived from the new model rating (CFRAM Gauging Station Modelling) at Newell's Bridge gauging station will be used for calibration or verification.
- The in-bank and out-of-bank calibration and verification events were chosen by first identifying which section of the model extent could be calibrated or verified. The criteria for this is that the upstream gauge must have level and flow data of good quality (ideally, a reliable rating above QMED) and a downstream level gauge. The period of record that these two gauges overlap will determine which events can be used. Events in the last 10 years are favoured over older events, as the current model will reflect the geomorphology during the flood event.
- Calibration and verification in N05 can be completed between 25050 and 25032 using data from the period 1978 to 1985. Calibration and verification can be completed between 25013 and 25124 using data from the period 1986 to present.
- Two in-bank events have been identified for upstream of Lough Ennell which will be between 25032 and 25050. The only overlapping data period at these two sites is between 1978 and 1985 so both events will be in this period. The chosen events are 31/01/1983 and 16/01/1984. Initially 1981 event was chosen but this event had a suspect water level at the downstream gauge (25032). These events were chosen as they featured highest on the ranked list of Amax flows for 25050. Both events remain in-bank and no out-of-bank events were available for the relevant period.
- Two extreme events have been identified downstream of Lough Ennell. These events will be modelled between 25013 and 25124 gauging stations. The events are 17/08/2008 and 20/11/2009. These two events were chosen as they ranked high on the list of Amax flows/levels for 25013. It was found from model runs that both events remained in bank, and no out-of-bank events are available for this reach.

- All available gauged events (that can be used for calibration) are in-bank. No out-of-bank calibration can therefore be undertaken. It should be noted that downstream of Lough Ennell all design events including the 1000-year event largely remain in-bank.

Calibration/Verification Strategy

- Upstream of Lough Ennell calibration between stations 25032 and 25050 using the 16/01/1984 event by inputting gauged flow at upstream gauging station 25050 (for HEP node number see calibration spreadsheet) and comparing the modelled water levels with gauged levels at station 25032.
- Upstream of Lough Ennell verification between stations 25032 and 25050 using the 31/01/1983 event by inputting gauged flow at upstream gauging station 25050 (for HEP node number see calibration spreadsheet) and comparing the modelled water levels with gauged levels at station 25032.
- Downstream of Lough Ennell calibration between stations 25013 and 25124 using the 20/11/2009 event by inputting gauged flow at upstream gauging station 25013, and scaled inflow hydrograph at the tributary inflow locations (for HEP node numbers see calibration spreadsheet) and comparing the model water level with gauged levels at station 25124.
- Downstream of Lough Ennell verification between stations 25013 and 25124 using the 17/08/2008 event by inputting gauged flow at upstream station 25013 (for HEP node number see calibration spreadsheet) and compare the model water level with gauged levels at 25124.
- Cross lake calibration to be completed between stations 25050 and 25013 using the 20/11/2009 event by inputting gauged flow at station 25050 (for HEP node number see calibration spreadsheet), inputting scaled flows into the lake (from other tributaries). The modelled levels are to be compared to gauged levels at 25085 and 25013.

Appendix A - Plan of Model N05



Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. *Coverage: ☒ *No Coverage: ☐
1	.pdf report	B-0063	42-0a Following period of heavy rainfall. The flooding was caused by throttling effect of an inadequately sized culvert under adjacent railway line. Impacts to property: Residential – 6 houses had back gardens flooded. Community – Mullingar Regional Hospital car park was flooded to 0.25m. NGR – N 432 541
2	pdf Study	B-0063	42-1a, 2a, 3a, 4a, 5a, 6a (duplicates) 18 page report on sewerage improvement and flooding study, references flooding in 10/1987 in the Bleach Yard, Lynn Road (section 1.2.1.2)
3	.pdf Study	B-0063	42-1a, 2a, 3a, 4a, 5a, 6a (duplicates) 18 page report on sewerage improvement and flooding study, references flooding in 1965 with photographs (poor quality). Section 2.8.3.3 discusses photographs that show flooding on Pearse St. Mullingar was <0.5m but also indicates that this may not have been at the peak.
4	pdf Study	B-0063	42-1a, 2a, 3a, 4a, 5a, 6a (duplicates) 18 page report on sewerage improvement and flooding study, references flooding in 1995 at Pearse Street (section 1.2.1.2)
All	.msg & .xls	C0116	Flow data for Station 25124 Ballynagore on the River Brosna Please note the following in relation to the River Brosna: The flow in the River Brosna is regulated by the operation of sluices on the river by mill operators. The first control is on the outlet of Lough Ennell, affecting the level of Lough Ennell (Station 25070 Whitebridge) and Station 25013 Newell's Br as well as Station 25124 Ballinagore directly downstream of the lake.

			The second control is a sluice regulating the water supply to the Grand Canal and Marshal's Mill (there is a Hydro generation at this location). The third control is at Kilbeggan Distillery. The fourth control is at Clara where there is a hydro generation station. The fifth control is at Belmont, where there is a hydro generation at this location, affecting the flow at Stations 25006 Ferbane upstream and 25011 Moystown downstream. Note: This station is downstream of the sluices controlling the level of Lough Ennell and may not reflect true water levels during drought periods.
All/ General Verification	Flooding Report	C-0103	West Meath County Council, Mullingar Sewerage Improvement Scheme and Flooding Study: Preliminary Report - Volume 5 hydrology study
All/ General Verification	Flood Risk Review	A-0031	Mullingar (CAR 42) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 13/4/2011
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of “benefiting lands” does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		Likely accuracy of Flow estimate	Likely accuracy of Gauged Level estimate	Known hydraulic conditions (1)	Supplementary known, useful flood levels(2)	Reliable flood history (levels, locations, dates) (3)	Indicative calibration score (sum of columns 2-6)	Calibration comment (with event number)
Category 1	Large gauged river within an AFA (HPW)	1(0) 2(1) 3(0) 4(1)	1(0) 2(1) 3(0) 4(1)	1(0) 2(0) 3(0) 4(0)	1(1) 2(0) 3(1) 4(0)	1(1) 2(0) 3(1) 4(0)	1(2) 2(2) 3(2) 4(2)	All storms do not seem appropriate for use as calibration events. Reasons: 1- small tributary upstream of the AFA, 2- no specific information on date, 3 - no continuous level of flow data in 1965, 4 - no specific information on date.
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2).

Appendix D – FSU Classification (Abstract from Inception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table D.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events.
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 - FSU Gauging Station Classification (from Hydro-Logic 2006)

	Phase 1
	Shannon CFRAM Study Calibration Information Refer to technical note TD041

Model No.	**S06**	Length	30 km
Unit of Management		24	

AFAs	Clarina, Adare, Limerick (part)
IRRs	None
River / Sub-catchment / Catchment	River Maigue / Maigue / Shannon Estuary South
Type of Flooding / Flood Risk	Fluvial non-tidal ☐ Fluvial tidal ☒ Coastal ☐
Comments	The rivers within the model are the River Maigue, River Barnakyle and two unnamed tributaries. Out of the four gauging stations within the model, only one has a rating review. The model extent covers three AFAs, namely, Adare, Clarina and a small section of Limerick City (the rest of Limerick City AFA is included within UoM 25/26). The River Maigue flows through the Adare AFA.

Completed by	Kieran Daly	Agnes Adjei	
Date	07/05/2013	16/04/2014	

	Potential flood events to consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	07/01/1999 (Some flood depth data is available)	1	0+1+0+1+1 = 3	Not suitable for calibration or verification
2	09/ 1992 (Flood extent outline is difficult to read)	1	0+0+0+0+1 = 1	Not suitable for calibration or verification
3	04/01/1995 (Source of flooding is tidal)	1	0+0+0+1+0 = 1	Not suitable for calibration or verification
4	1946 (Extent of flooding provided. Source of flooding is tidal)	1	0+0+0+1+1 = 2	Not suitable for calibration or verification
5	01/12/1973 (Location not specified)	1	0+1+0+0+1 = 2	Not suitable for calibration or verification
6	10/02/1997 (Source of flooding is tidal)	1	0+0+0+0+1 = 1	Not suitable for calibration or verification
7	Gauge data only - out-of-bank events	1	To be identified in Phase 2	Possible calibration
8	Gauge data only – In-bank events	1	To be identified in Phase 2	Possible verification

*Appendix B for Event Details, **Appendix C for Quality Category and Quality Score (Score 5 (Poor) to 18(Good))

See Appendix D for Key to FSU Station Classification (A1 (Good) to C (Poor)

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage both)	Gaugeboard Datum (mAOD Malin/Poolbeg)	FSU Classification*	Comment
24009 Adare Manor	1/11/1973 to Present	Water Level	4.55mAOD(P)	Not FSU Classified	-
24061 Ferry Bridge	1/1/1940 to present	Water Level	0.00mAOD(P)	Not FSU Classified	Tidal gauge
24062 Adare Quay	1/8/1966 to present	Water Level	3.00mAOD (P)	Not FSU Classified	Tidal gauge
24008 Castleroberts	1/11/1973 to present	Water level & flow	6.18 mAOD (M)	A2	-

Control structures – To be Completed by the Modellers/ Modellers Input Statement

Reference	Type		Description
			No relevant structures.

Conclusions from Phase 1

Phase 1 suggested:

- There are observational details of 6 events along the model extent S06.
- Event 1 is made up a map and notes of recorded flood debris marks on in the vicinity of the Station Road in Adare. Locations and level units and datum cannot be distinguished. Not suitable for calibration or verification.
- Event 2 is a flood extent map with records of flooding up to 1ft deep. The map is not of good quality and flood extent outline is difficult to read. Information is not suitable for calibration or verification.
- Event 3 is detailed in two reports which mention flooding within parts of the Maigue catchment. It also mentions overtopping of embankment and some flooding of the road, a national primary route. Source of flooding is tidal. As no tidal level boundary data is available for events before 2002 this event is not suitable for calibration or verification.
- Event 4 is an Engineer's report on flooding in Adare as a result of the breaches in existing embankment. Breaches and flooding may be as result of tidal influences. This report includes a flood map showing the extent of flooding. As no tidal level boundary data is available for events before 2002 this event is unsuitable for calibration or verification.
- Event 5 comprises of photographs showing flooding at Croom/Adare. There is limited information on the location and depth of flooding. The source of flooding is tidal. As no tidal level boundary data is available for events before 2002 that information is not suitable for verification or calibration.
- Event 6 is a report which mentions flooding on the N21 as a result of high tides. As no tidal level boundary data is available for events before 2002 this information is not suitable for calibration or verification.
- Events 3, 4, 5, 6 are not suitable for model calibration or verification as there is no downstream (tidal) boundary level data before the year 2002.
- Calibration or verification may be possible between stations 24008 and 24009 for Adare, which is investigated in more detail in Phase 2 below.

Phase 2

Gauging Station Information Used – Out of Bank

Run	Main Stem		Main Stem		
Type	Calibration		Verification		
Flood Event	7a – 10/01/2008	7a – 10/01/2008	7b – 19/11/2009	7b – 19/11/2009	
GS Number	24008	24009	24008	24009	
Station Name	Castleroberts	Adare Manor	Castleroberts	Adare Manor	
Recorded Start of peak level	09/01/2008 (17:30)	09/01/2008 (17:30)	19/11/2009 (03:30)	19/11/2009 (03:30)	
Recorded Finish of peak level	12/01/2008 (18:45)	12/01/2008 (18:45)	21/11/2009 (08:30)	21/11/2009 (08:30)	
Peak level *(mAOD Malin)	8.63	4.13	8.48	3.86	
**Peak flow (m^3/sec)	172.68	X	139.22	X	

Gauging Station Information Used – In Bank*

Run	Main Stem		Main Stem		
Type	Verification		Verification		
Flood Event	8a - 07/01/1996	8a - 07/01/1996	8b - 25/12/1999	8b - 25/12/1999	
GS Number	24008	24009	24008	24009	
Station Name	Castleroberts	Adare Manor	Castleroberts	Adare Manor	
Recorded Start of peak level	05/01/1996 (08:30)	X	24/12/1999 (15:00)	X	
Recorded Finish of peak level	08/01/1996 (09:15)	X	30/12/1999 (03:45)	X	
Peak level *(mAOD Malin)	8.39	4.16	8.45	4.44	
**Peak flow (m^3/sec)	123.61	X	133.03	X	

*Stage plus datum (see Phase 1) from topographical survey (Stage in brackets).
**Flow will be derived based on a model rating from the CFRAM Catchment Wide Model.
X – data not available

Discussion and Strategy

Discussion

- There is limited observational data for verification and no observational data for calibration.
- Event 1 has a map and notes of flood debris marks. This information will be used in verification.
- Event 2 has a flood extent map with records of 1ft depth of flooding in places. Flood extent outline cannot be distinguished. This information is not suitable for calibration or verification.
- The source of flooding for Events 3, 4, 5, and 6 is tidal and cannot be used for fluvial calibration or verification as tidal boundary data is only available from 2002.
- Calibration and verification will be attempted within Adare AFA on the River Maigue between stations 24008 Castleroberts and 24009 Adare Manor. These will be used for out-of-bank calibration and verification.
- Two out-of bank events have been identified. The 10/01/2008 event will be used for calibration and the 19/11/2009 event for verification.
- On further investigation the two In-bank events identified, namely, events 07/01/1996 and 25/12/1999 cannot be used for calibration or verification as there is no tidal data available for these gauging station locations for the 07/01/1996 and 25/12/1999 events.

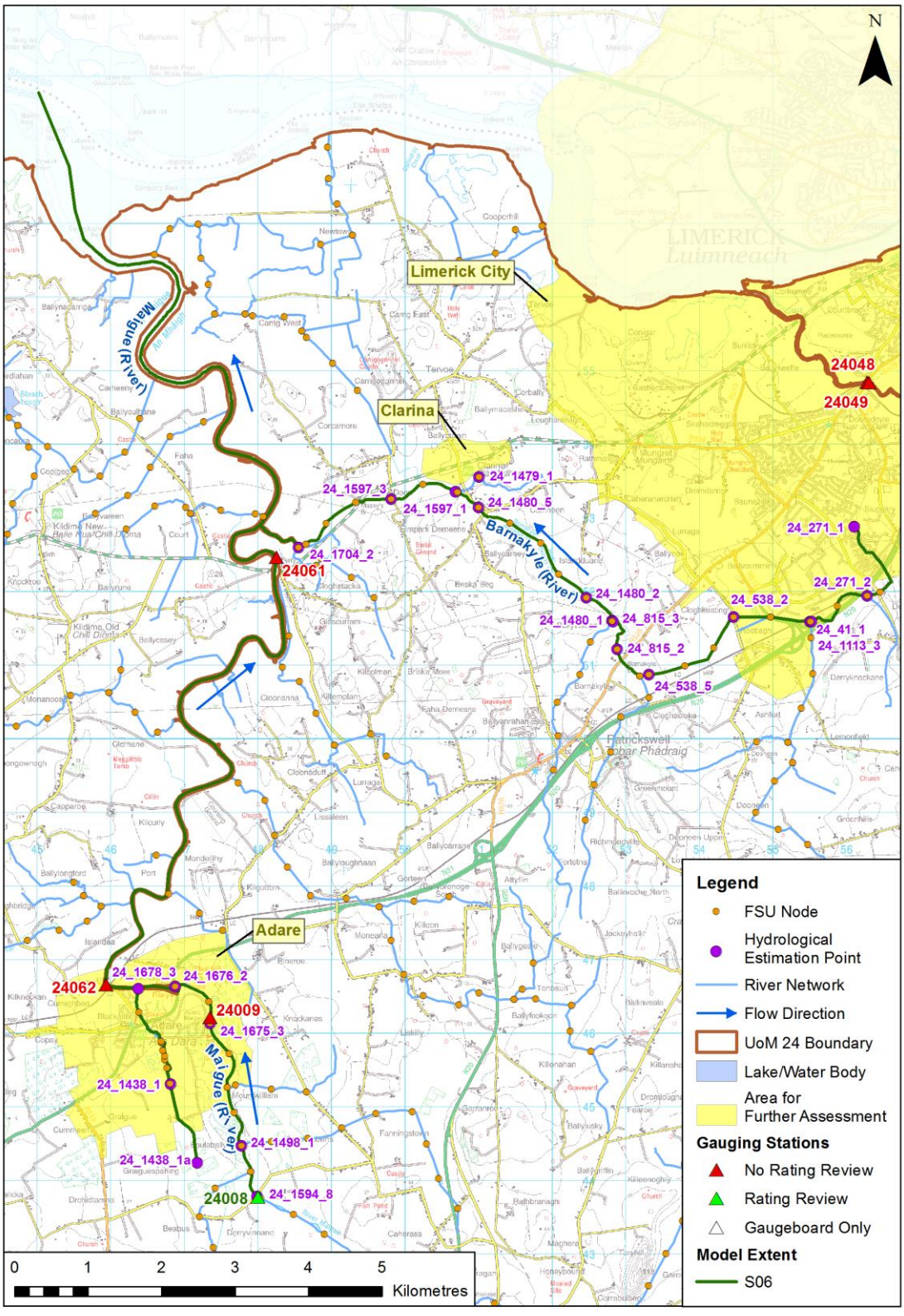
Calibration Strategy/Verification

- Out-of-bank main stem calibration between stations 24008 and 24009 will be completed using the 10/01/2008 and 11/11/2009 events by applying the gauged flows at 24008 (for HEP node number see calibration spreadsheet) and comparing the modelled water levels with the downstream gauging station level at station 24009.
- In-bank main stem verification cannot be completed using the 07/01/1996 and 25/12/1999 events between Stations 24008 and 24009 as there is no tidal data available for these stations to account for the important tidal influence on the watercourse.

Tidal Calibration/Verification

- The Maigue has a tidal river gauge at the downstream extent of S06 Adare Quay (24062) and also further downstream at Ferry Bridge (24061). Calibration is possible between Station 24008 (Castleroberts) and Stations 24061 and 24062. Tidal levels are only available from 2002. The events of 08/10/2002, 30/03/2006, 08/10/2006 and 10/03/2008 have been identified as large tidal events from the AMAX series at 24061.
- The Carrigaholt tidal gauge in the Shannon Estuary will be used to provide the tidal boundary for the calibration events on the Maigue. This station only has data from 2002.
- The Barnakyle River is not gauged and there is no anecdotal information to allow calibration or verification of this watercourse through Clarina AFA.

Appendix A - Plan of model S06



Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
All/ General Verification	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☒ **No Coverage: ☐
	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December *Coverage: ☐ * No Coverage: ☒
1	Excel sheet	B-0063	03-6d Level data based on flood debris marks Values are difficult to read.
1	Pdf	B-0063	03-2a Photocopy of levels from notebook. Location and date unclear.
2	Map	B-0063	9-1d Map showing extent of flooding. 1foot depth of flooding.
3	Report to Regional Engineers	B-0063	03-4a Overtopping of embankment, flooding the road, a national primary route. Embankment in many instances in excess of 300mm below design crest of 24ft OD.
3	Reports from Regional Hydrometric Technicians	B-0063	03-4b Land waterlogged in parts of the Maigue catchment. Road flooding.
4	Engineers report, map and photographs	B-0063	03-6f Breaches in embankment in Adare. OS Map showing areas that were “damaged” highlighted in blue.
5	Photograph	B-0063	03-5a Flooding location unclear. States “Croom/ Adare” area
6	OPW memo	B-0063	03-3 States “near record tides, the N21again flooded”. Refers to report 27/02/1996 for data. No other useful data.
All/ General Verification	Meeting minutes	B-0063	03-6g Flooding in Station road area.
All/ General Verification	OPW Mungret Memo	B-0063	03-6e 150mm deep flooding on road in Adare. Flood mechanism; Combined Tidal & Fluvial.
All/ General Verification	Photographs	B-0063	03-6a, 6b, 6c Photographs of flood extent near Adare Castle.
All/ General Verification	FRR site visit	A- 0084	Clarina - Notes, marked up plans, photographs and videos during UoM 24 Site Visit
All/ General Verification	FRR site visit	A- 0079	Adare - Notes, marked up plans, photographs and videos during UoM 24 Site Visit

*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question.
**The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment**
Category 1	Large gauged river within an AFA (HPW)	1(0) 2(0) 3(0) 4(0) 5(0) 6 (0)	1(1) 2(0) 3(0) 4(0) 5(1) 6 (0)	1(0) 2(0) 3(0) 4(0) 5(0) 6 (0)	1(1) 2(0) 3(1) 4(1) 5(0) 6 (0)	1(1) 2(1) 3(0) 4(1) 5(1) 6 (1)	1(3) 2(1) 3(0) 4(2) 5(2) 6 (1)	
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely. Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table 3-i: FSU gauging station classification (from Hydrologic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N07**	Length	28 km
Unit of Management		25/26	
AFAs	Rahan, Clonaslee		
IRRs	None		
River / Sub-Catchment / Catchment	River Clodiagh / Brosna / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model extent N07 is comprised of the River Clodiagh (a tributary of the River Brosna), the River Tullamore and the River Gorragh which are both tributaries of the Clodiagh. There are two AFAs located within this model extent known as Rahan and Clonaslee. Both the River Clodiagh and River Gorragh flow through Clonaslee AFA. There are 5 gauging stations within this model extent which measure level and/or flow.		
Completed by	Kieran Daly	James Cullinane	Alice Wiggins
Date	05/04/2013	17/07/2013	24/07/2013

Potential Flood Events to consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	18 -19/08/2008 – aerial photograph near Rahan	2	1+1+0+1+1=4	Verification
2	07/02/1990 – Cross section with water levels marked on - Outside model extent.	2	0+0+0+1+1=2	Not suitable for calibration/ verification
3	11/1968 – 01/1969 – Very general flood description, not specific.	2	0+0+0+0+0=0	Not suitable for calibration/ verification
4	Gauge data only – In-bank events	2	To be identified in phase 2	Possible calibration/verification
5	Gauge data only – Out-of-bank events	2	To be identified in phase 2	Possible calibration/verification

The flood event data above and in Appendix B are taken from www.floodmaps.ie.database.

* See Appendix B for Event Details of events 1-4, ** See Appendix C for Quality Category and Quality Score
(Scoring - 0 (Not suitable for calibration) to 18(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)					
Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification	Comment
25016 Rahan	01/08/1951 - present	Level and flow	45.32	B	Jacobs' rating review completed up to 3xQMED
25007 Gorteen	01/08/1954 - 15/07/ 2003	Level and flow	76.04	Not FSU Classified	Two distinct trends observed at 25007 when check gaugings are plotted against time. This would indicate a datum shift at this site. Data since 1999 not yet digitised. Existing rating verified up to 0.5xQMED (HGF/$QMED_{syn}$ =0.46).
25149 - Tullamore	01/02/2001 – present	Level and flow	Gauge datum not found	Not FSU Classified	No Jacobs rating review, rating verified up to 1.6xQMED. Located on the River Tullamore.
25301 – Bracknagh Bridge	02/07/2002 – present	Level and flow	83.47	Not FSU Classified	Very few check gaugings at this site (7 gaugings) with the highest flow of 2.44 m^3/s. No Amax series available.
25331 – Tullamore Weir	12/10/ 2006 - present	Level and flow	Gauge datum not found	Not FSU Classified	No Jacobs' rating review, EPA gauging station, rating verified up to 1.1xQMED. Located on the River Tullamore.
* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor)					

Control structures		
Reference	Type	Description
Weirs on River Clodiagh	Weir	Sharp crested weir and a round nosed crested weir on the River Clodiagh

Conclusions from Phase 1

Phase 1 suggested:

- Observational data available for Events 1 to 3.
- Event 1 observational data consists of an OPW report on flooding in Tullamore and aerial photo of flooding at Killina for the August 2008 event. Tullamore is outside the model extent so the OPW report on flooding in Tullamore will not be used for verification. Killina is within the model extent and may be used for calibration.
- Event 2 observational data is a sketched long-section through the Tullamore River which details water levels for the February 1990 event. This data is outside the model extent.
- Event 3 observational data is a hydrometric report for the February 1969 event without specific information to aid calibration or verification.
- Stations 26016, 25149, 25331 and 25007 are flow gauges which may be considered for calibration/verification.
- Station 25301 has level data, but no rating is available and only limited check gauging. A model rating may be extracted from the N07 model at gauging station 25301 to be used for verification, but as this is not a rating review site such estimated flows should be used with caution.

Phase 2					
Gauging Station Information Used – Out of Bank*					
Run	Main Stem	Trib	Main Stem	Trib	
Type	Calibration		Verification		
Flood Event	5a - 18/08/2008	5a - 18/08/2008	5b - 20/11/2009	5b - 20/11/2009	
GS Number	25301	25149	25301	25149	
Station Name	Bracknagh Bridge	Tullamore	Bracknagh Bridge	Tullamore	
Recorded Start of peak level	16/08/2008 (00:00)	16/08/2008 (00:00)	18/11/2009 (00:00)	18/11/2009 (00:00)	
Recorded Finish of peak level	24/08/2008 (09:45)	24/08/2008 (09:45)	24/11/2009 (04:45)	24/11/2009 (04:45)	
Peak level **(mAOD Poolbeg/Malin)	X (2.47m)	X (2.45m)	X (1.87m)	X (2.10m)	
Peak flow (m^3/sec)	To be confirmed by model rating	16.07	To be confirmed by model rating	10.52	
Other gauging stations for same event	Rahan (25016)	Rahan (25016)	Rahan (25016)	Rahan (25016)	
Gauging Station Information Used – In Bank*					
Run	Main Stem	Trib	Main Stem	Trib	
Type	Calibration		Verification		
Flood Event	4a - 26/10/2008	4a - 26/10/2008	4b – 31/01/2009	4b – 31/01/2009	
GS Number	25301	25149	25301	25149	
Station Name	Bracknagh Bridge	Tullamore	Bracknagh Bridge	Tullamore	
Recorded Start of peak level	25/10/2008 (00:00)	25/10/2008 (00:00)	28/01/2009 (22:30)	28/01/2009 (22:30)	
Recorded Finish of peak level	28/10/2008 (16:15)	28/10/2008 (16:15)	07/02/2009 (10:30)	07/02/2009 (10:30)	
Peak level **(mAOD Poolbeg/Malin)	X (0.94m)	X (1.71m)	X (1.90m)	X(1.95m)	
Peak flow (m^3/sec)	To be confirmed by model rating	5.23	To be confirmed by model rating	8.35	
Other gauging stations for same event	Rahan (25016)	Rahan (25016)	Rahan (25016)	Rahan (25016)	

*Calibration events may include more than one gauging station but the table above indicates the details for the most upstream gauging station which will provide the level and flow data for the calibration/verification.

**Stage plus datum (see Phase 1) from topographical survey (Stage in brackets).

X – data not available

Discussion and Strategy

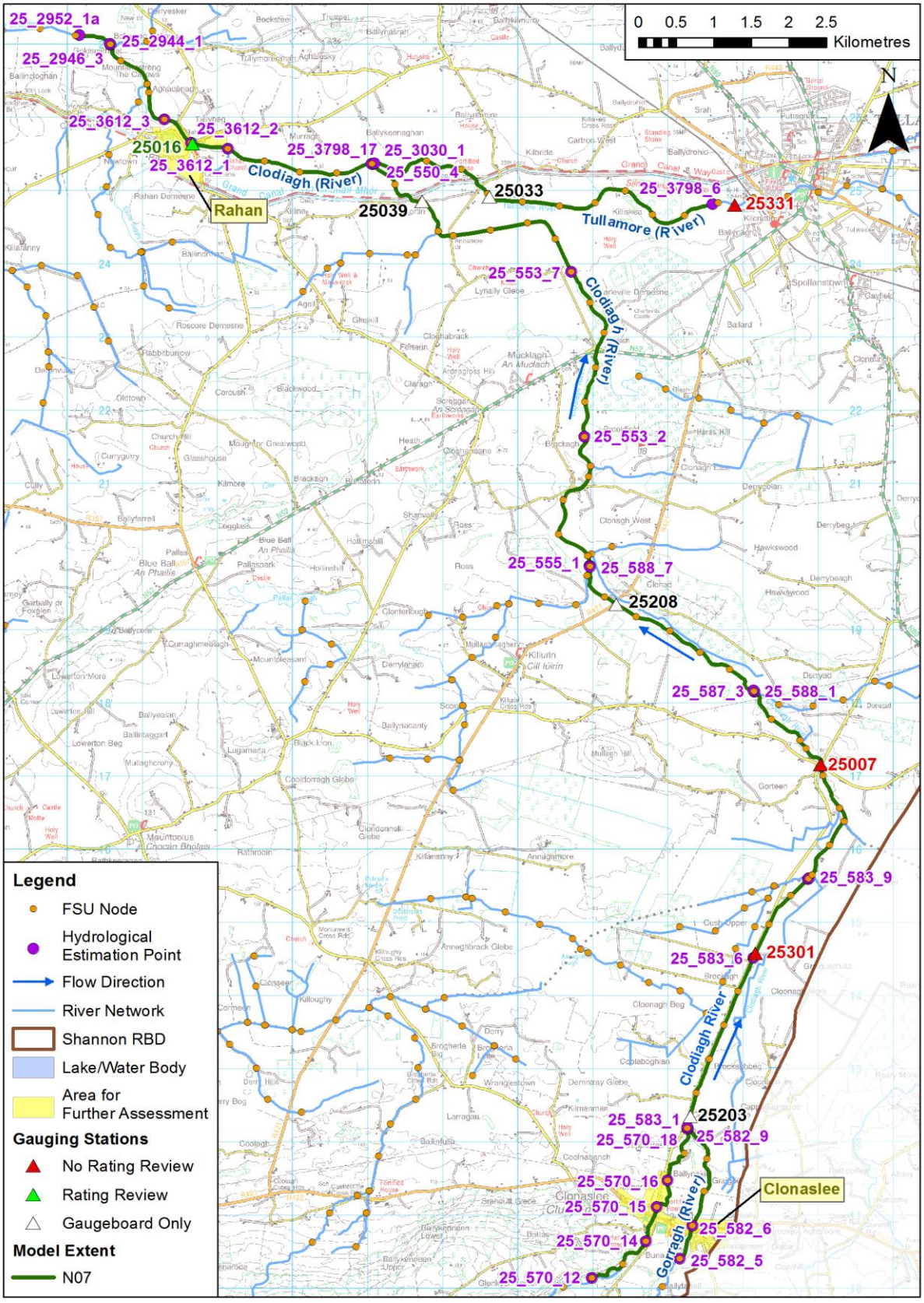
Discussion:

- There is limited observational data for verification and no observational data for calibration.
- Calibration and verification may be completed on this model extent between stations 25301 and 25016 and on the River Tullamore from the top of the model extent to the confluence with River Clodiagh.
- Calibration and verification is not feasible within Clonaslee AFA, as there is no gauged or observed data in that area.
- There are a number of gauging stations which can be used for calibration and verification, including 25016, 25149, and 25301. These will be used for in-bank or out-of-bank calibration.
- There is no rating for station 25301 so the CFRAM model will be used to derive a model rating at this station to inform the verification inflows. As this is not a rated site (and not subject to a rating review as part of the CFRAM study) the flows derived from the model should be used with caution.
- Two in-bank events have been identified from the gauged data which cover the main stem and tributary. One event will be used for calibration and the other for verification.
- Two out-of-bank events have also been identified from the gauged data which will cover the main stem and tributary. One event will be used for calibration and the other for verification.
- Verification can also be completed on a small stretch at Killina using observational data.

Calibration/Verification Strategy:

- Extract modelled flow and levels from the N07 model at Station 25301 to a rating.
- Out-of-bank main stem verification between Stations 25301 and 25016 and tributary calibration between 25149 and 25016 to be completed using the 18/08/2008 and 20/11/2009 events by applying the gauged flows at 25301 and 25149 (for HEP node number see calibration spreadsheet) and comparing the modelled water levels with the downstream gauging station level at station 25016.
- In-bank main stem verification between Stations 25301 and 25016 and tributary calibration between 25149 and 25016 to be completed using the 26/10/2008 and 31/01/2009 events by applying the gauged flows at 25301 and 25149 (for HEP node number, see calibration spreadsheet) and comparing the modelled water levels with the downstream gauging station level at 25016.
- Calibration can be completed at Killina using the aerial photo from the August 2008 event. The model flood depths and outlines will be compared to the August 2008 aerial photos to verify that the model results seem consistent with the observed level data (**calibration**) and the estimated return period of the event (**design flood verification**), which is predicted to be approximately 1 in 10 AEP event based on single site analysis using the EV1 distribution at gauging station 25016. The aerial photo was not taken at the peak flood level.

Appendix A - Plan of Model N07



Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☐ *No coverage: ☒
	GIS layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No coverage: ☒
	GIS layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☐ *No coverage: ☒
All/ General Verification	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☒ **No coverage: ☐
1	Aerial Photograph	B-0049	49-1a Aerial photograph of flooding in Killina, Co Offaly on 18th August 2008 (below peak levels).
1	OPW Report	B-0049	Flooding in Tullamore during August 2008, including flood extent maps, flood water levels and photographs of flooding at Whitehall Estate, Tullamore on 18th August 2008 at 50 to 100mm below peak.
2	Cross- section Drawing	B-0049	Long section through the Tullamore river in Tullamore display river levels on 2 dates in 1990. Outside the model extent.
3	Hydrometric report	B-0049	43-3a The highest flow of the post-drainage period was recorded at Rahan on the Clodiagh River.
General Verification	E-mail	B-0050	Confirmation of no flooding at Clonaslee during recent heavy rainfall during July 2012
General Verification	Meeting minutes	B-0063	49-2a Offaly County Council; Gives an indication of areas prone to flooding but does not provide any specific detail.
All/ General Verification	FRR site visit	A-0052	Rahan (CAR 49) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 06/05/2011
All/ General Verification	FRR site visit	A-0112	Clonaslee (CAR 23) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 27/05/2011
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of “benefiting lands” does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		Likely accuracy of Flow estimate	Likely accuracy of Gauged Level estimate	Known hydraulic conditions (1)	Supplementary known, useful flood levels(2)	Reliable flood history (levels, locations, dates) (3)	Indicative calibration score (sum of columns 2-6)	Calibration comment
Category 1	Large gauged river within an AFA (HPW)							
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW	1(1) 2(0) 3(0)	1(1) 2(0) 3(0)	1(0) 2(0) 3(0)	1(1) 2(1) 3(0)	1(1) 2(1) 3(0)	1(4) 2(2) 3(0)	All storms are not appropriate for use as calibration events. Reasons: 1-Some information for verification. 2-outside the model extent, 3-no specific information on dates, levels or flows.
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely. Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2).

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table D.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 FSU Gauging station classification (from hydrologic 2006)

Appendix E – Further notes on Events

Tullamore Flood event August 2008 – Data Collation Report – October 2008, written by the OPW

- This report contains a series of aerial photographs taken on the 19/08/2008 after the 18/08/2008 flood event. An OS map of the Tullamore area with flood extents based on the aerial photographs superimposed is provided.
- A long profile of surveyed flood levels carried out by the OPW East Region Maintenance team on 18/08/2008 is also provided.
- Water level recorder gauge data from Kilcruttin Bridge in Tullamore is also provided in the report.

1968_1969 flood report.pdf – February 1969 (B-0049/43-3a)

- This report provides a brief description of the locations where flooding was experienced during this rainfall event (i.e. farmland upstream of Tullamore, Pollagh and Ballycumber). It also mentions the highest flow at Rahan prior to 1969.

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N08**	Length	126km
Unit of Management		25/26	
AFA	Castlerea, Athleague		
IRRs	none		
River / Catchment / Sub-catchment	River Suck and River Francis / Suck / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model extent N08 comprises of the River Suck and its tributary, the River Francis. There are three gauging stations along the River Suck within the N08 model extent and four gauging stations on tributaries outside of the model extent. There are two AFAs within the model extent: Castlerea and Athleague. It may be possible to complete calibration/verification in Athleague, but not possible in Castlerea.		
Completed by	Kieran Daly	Yiwen Zhao	
Date	04/04/2013	03/09/2013	

Potential Flood Events to Consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or Verification
1	2009 Event – 21/11/2009 - Jacobs delineated flood extent and reported flood levels in Athleague. 30/11/2009 – SERTIT flood outline - Out of bank event	1	2+2+1+2+3=10	Calibration/ Verification
2	11/01/2005 – No specific date - Out of bank event	1	1+1+1+1+1=5	Verification
3	06/02/2002 – Out of bank (Phase 2 only)			Calibration
4	28/10/2002 – In bank (Phase 2 only)			Calibration/ Verification

The flood event data above and in Appendix B are taken from www.floodmap.ie database.
* See Appendix B for Event Details of events 1-2, ** See Appendix C for Quality Category and Quality Score
(Scoring - 0 (Not suitable for calibration) to 18(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
26006 - Willsbook	1952 to Date	Level and Flow	58.609	A1	Jacobs rating review confirmed OPW rating was acceptable up to

					3xQMED.
26002 - Rookwood	1952 to Date	Level and Flow	45.202	A2	Jacobs rating review completed up to 3xQMED
26005 - Derrycahill	1954 to Date	Level and Flow	39.87	A2	Jacobs rating review completed up to 3xQMED.
26309 - Mounttalbot	2001 to Date	Level and Flow	Not found	Not FSU Classified	On tributary; No rating review
26310 – Longford Spring	2001 to 2002	Level only	Not found	Not FSU Classified	On tributary; No rating review.
26001 - Ballinamore	1952 to Date	1952-1969 Level and flow; post 1976 Level only	44.48	Not FSU Classified	On tributary; Jacobs rating review completed up to 3xQMED, lots of missing data.
26004 - Bookala	1972 to Date	Level only	59.76	Not FSU Classified	On tributary; Jacobs rating review completed up to 3xQMED

* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor)

Control Structures

Reference	Type	Description
26FRAN00055 W_FP01	Sluice	Two sluice gates at Casterea AFA on the River Francis. River channel <10m approx.
26SUCK06624 X_LB	Sluice	Three sluice gates, fish pass and weir situated in Athleague. River channel >20m approx.

Conclusions from Phase 1
Phase 1 suggested: • Observed data available for events 1 can be used for calibration or verification. • Observed data available for event 2 cannot be used for calibration as the data has no specific date and it is difficult to define the exact flood extent, but may possibly be used for verification. • Station 26006 has a rating review completed by Jacobs which verified the OPW rating up to 3XQMED. It is not possible to use this station for calibration as there are no suitable stations upstream and the downstream station (26002) is a significant distance away (42km) with a number of ungauged inflows. • Station 26002 has a rating review completed by Jacobs up to 3xQMED. The rating review highlighted some uncertainty in the rating, particularly as the November 2009 check gauging completed during the November 2009 event (Event 1) is an outlier from the main cluster of check gaugings and the model rating. It is felt that this station is still suitable to be used for calibration. • Station 26005 (near the downstream boundary of N08) has a rating review by Jacobs completed up to 3xQMED, and can be used for calibration. • Other stations (listed in the table above) lie on tributaries outside of the model extent and cannot be used for calibration. • There is no observed or gauged flood event data available in AFA Castlerea, so calibration cannot occur in this AFA. • There is observed and gauged flood event data available in AFA Athleague, so calibration and verification should be completed.

Phase 2				
Gauging Station Information Used – Out of Bank*				
Location**	Section 1	Section 2		
Type	Calibration /Verification	Calibration/ Verification	Verification	Verification
Flood Event	1 (21/11/2009)	1 (21/11/2009)	2 (11/01/2005)	3 (06/02/2002)
GS Number	26002	26002	26002	26002
Station Name	Rookwood	Rookwood	Rookwood	Rookwood
Approximate Start of peak level	16/11/2009 04:30:00	16/11/2009 04:30:00	06/01/2005 01:30	01/02/2002 09:45:00
Approximate Finish of peak level	30/11/2009 22:15:00	30/11/2009 22:15:00	17/01/2005 00:00:00	18/02/2002 23:45:00
Peak level*** (mAOD Malin)	47.852 (2.65m)	47.852 (2.65m)	47.192 (1.990m)	47.2 (1.998m)
Peak flow (m^3/sec)	161.15	161.15	77.595	78.42
Other gauging stations for same event	N/A	Derrycahill (26005)	Derrycahill (26005)	Derrycahill (26005)

Gauging Station Information Used – In Bank* – Not possible for Section 1 as no observed levels

Location	Section 2
Type	Calibration
Flood Event	4 (31/10/2002)
GS Number	26002
Station Name	Rookwood
Approximate Start of peak level	20/10/2002 09:00:00
Approximate Finish of peak level	09/11/2002 02:30:00
Peak level*** (mAOD Malin)	47.018 (1.816m)
Peak flow (m^3/sec)	62.149
Other gauging stations for same event	Derrycahill (26005)

*Calibration events may include more than one gauging station but the table above indicates the details for the most upstream gauging station which will provide the level and flow data for the calibration/verification.
**The calibration will be split into two sections: Section 1 from upstream of Athleague at HEP node 26_1452_1 (to be confirmed by modeller) to station 26002; Section 2 is from station 26002 to station 26005.
***Stage plus datum (see Phase 1) from topographical survey (Stage in brackets).

Discussion and Strategy

Discussion

- Flood events 1 can be used for calibration or verification and event 2 can be used for verification only.
- There are two AFA's within the model extent, which are Athleague and Castlerea.
- Station 26006 is the most upstream gauging station within the N08 model, which is 7.3km downstream of the AFA Castlerea. This station cannot be used for calibration using gauged

event data as there is no suitable upstream gauging station and the distance to the downstream station is 42km, with a number of inflows from ungauged tributaries.

- There is no observed flood data recorded for Castlerea. Therefore, no calibration can be undertaken at Castlerea.
- Stations Rookwood (26002) is in the middle of the model and is located at 5 km downstream of Athleague.
- Derrycahill (26005) is downstream of station 26002, close to the N08 boundary.
- Calibration of the N08 model can be divided into two sections: Section 1 is from upstream of Athleague at HEP node 26_1452_1 to station 26002 and Section 2 is from station 26002 to station 26005.
- As Athleague is close to station 26002, it may be possible to calibrate and verify Section 1 of the model using gauging and observed records (levels, extents or photos).
- For Section 2, calibration may be possible between stations 26002 and 26005. Major inflows between station 26002 and station 26005 need to be taken into consideration. These inflows can be estimated based on a 'historic event growth factor' (gauged event peak flow / synthetic flow) and a hydrograph shape which is adjusted based on the HEP location and event.
- The 2009 event can be used for out-of-bank calibration and verification in Section 1 (Athleague AFA) as there is significant observed and gauged event data.
- The 2009 event can be used for out-of-bank calibration and verification in Section 2 (Station 26002 to Station 26005).
- Out-of-bank verification may also be possible using the 2005 observation event data and February 2002 gauged flood event data.
- The October 2002 gauged data can be used for in-bank calibration in Section 2.

Calibration/Verification Strategy:

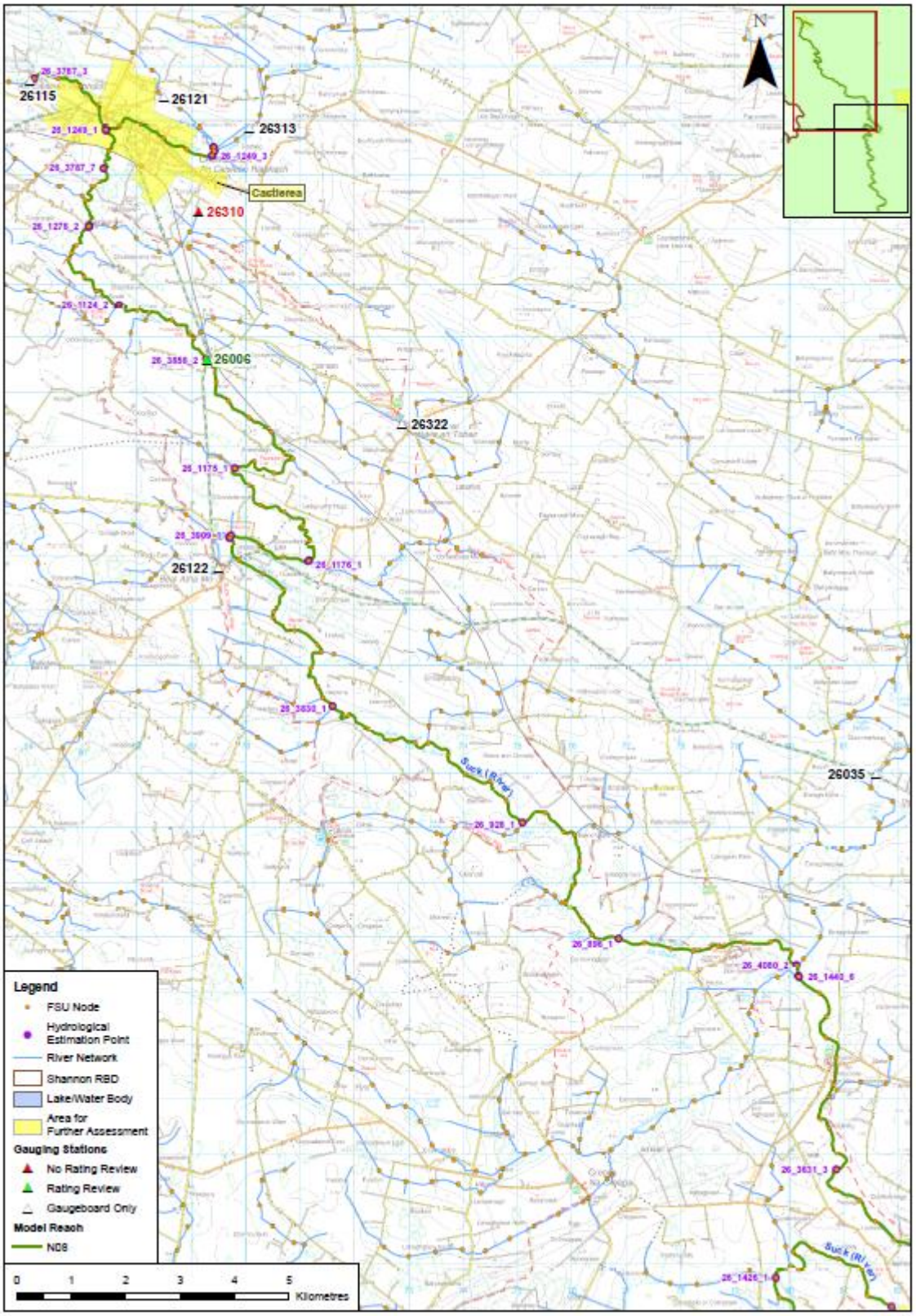
- Section 1, out-of-bank calibration is possible from upstream of Athleague (26_1452_1) to stations 26002 using the 21/11/2009 event by applying gauged flow upstream of Athleague (26_1452_1) and comparing the modelled water levels with gauged levels at station 26002, as well as comparing to observed water levels and photos.
- Section 2, out-of-bank calibration may be possible between stations 26002 to 26005 using the 21/11/2009 event by applying gauged flow in 26002 (and ungauged estimated inflows along the section) and comparing the modelled water levels with gauged levels at station 26005. The calibration of this section may be problematic as the distance is still considerable with a number of ungauged inflows.
- Section 2, out-of-bank verification may be possible using the 28/10/2002 and 11/01/2005 events, by applying gauged flow data at station 26002 and comparing the modelled water levels with gauged levels at gauging station 26005. For 11/01/2005 event the flood outline will be compared to the provided aerial photos as well.
- Section 2, in-bank calibration is possible between stations 26002 to 26005 using the 31/10/2002 event by applying gauged flow in 26002 (and ungauged estimated inflows along the section) and comparing the modelled water levels with gauged levels at station 26005.

Post Verification Strategy:

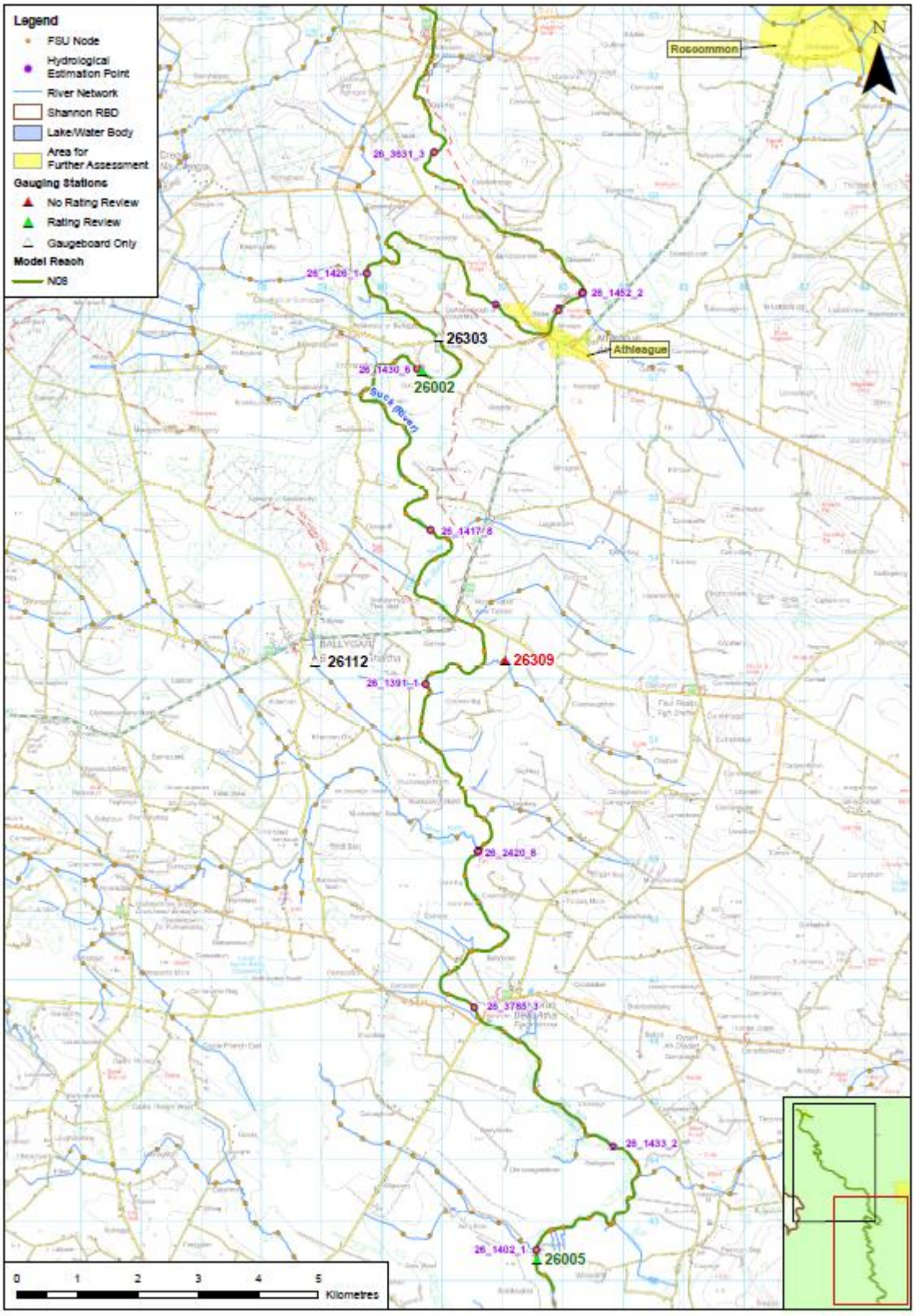
- Section 1 can be verified using SERTIT flood extent data which was collected after the 2009 event, by comparing the gauged 2009 event outline to the SERTIT outline (possibly taken considerably after the peak water level).
- Section 2 can be verified using SERTIT flood extent data which was collected after the 2009 event, by comparing the gauged 2009 event outline to the SERTIT outline (possibly taken considerably after the peak water level).

Appendix A - Plan of model N08 - DRAFT

N08 North



N08 South


Legend
FSU Node
Hydrological Estimation Point
River Network
Shannon RBD
Lake/Water Body
Area for Further Assessment
Gauging Stations
No Rating Review
Rating Review
Gaugeboard Only
Model Reach
N08
Roscommon
Athleague
26303
26002
26112
26309
26005
Suck (River)
0 1 2 3 4 5
Kilometres
N

Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
1	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☒ *No Coverage: ☐
	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No Coverage: ☒
1	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☒ *No Coverage: ☐
	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. *Coverage: ☐ *No Coverage: ☒
1	jpg. tif. fff. photographs and videos	B-0007, B-0013, B-0014, B-0015, B-0025, B-0028, B-0029, B-0035	A collection of photographs and videos of the November 2009 event. This imagery was used to create the Jacobs 2009 digitisation of the November 2009 event. The digitisation notes refer to specific photographs or videos used to identify the flood extent.
1	.pdf report	B-0063	09-0a Consultant report on flooding at Athleague Nov 2009 – includes maps and photos. The main objectives of this study are to assess the hydraulic performance of the existing surface water drainage system, determine the existing flood plain of the River Suck, assess a number of proposed flood alleviation works and outline a preferred scheme to improve flood protection and surface water drainage within the village of Athleague. The recorded flood level in the centre of Athleague was between 49.712 and 50.015mAOD, which was reported in Athleague Flood & Surface Water Study Detailed locations were unknown.
1	jpg. photographs	B-0013	Photographs with markings showing flood extent in Athleague, Dooamon and Castlecoote; detailed locations are unknown.
1	doc.	C-0182	C-0182 now has a brief report on 2009 flooding from the River Suck which is undated, unauthorized. The report includes photographs and description of flooding.
1	pdf. Report	B-0037	Flood mitigation study of Strokestown/ Tulsk. The report primarily deals with flooding from a watercourse (Scragmoge River) outside of the model extent.
1	pdf drawing	A-0183	Drawing showing photographs of flooding in Athleague, includes plan of photograph

			locations and proposals to manage flood risk. Drawing is scanned over a number of pdfs.
All/ General verification	pdf. Engineers meeting minutes	B-0063	19-1a Roscommon Engineer Meeting on repeat flooding areas. No specific levels / dates provided.
2	jpg. photographs	B-0063	09-1, 1a, 1d, 1e, 1f, 1g: Aerial photographs of River Suck during 2005 event. Note specific date provided, resolution makes it difficult to determine specific flood extents.
All	Excel sheet	B-0063	09-4a, 4d SAC designated Turlough locations – Report
All/ General Verification	pdf	A-0009	Preliminary Assessment of the Shannon Flood Problem (February 2003) Final Report
All/ General Verification	pdf	A-0010	Flood Risk Management Opportunities: Pre-Feasibility Study (September 2004) Final Report
All/ General Verification	pdf	A-0011	River Shannon Flood Problem: Report on First Stage of Investigations (1961)
All/ General Verification	Ppf	A-0027	Existing models for the River Shannon study area particularly those used in design of existing defences (as listed in Tables 4, 6 and 7 of the Stage II Brief), including models themselves and associated reports.
All/ General Verification	FRR site visit	A-0070	Castlerea (CAR 19) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 12/05/2011
All/ General Verification	FRR site visit	A-0066	Athleague (AFRR 6) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 11/05/2011
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment (with event number)**
Category 1	Large gauged river within an AFA (HPW)	1(2) 2(1)	1(2) 2(1)	1(1) 2(1)	1(2) 2(1)	1(3) 2(1)	1(10) 2(5)	**1- Various data sources for 2009 event.** **2- Limited information on date or location.**
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table B.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 - FSU Gauging station classification (from Hydro-Logic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N09**	Length	193 km
Unit of Management		26	
AFA	Ballinasloe, Ahascragh		
IRRs	none		
River / Catchment / Sub-catchment	River Suck, Tributaries Bunowen-Ahascragh, Deerpark , Ballyhugh and Mackney / Suck / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model extent N09 is comprised of the River Suck and its tributaries that flow through Ahascragh and Ballinasloe AFAs. GS26007 together with the GS26005 (approximately 640 m u/s of the model extent) are to be used for calibration of the main River Suck. There are no suitable data for calibration of the tributary Bunowen running through Ahascaragh. Additional works (relief culverts and flood walls) have been constructed after the 2009 event. (Ref. Asset management surveys). Calibration or verification is not possible at the AFAs. Bellagill gauging station (26007) has an A1 flood flow rating classification and flow measurements were carried out by the OPW during the November 2009 event, (Cawley and Cunnane, 2010). The very high first and second day rainfalls on the 17th and 19th November were the catalyst for consecutive events of flooding at Ballinasloe, (Cawley and Cunnane, 2010).		
Completed by	Kieran Daly	Yiwen Zhao	
Date	08/05/2013	07/11/2013	

Potential flood events to consider for calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	21/ 11/ 2009 – Out of bank (extensively in Ballinasloe and all along the main river)	1	3+3+0+3+3 = 12	Calibration / Verification
2	26/12/1999 – Out of bank (local houses in Derrymullan and Ballinasloe)	1	3+3+0+3+0 = 9	Calibration / Verification
3	16/06/1993 – In bank	N/A	N/A	Calibration / Verification
4	25/11/1982 – In bank	N/A	N/A	Calibration / Verification
5	17/ 02/ 1995 – Out of bank (local houses in Derrymullan and & roads from Derrymullan and Killure to Ahascragh)	1	3+3+0+1+0 = 7	Data missing at 06005 and triple peaks at 26007; not suitable for calibration or verification

6	01/01/2005 – Out of bank (local houses in Derrymullan and Ballinasloe & R358)	1	3+3+0+3+0 = 9	Data missing at GS26007; not suitable for calibration / verification
7	08-21/12 / 1954 – Out of bank (extensively in Ballinasloe)	1	3+3+0+0+0 = 6	Data missing at GS26007; not suitable for calibration / verification

* See Appendix B for Event Details of events 1-4, ** See Appendix C for Quality Category and Quality Score
(Scoring - 0 (Not suitable for calibration) to 15(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
26007 - Bellagill	1952 to Date	Level and Flow	37.409	A1	Jacobs rating still to be undertaken
26003 - Ballinruane	1954 to 1989	1972-1978 Level and Flow	unknown	Not FSU Classified	Large amount of data missing
26140 – Ahascragh Pump House	1989 to Date	Level only	unknown	Not FSU Classified	
26005 - DERRYCAHILL	1954 to Date	Level and Flow	39.886	A2	Jacobs rating showed a good agreement with OPW rating

* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor))

Control structures

Reference	Type	Description

Conclusions from Phase 1

Phase 1 suggested:

- Station 26005 is 10.5km u/s of the Station 26007. Jacobs rating review showed good agreement with OPW rating. Data at Station 26005 is suitable for calibration of the upper reach.
- Station 26007 located u/s of Ballinasloe, classified as A1, is suitable for calibration.
- Other stations listed in the above table do not have sufficient data for calibration.
- Flood event 01/01/2005 was used for Ballinasloe Flood Relief Study, yet levels and flows are missing; data is not available for this study.
- Data from Station 26302, 26032 and 26003 were requested. Flow measurements at 26302 and 26032 were received, which are not suitable for calibration. Data from 26003 is still pending and not available for this study.

Phase 2

Calibration Reach (GS26005 to GS26007)					
Type	Out of Bank Calibration	Out of Bank Calibration / Verification	In Bank Calibration	In Bank Calibration	
Flood Event	1 (21/ 11/ 2009)	2 (26/12/1999)	3 (16/06/1993)	4 (25/11/1982)	
GS Number	26005	26005	26005	26005	
Station Name	DERRYCAHILL	DERRYCAHILL	DERRYCAHILL	DERRYCAHILL	
Approximate Start of peak level	19/11/2009 17:00:00	23/12/1999 11:45:00	13/06/1993 02:00:00	04/12/1982 21:30:00	
Approximate Finish of peak level	25/11/2009 03:15:00	31/12/1999 00:00:00	21/06/1993 03:45:00	06/12/1973 15:30:00	
Peak level*** (mAOD Malin)	43.16 (3.274m)	42.511 (2.625m)	42.276 (2.39)	42.197 (2.311)	
Peak flow*** (m^3/sec)	179.49	108.659	88.261	94.128	
Other gauging stations for same event	26007	26007	26007	26007	

*Calibration events may include more than one gauging station but the table above indicates the details for the most upstream gauging station which will provide the level and flow data for the calibration/verification.
**Stage plus datum (see Phase 1) from topographical survey (Stage in brackets).
***There are minor data discrepancies between AMAX series and 15min data. Peaks based on 15min event data are given in the above table.

Discussion and Strategy

Discussion

- Due to the data availability and the locations where constructions (relief culverts and flood walls) were taken after 2009 events, calibration can only be achieved for the main River Suck between Station 26005 and 26007 within the model extent N09.

  The model extent used for this calibration should extend sufficiently far downstream of Station 26007 in order to avoid the influence of backwater effects at the downstream model boundary to the water levels at the gauging station.

- Major inflows between stations are to be included. Ungauged tributary peak flows were estimated for all gauged stations and HEP locations. An event 'growth factor' (gauged event peak flow/QMED) was determined at Station 26005 and used to scale the design 2-year inflows at intermediate HEPs to obtain event inflows for the laterally contributing catchments.

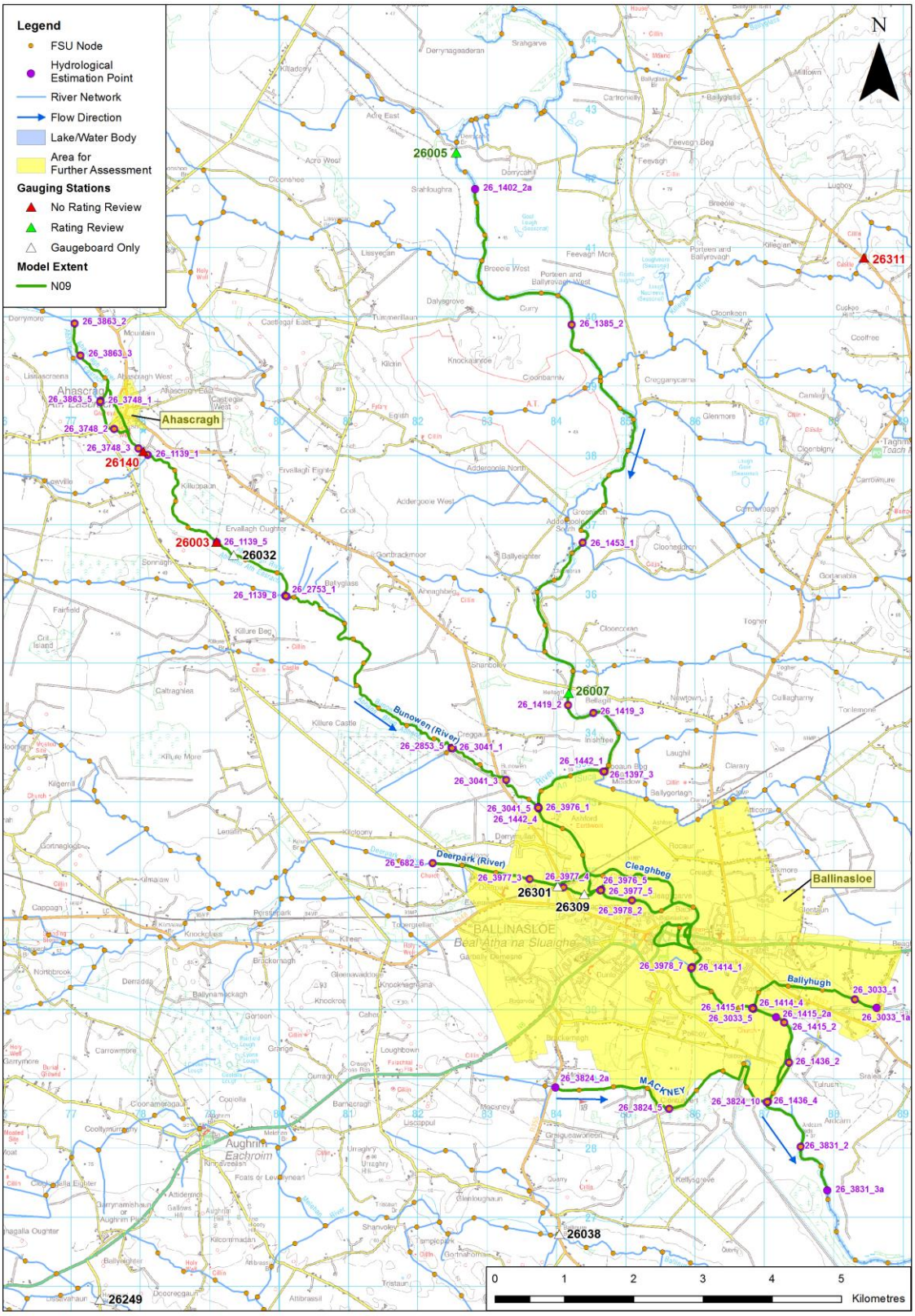
Calibration/Verification Strategy

GS 26005 flows are to be used as top inflows of the River Suck (@ HEP 26_1402_2a), additional inflows to be added to two HEP locations in order to account for tributary inflows upstream of the GS 26007, and model outputs of levels at GS 26007 are to be checked with the observed levels of GS 26007.

Post-Design Event Modelling Verification:

- Historical data of flood extent is available for Event 1 (2009), which will be used for model verification. (Shapefile: *sertit_safer_ercs022_ireland_waterbodies_spot4_20091130.shp*)

Appendix A - Plan of model N09



Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
1	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December *Coverage: ☒ * No Coverage: ☐
	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☐ **No Coverage: ☒
7/ General	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☒ *No Coverage: ☐ *Covering d/s of the AFA Ballinasloe*
1/ General	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☒ *No Coverage: ☐
1/ General	Report	B-0063	05-0a Staff gauge readings from 1988 to 2009 at Ahascragh pump house. Flooding of commercial property in Ahascragh.
1	Photograph	B-0049	Aerial photographs of Ahascragh village giving time/ date and easily assessable location. *Not available*
1	Map	B-0063	08-1a to 08-1d Aerial map of flood extent from satellite imagery. Poor quality resolution.
1	Photographs	B-0052	Calibration / verification data relating to the November 2009 flooding in Ballinasloe – Includes ground level photographs and GIS layer indication location/date/time
1/ General	Report	B-0008	Ballinasloe Flood Relief Study aimed at identifying flood mitigation measures in the aftermath of the 2009 event.
1	Water levels	C-0182	Water levels for the River Suck, November 2009 flood event.
6/ General	Aerial Photographs	B-0063	08-4a to 08-4i 18 no. aerial photographs taken of flooding on river Suck. No exact date or time given. *Jan/2005 and areas are indicated in 08-4 (PDF)*
All/ General	Report	B-0024	Atkins ecology report for proposed river maintenance on Ahascragh River
2	Report	B-0063	08-3a ESBi report detailing the flood event of winter 1999/ 2000.
2	Newspaper	B-0049	Extract from newspaper showing height flood at ground level. No date and time given.
7	Newspaper articles	B-0063	08-3, 08-3b to 08- 3s “Hundreds flee from flooding” Details of areas flooded during event.
5	Report & Photograph	B-0049	Report of “houses and property flooded” in Ballinasloe. Poor quality ground level photograph.
All/ General	Meeting minutes	B-0063	05-1a

Verification			Meeting with area engineers on 27 areas that are prone to flooding.
All/ General Verification	FRR site visit	A-0111	Ballinasloe (CAR 8) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 26/05/2011
All/ General Verification	FRR site visit	A-0109	Ahascragh (AFRR 46) - Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 26/05/2011
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment (with event number)**
Category 1	Large gauged river within an AFA (HPW)	**1(3) 6(3) 2(3) 7(3) 5(3)**	**1(3) 6(3) 2(3) 7(3) 5(3)**	**1(0) 6(0) 2(0) 7(0) 5(0)**	**1(3) 6(3) 2(3) 7(0) 5(1)**	**1(3) 6(0) 2(0) 7(0) 5(0)**	**1(12) 6(9) 2(9) 7(6) 5(7)**	**1- Adequate information on the flood event. 6- No specific levels given for event. 3- No specific levels given for event. 4- No specific levels given for event. 5- No specific levels given for event. Due to data availability and the constructions taken after 2009, model reaches of HPW cannot be calibrated. The model reach of MPW may be calibrated between station 26005 and 26007**
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table B.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 - FSU Gauging station classification (from Hydro-Logic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N11**	Length	76km
Unit of Management		25/26	
AFA	Roscrea/ Birr		
IRRs	none		
River / Catchment / Sub-catchment	Little Brosna river/ Shannon/ Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model extent N11 is comprised of the River Little Brosna and its tributaries, namely; River Bunnow (and its tributaries – Cornville & Scart); River Srahanbregagh; and River Camcor (and its tributary Clonghil). The River Bunnow flows through AFA Roscrea whereas Rivers Camcor and Srahanbregagh flow through Birr AFA.		
Completed by	Kieran Daly	Yiwen Zhao	
Date	08/ 05/2013	10/10/2013	

Potential flood events to consider for calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	28/01/1995 – Flooding at Kennedy's Cross	1	2+2+0+2+0=6	design event verification
2	29/01/1990 – Flooding at Cappaneale	1	0+1+0+0+0=1	design event verification
3	1995, 2005 – recurring flooding at Caravan Park	1	0+0+0+0+0=0	design event verification
4	02-04/ 08/ 1997- Unknown location	1	0+0+0+0+0=0	Not suitable for verification
5	23/11/2009 – Flooding at Croghan Bridge, area close to Clonfree, Castletown, Tinnakilly etc	1	2+2+0+0+0=4	design event verification

* See Appendix B for Event Details of events 1-4, ** See Appendix C for Quality Category and Quality Score
Scoring - 0 (Not suitable for calibration) to 15 (Suitable for calibration)

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
25021 Croghan	1961 to Date	Level and Flow	39.08	A2	OPW rating retained; flows above QMED are uncertain
25022 Syngefield	1953 to Date	Level and	55.56	B	Jacobs Rating

		Flow			review completed up to 2.4xQMED; revised AMAX post-1975.
25023 Milltown	1972 to Date	Level and Flow	NA	A1	No Jacobs rating review
25024 Newbridge	1953 to Date	Level and Flow	32.05	Not FSU Classified	Jacobs rating review to be produced once the model completed
25040 Roscrea	1980 to Date	Level and Flow	87.097	A2	No Jacobs rating review. Existing AMAX series used for design hydrology

* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor)

Control structures

Reference	Type	Description
N/A		To be completed by modeller

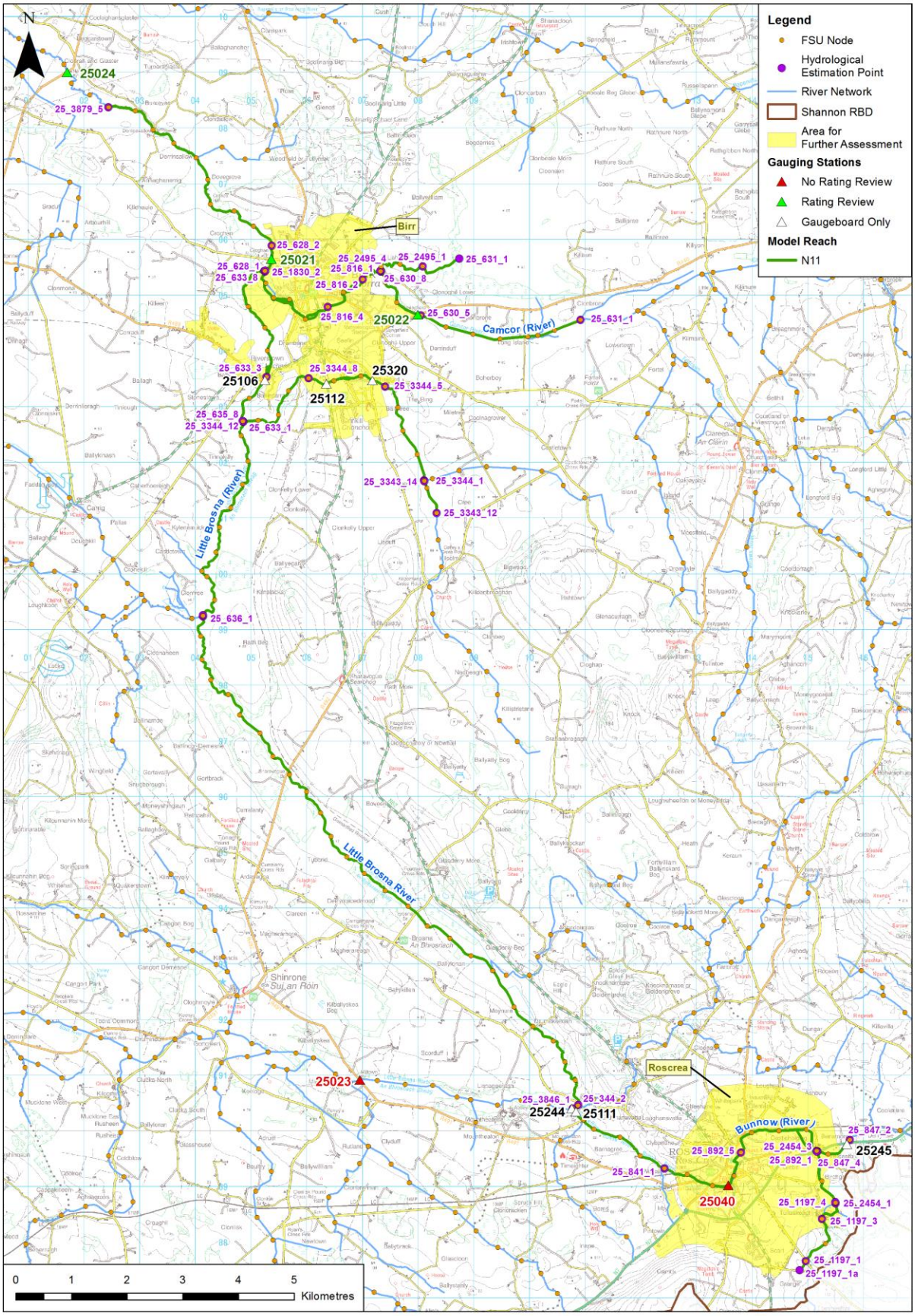
Conclusions from Phase 1

Phase 1 suggested:

- Stations 25021 and 25023 have 15min level and flow data available for all the flood events identified. The distance between the two stations is more than 20 km.
- Calibration using gauged data at two or more gauging stations alone (e.g. for in-bank calibration) is not considered feasible as the available
- Station 25022 has 15min level and flow data available for all the flood events except Nov 2009 event. However, there are no historical flood level observations in the vicinity of this station.
- Station 25024 is just downstream of the N11 domain, in Model N10. It only has 15min level data from 1980 and later available. There is no rating for this station, and the CFRAM rating review highlighted that no recent high flow gaugings were available to validate any new rating. The latest high flow gaugings are from the 1950s and show a poor fit with the CFRAM modelled rating (with realistic model parameters), making any stage-discharge rating at this station too uncertain to be of use.
- Station 25040 only has post-2005 15min level data available for this study. No historic flood level observations are available near the station to enable model calibration.

Phase 2
Gauging Station Information Used – Out of Bank* - Calibration is not possible
Gauging Station Information Used – In Bank*- Calibration is not possible
Calibration is not possible for both scenarios. See details in Discussion
Discussion and Strategy
Discussion For calibration of a hydraulic model, inflow hydrograph for a gauging station within the modelling extent and concurrent flood levels at downstream locations (from historic flood or D/S gauging station) is necessary. However, this is not the case for Model N11, and hence, calibration is not possible for this model due to the followings: 1) Although GS 25040 has FSU rating A2, there are no recorded historic flood levels or extents in or around Roscrea to enable calibration of the Bunnow with event hydrographs at this station. 2) Distance between GS 25040/25023 and GS 25021 (upstream and downstream of a potential Little Brosna calibration reach) is greater than 20 km, too far for reliable calibration as sweeping assumptions would have to be made about the lateral inflows between the two locations. Many of the intervening tributaries between the upstream and downstream gauges are ungauged. 3) Although GS 25022 has good data to inform event hydrographs, there are no recorded historic flood levels or extents on the Camcor at Birr/Syngefield to enable calibration or verification of the model. Design event verification may be undertaken as photos of historical floods are available. However, return periods of those flood events are unknown. Calibration/Verification Strategy • N/A Design Event Verification: • Use of recurrence flooding at the Little Brosna near Shinrone (Little Brosna) can be used for a broad verification of the model, by ascertaining that there are overland flows/local flooding at the 50% AEP (QMED) event.

Appendix A - Plan of model N11



Appendix B – Details Flood Event Records			
Flood Event	Material type	Data location	Contains
All / General verification	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☒ * No Coverage: ☐
All / General verification	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☒ **No Coverage: ☐
	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No Coverage: ☒
1	Engineers Report	B-0063	11-1a 400mm @ N52 & >670mm @ N62 (end of Jan). Additional 70mm following interim rainfall.
1	Newspaper article	B-0063	11-3i Severe flooding in Offaly with losses of livestock & fodder. Flooding on people's land & premises @ Ballindown & Ballywilliam, Birr. Kennedy's Cross - flooding caused serious traffic hazard. Car impassable. Phil McIntyre's house has escaped from flooding.
1	Newspaper Article	B-0063	11-3g “Offaly CC seeks funding for Flooding problems”
1	Newspaper Article	B-0063	11-3h Reported 2 houses in Ballindown, Birr and Kennedy's Cross flooded. Kennedy's Cross - one of the Midlands biggest flooding blackspots. Road has been raised 20" but road to Cloghan is still closed off in the flood. Bushes and signs @ each side of Kennedy's Cross are almost submerged. Estimated 25 acres in the area are covered in water.
1	Newspaper Article	B-0063	11-3i £2million compensation available for flood victims. No specific date/ level provided. "Flooding has never been as bad as this year". Laneway which provides access for 6 houses has 4ft of water in one section & 3ft in another. Townlands mentioned (Ballindown, Ballywilliam, Kennedy's Cross)
1	Letter & Map	B-0063	11-1b N52 Birr/Tullamore Rd nr Goods Caravan Park was flooded Registered letter to landowners requiring action to clear land drains which was a catalyst for the recent flooding.

2	Summary sheet	B-0063	11-3 29mm in 12 hours, Borrisokane Rd outside Ardcroney to Ballycommon reports of Bridge damaged. “Worst flooding in 45 yrs” in Kilcormac.
4	Newspaper article	B-0063	11-3l Describes flood event as bringing hardship to the region.
5	Newspaper article	B-0063	11-3d Newspaper describing 2” of rain in Birr Location: Birr/Roscrea Rd, Kennedy’s Cross (junction between N52 & N62 north of Birr)
All	Meeting minutes	B-0063	11-3a Areas that experience repeat flooding (low lying area of road was flooded due to run-off from agricultural land). Generic information with no specific flood levels or extents provided.
All/ General Verification	FRR site visit	A-0133	Birr (CAR11) Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 01/06/2011
All/ General Verification	FRR site visit	A-0141	Roscrea (CAR52) Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 02/06/2011
All/ General Verification	Rainfall data	D-0055	Daily rainfall for catchment 9,11,19 and 29 Hourly rainfall for Birr.

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment**
Category 1	Large gauged river within an AFA (HPW)	**1(2) 2(0) 3(0) 4(0) 5(2)**	**1(2) 2(1) 3(0) 4(0) 5(2)**	**1(0) 2(0) 3(0) 4(0) 5(0)**	**1(2) 2(0) 3(0) 4(0) 5(0)**	**1(0) 2(0) 3(0) 4(0) 5(0)**	**1(6) 2(1) 3(0) 4(0) 5(4)**	Verification only
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table B.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 - FSU Gauging station classification (from Hydro-Logic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N13**	Length	17km
Unit of Management		25/26	
AFA	Borrisokane		
IRRs	None		
River / Catchment / Sub-catchment	River Ballyfinboy / Lower River Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Tidal ☐		
Comments	There is one level and flow gauge within the model extent and two gaugeboards. The model extent flows into Lough Derg.		
Completed by	Kieran Daly	Alice Wiggins	
Date	05/04/13	20/06/2013	

Potential Flood Events to consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	05/12/2009 – Very Limited Coverage	2	0+0+0+0+1=1	Verification

The flood event data above and in Appendix B are taken from www.floodmaps.ie.database.

*Appendix B for Event Details of Event 1, **Appendix C for Quality Category and Quality Score (Scoring - 0 (Not Suitable for Calibration) to 8(Suitable for Calibration))

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
25025 – Ballyhooney	01/10/1957 - Present	Level and Flow	Not found from survey data	A1- (2 records, both A1)	OPW website indicated high and low ratings where truncated, concerns over stability, uncertain of accuracy of some gaugings

* See Appendix D for Key to FSU Station Classification (A1 (Good) to C (Poor))

Control Structures

Reference	Type	Description
None	None	None

Conclusions from Phase 1

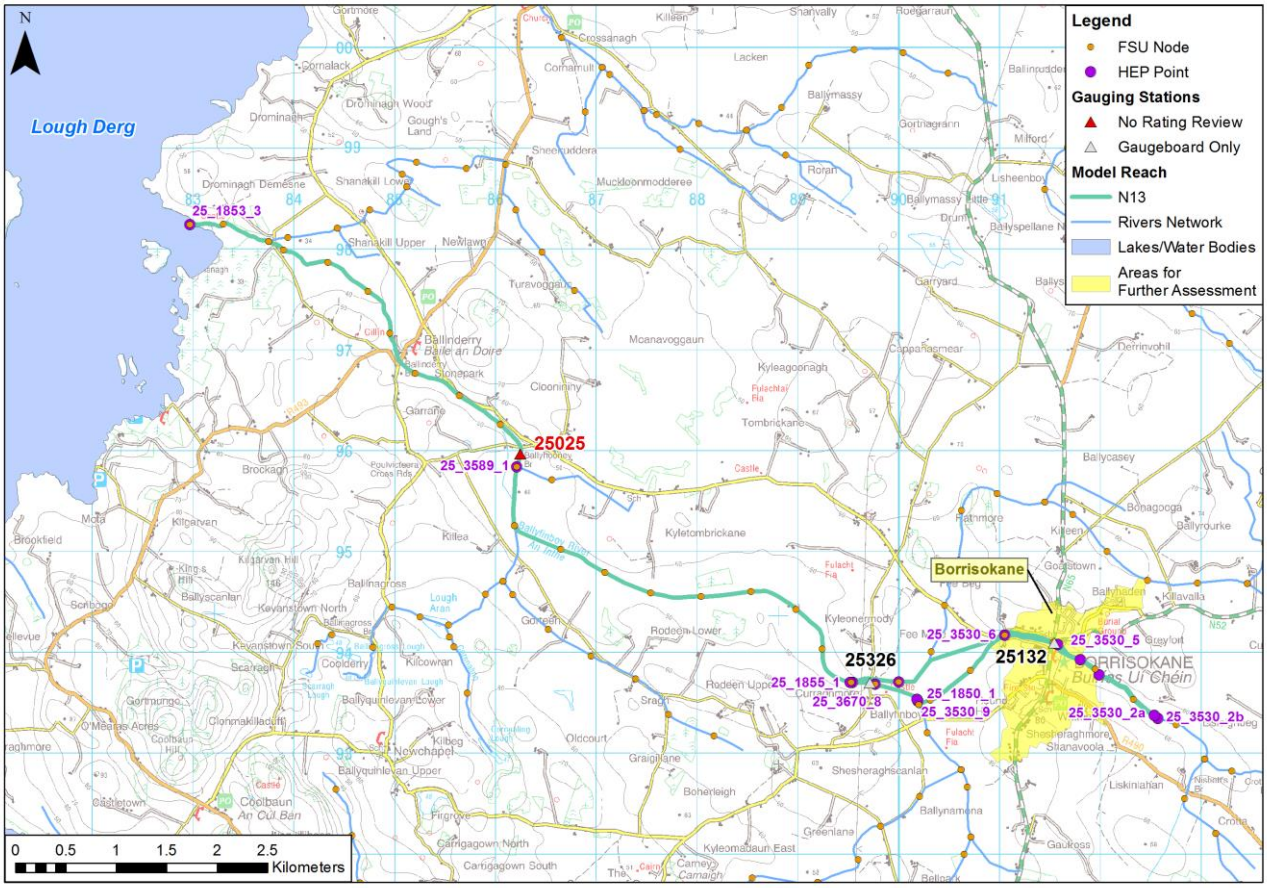
Phase 1 Suggested:

- Observation data for flood event 1, which is the 2009 flood outline from the SERTIT source (See Appendix B), is the only flood event data within this model extent and only covers a very small part

of the catchment upstream of the gauging station in a rural setting. This event may be used for verification. • There is only one gauging station with a recorder within the model extent or catchment. • Station 25025 has not had a rating review completed by Jacobs. OPW notes in their AMAX series for 25025 that the rating has been truncated just above QMED (truncated above flows of 11.5 m^3/s which is 1.1XQMED) and high flows should be used with caution. • The model extent flows into Lough Derg.

Phase 2 – Gauging station event table omitted as no sufficient observation or gauged flood event data in Model Extent N13
Discussion and Strategy
Discussion: • Flood event 1 cannot be used for calibration as it has very limited coverage of the model extent • Station 25025 is significantly downstream of the Borrisokane AFA. Station 25025 has a reliable rating up to QMED, but has been truncated at 1.1XQMED so is not reliable for high flows. This contradicts the FSU classification of station 25025, which is A1. • There is insufficient gauging station data to carry out reliable calibration. • Verification may be possible using the Flood Event 1 data. Calibration Strategy: • No calibration can be undertaken. Post-Design Event Modelling Verification Strategy: • The modelled flood outlines will be compared to the SERTIT 2009 event data at the known flood locations, to verify that the model results seem consistent with the observed data and the estimated return period of the 2009 event, which is predicted to have around a 50 year return period based on single site analysis for station 25025 using an EV1 distribution.

Appendix A – Plan of Model N13 (Draft)



Appendix B – Details Flood Event Records			
Flood Event	Material type	Data location	Contains
1	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 (limited coverage). **Coverage: ☒ *No coverage: ☐
	GIS layer	B-0020	Digitisation of 1954 flood event. **Coverage: ☐ *No coverage: ☒
	GIS layer	B-0054	Jacobs digitisation of 2009 flood event. **Coverage: ☐ *No coverage: ☒
	GIS layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☐ *No coverage: ☒
All/ General Verification	Meeting minutes	B-0049	Reference to a road that repeatedly floods outside Borrisokane, but no level or specific dates given.
All/ General Verification	FRR notes	A-0131	Borrisokane (CAR12) Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 31/05/2011 (no flood event data)

*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question.

**The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment**
Category 1	**Large gauged river within an AFA (HPW)**	0	0	0	0	**1**	**1**	Insufficient data for calibration or verification
	Small gauged river within an AFA (HPW)							
Category 3	**Large ungauged river within an AFA (HPW)**							
	Small ungauged river within an AFA (HPW)							
Category 2	**Gauged MPW**	**1 (0)**	**1 (0)**	**1(0)**	**1(0)**	**1(1)**	**1 (1)**	**1 – The 2009 event has very limited coverage along the model extent and is located upstream of the gauge in a rural setting.**
Category 4	**Ungauged MPW**							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2).

Appendix D – FSU Classification (Abstract from Inception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table D.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events.
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1: FSU Gauging Station Classification (from Hydro-Logic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N14**	Length	26 km
Unit of Management		25/26	
AFAs	Nenagh		
IRRs	None		
River / Sub-catchment / Catchment	River Nenagh / Nenagh / Lower Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	The River Nenagh is found within UoM 25/26 and flows through Nenagh AFA into Lough Derg. The catchment area of the River Nenagh as it enters Lough Derg is approximately 320 km^2. The most significant tributary of the Nenagh is the River Ollatrim (120 km^2). Other tributaries to the River Nenagh include the Benedin tributary (3.5 km^2) and Moyroe Stream (8.7 km^2).		
Completed by	Kieran Daly	James Cullinane	
Date	08/05/13	15/05/14	

Potential flood events to consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification (to be updated by modelling team)
1	13-16/01/1984 – Flooding of an industrial estate located on the right bank of the River Nenagh. Observed peak flood flows at Clarianna and Gourdeen gauging stations with approximated flood flows at Bennetts Bridge based on water levels at a temporary staff gauge.	1	3+3+0+2+2 =10	Verification
2	06/02/1990 – Level survey data taken at IDA industrial estate in Nenagh. Crude flood extents sketched on an OSi map provided also.	1	3+3+0+2+2 =10	Verification
3	11/1968 - 01/1969 – OPW Hydrometric Report which very broadly reviews flooding at catchments nationwide, including Nenagh. No specific event dates, water levels or discharge rates provided.	1	3+3+0+0+0 =6	Not suitable for calibration/verification
4	12/1994 - 01/1995 – Report from Regional Hydrometric Technicians with brief details of locations commonly subject to flooding in Nenagh. No specific water levels or flood extents provided.	1	3+3+0+0+0 =6	Not suitable for calibration/verification
5	05/12/2009 – SERTIT mapped water bodies available for the Nenagh catchment. No specific water levels or	2	3+3+0+0+0 =6	Not suitable for calibration/verification

	discharge rates.			
6	Gauge Data Only – In-bank events	1	To be identified in Phase 2	Calibration/Verification
7	Gauge Data Only – Out of bank events	1	To be identified in Phase 2	Calibration/Verification

The flood event data above and in Appendix B are taken from www.floodmaps.ie database.

*See Appendix B for Event Details of events 1-5, **See Appendix C for Quality Category and Quality Score Scoring - 0 (Not suitable for calibration) to 15 (Suitable for calibration)

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
25027 - Gourdeen	22/02/1967 - present	Level and Flow	50.47	A1	Jacobs rating review completed up to 3xQMED. Jacobs rating verified up to QMED (post Drainage Works – 1965 onwards). Only one check gauging within the range of QMED, and none higher.
25028 - Annabeg	01/11/1950 - 01/08/1955	Not available	31.09	Not FSU Classified	GS 25028 was only active for less than 5 years in the 1950. There are no records for that period for the other gauging stations.
25029 - Clarianna	19/01/1973 - present	Level and Flow	41.92	A2	Jacobs rating review completed up to 3xQMED. Rating verified with check gauging's up to 1.1xQMED. High flow gauging's have not been recorded since 1968, recommended that further high flows gauging's undertaken.
25038 - Tyone	14/03/1989 - present	Level and Flow	50.65	Not FSU Classified	No Jacobs rating review undertaken. EPA gauging station, rating verified up to 1.1xQMED.

* See Appendix D for Key to FSU Station Classification (A1 (Good) to C (Poor))

Control structures – To be Completed by the Modellers

Reference	Type	Description
Weirs	Weir	Weirs located at ISIS cross-section 25NENA00474
Sluice Gates	Sluice gate	Sluices located at ISIS cross-section 25NENA00474

Conclusions from Phase 1

Phase 1 suggested:

- Event 1 (Jan 1984) observational data is an OPW report entitled "Flooding of industrial estate at Lisbunny, Nenagh on 13th and 16th January 1984". It mentions how the industrial estate in the townland of Lisbunny, just d/s of Bennetts Bridge was flooded on 2 separate occasions, 13th and 16th January 1984. According to this report peak flows of 27.3 m^3/s and 57.3 m^3/s were recorded at 25027 (Gourdeen) and 25029 (Clarianna) gauging stations respectively. Based on single site analysis of the annual maximum flow records to the present day this corresponds to between a 10 year and 20 year

return period (RP) event at station 25027 and a just greater than a 2 year RP event at station 25029. Maximum water levels of 2.43 m and 2.49 m were also recorded for this event at a temporary staff gauge near Bennetts Bridge. A stage-discharge curve was derived from 5 flow measurements at this site and so the corresponding flows for the aforementioned water levels are 27 m^3/s and 28 m^3/s respectively according to this stage-discharge relationship. Flood frequency analysis in this report states that these flow estimates at Bennetts Bridge have a return period of just less than 10 years. The temporary gauge datum is unknown. There are no further observations that could be used for calibration or verification of the model.

- Event 2 (Feb 1990) observational data is a level survey book and an OSi map with a (crude) flood outline, apparently based on these levels. The level recordings were taken on 09/02/1990, 3 days after the peak of this event. The descriptions of the locations where the levels (apparently in feet) were recorded are not specific, and no datum is specified.

- Event 3 observational data is an OPW Hydrometric Report dated from 7th February 1969. It does not contain specific water level or flow data. It broadly describes flooding that occurred between November 1968 and December 1969 in various catchments nationwide including the Nenagh catchment. The information is non-specific in location and time, and therefore not suitable for calibration or verification of the model.

- Event 4 observational data is a brief report dated 07/02/1995, from regional hydrometric technicians, that mentions roads affected by flooding near Nenagh from the end of December 1994 to January 1995. It states there was much flooding of roads between Limerick and Nenagh, Nenagh and Newport, and Nenagh and Borrisokane. The report contains no specific water level or flow data nor specific dates. There is insufficient detail to use this data for calibration or verification.

- Event 5 observational data is RADARSAT-2 data containing mapped water bodies acquired on 5th December 2009 from SERTIT. Within the N14 model extent this dataset does not show significant flooding, but this is most likely to be a consequence of the lack of precision and resolution of the dataset. These data are not suitable for calibration or verification.

- There is some general information on flooding in the Nenagh area described in the minutes of a meeting dated from 07/02/2005. Participants included the Area Engineer and general services foremen from North Tipperary County Council and the ESBI Search Manager. These minutes can be found within folder B-0063 on the CITRIX server (03_B-Historical_Flood_Data\B-0063\ Floodmaps.ie\APSRs\HA2526\43 Nenagh\ 43-4a tpn_mm_bm_0000002631.pdf)**.** It briefly states that:

  (i) Regular flooding at Nenagh/Newport Road causes deep water under the N7 Bypass to the point that it is impassable.
  (ii) At Coolahologa (north of Nenagh) the stream floods the road to a depth of 0.50 m and access to 10 houses is impacted as a result.
  (iii) Ballygraigue Estate and Creamery has been flooded historically by the nearby stream (Clareen Stream) and some remedial works have been carried out.

- Gauging station 25038 has a reasonable accuracy for flows up to approximately QMED. Stations 25027 and 25029 can be used for floods in excess of QMED as they have been subject to hydraulic modelling as part of the CFRAM rating reviews.

- Gauging station 25028 has not been considered for calibration or verification given that it was only active from the period 01/11/1950 to 01/08/1955. The short period of recording is insufficient for use in calibration or verification.

Phase 2					
Gauging Station Information Used – Out of Bank					
Flood Event	03/11/2000		08/01/2005		
Run	7 - Calibration		7 - Verification		
Reach	Main Stem	Tributary	Main Stem	Tributary	
GS Number	25038	25027	25038	25027	
Station Name	Tyone	Gourdeen	Tyone	Gourdeen	
Recorded Start of peak level	01/11/2000 (23:00)	01/11/2000 (23:00)	06/01/2005 (21:45)	06/01/2005 (21:45)	
Recorded Finish of peak level	04/11/2000 (14:00)	04/11/2000 (14:00)	10/01/2005 (9:30)	10/01/2005 (9:30)	
Peak level *(mAOD Malin)	52.45 (1.86 m)	52.70 (2.23 m)	52.63 (2.04 m)	52.56 (2.09 m)	
Peak flow (m^3/sec)	33.26	28.62	37.33	26.53	
Other gauging station for same event	25029 (Clarianna)		25029 (Clarianna)		
Gauging Station Information Used – In Bank					
Flood Event	20/11/2009		31/01/2009		
Run	6 - Calibration		6 - Verification		
Reach	Main Stem	Tributary	Main Stem	Tributary	
GS Number	25038	25027	25038	25027	
Station Name	Tyone	Gourdeen	Tyone	Gourdeen	
Recorded Start of peak level	17/11/2009 (17:15)	17/11/2009 (17:15)	29/01/2009 (10:15)	29/01/2009 (10:15)	
Recorded Finish of peak level	21/11/2009 (12:00)	21/11/2009 (12:00)	03/02/2009 (04:00)	03/02/2009 (04:00)	
Peak level *(mAOD Malin)	52.86 (2.27 m)	50.47 (1.97 m)	52.63 (2.04 m)	52.74 (2.27 m)	
Peak flow (m^3/sec)	28.07	35.47	30.21	23.89	
Other gauging station for same event	25029 (Clarianna)		25029 (Clarianna)		
*Stage plus datum (see Phase 1) from topographical survey (Stage above local datum in brackets).					

Discussion and Strategy

Discussion:

- Three gauging stations can be used for calibration and verification of the N14 model. These gauging stations are 25038 (Tyone), 25029 (Clarianna) and 25027 (Gourdeen) with the first two stations located on the Nenagh River and the latter located on the Ollatrim River (tributary to the Nenagh River).
- Two out-of-bank and two in-bank events have been identified from the gauged data which covers both a portion of the Nenagh River and the Ollatrim River between gauging stations 25027, 25029 and 25038. For both the out-of-bank and in-bank event model runs, two events will be used for calibration and the other two for verification.
- Two of the most significant flood events (in terms of ranked annual maximum flows) to occur within the Nenagh catchment were the 16/01/1984 (Event 1) and 06/02/1990 (Event 2) flood events. Their use for calibration/verification is discussed below:
    - The OPW report on the 16/01/1984 event (detailed in Phase 1) contains an estimate of the peak flow on the Nenagh at Bennetts Bridge, just downstream of the Nenagh

River/Benedin tributary confluence. OPW estimated a flow for a peak flood level recorded at the bridge staff gauge during the 16/01/1984 event. This estimate cannot be used for calibration/verification as there is too much uncertainty in the rating applied and there was no specific time or hydrograph shape associated with the flood wave from the Nenagh. Therefore, a hydrograph shape could not be suitably timed in relation to the hydrograph from the Ollatrim. There are recorded water levels at a temporary staff gauge at the bridge, but there is no gauge datum for this gauge. This information can therefore not be used for calibration/verification.

  - The 06/02/1990 observational data (detailed in Phase 1) was dismissed for calibration due to a lack of accuracy and absence of flow data, and the observations are not suitable for broad-brush verification because (1) they are not clear on the precise locations and (2) the datum for the levels is not quoted.

- Calibration and/or verification is not feasible along the Nenagh River immediately downstream of gauging station 25029 to where it discharges into Lough Derg as there is no gauged or observational data downstream of 25029.
- Calibration is not possible for the two minor tributaries to the Nenagh River, the Moyroe Stream and the Benedin tributary as these are ungauged watercourses. Some broad-brush verification may be possible with the general information referred to in bullet point six of Phase 1. This information is not linked to specific flood events.
- Inspection of the SERTIT mapped waterbody data for the Nenagh catchment shows there is no useable flood data related to the November 2009 event within the N14 model domain for calibration/verification.

Calibration/Verification Strategy:

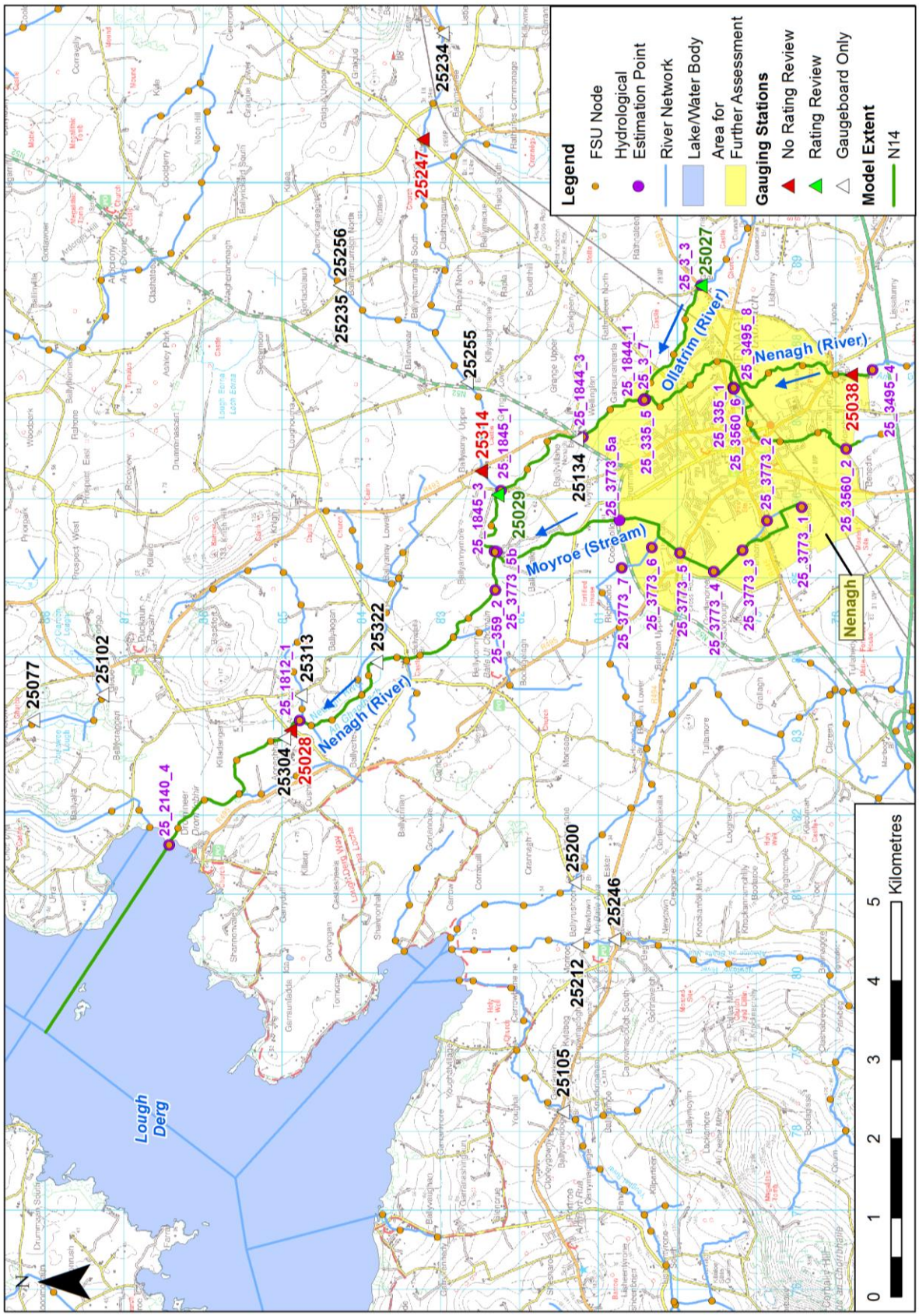
- Out-of-bank and in-bank calibration and verification is to be undertaken along the Nenagh River and Ollatrim River reaches between gauging stations 25027, 25029 and 25038. This will be done by inputting the gauged flows at gauging stations 25038 and 25027 and then comparing the resulting modelled flows and water levels downstream at gauging station 25029 with gauged flows and water levels. This is to be completed for 4 events:

  - 03/11/2000 (Out-of-bank) - Calibration
  - 08/01/2005 (Out-of-bank) - Verification
  - 20/11/2009 (In-bank) - Calibration
  - 31/01/2009 (In-bank) – Verification

Post-Design Event Modelling Verification:

- Broad-brush verification can be attempted with the general flood information produced in Dec 2005 in the 6th bullet point as shown in Phase 1 above. This is not flood event specific information and only identifies three areas around Nenagh that have been subject to flooding in the past with unknown frequency.

Appendix A – Plan of model N14



Appendix B – Details Flood Event Records			
Flood Event	Material type	Data location	Contains
5/ General Verification	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☒ * No Coverage: ☐
	GIS Layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☐ **No Coverage: ☒
	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☐ *No Coverage: ☒
1	Report	B-0063	43-1, 43-1a An Industrial Estate (on the right bank of the Nenagh River in Lisbunny Townland just d/s of Bennett's Bridge on the Dublin-Limerick Road) near Nenagh was flooded. Peak level (TBC): 13/01 - 2.43 m, 16/01 2.49 m (both at Bennett's Bridge gauge) Flow (TBC): 27.3 m^3/s (Gourdeen); 57.3 m^3/s (Clarianna); estimated 26.8 m^3/s on 13/01 & 27.6 m^3/s on 16/01 @ Bennett's Bridge)* various estimates.
2	Map & Survey levels	B-0063	43-2a Map with copy of level survey book. Level data based on flood debris marks and includes top of embankment and top of concrete levels. Industrial Estate, Nenagh Co Tipperary Feb 1990. Flood levels are taken from Bennetts Bridge. Flooding in same location as for event 1
3	Engineers minute	B-0063	43-3, 43-3a A considerable area of land was under water for about 24 hours. Flooding also at Ballyartella where a road and a mill were flooded. At Islandbawn, The Neagh-Dublin Rd, a dwelling and a shop were flooded. Some flooding in the embankment section where the pump capacity was exceeded by the inflow. Flow (TBC) 3000 cfs (Clarianna Bridge - design flow = 1800 cfs) Specific dates not available
4	Newspaper articles	B-0063	06-4b, 06-5b Much road flooding – roads between Limerick & Nenagh, Nenagh & Newport & Nenagh & Borrisokane.

			No specific details provided beyond articles
All	Meeting Minutes	B-0063	43-4 These minutes discuss various flood events with no detail for numerous areas around Nenagh – may not all apply to these rivers
All/ General Verification	FRR site report	B-0142	Nenagh (CAR43) Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 03/06/2011
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment**
Category 1	Large gauged river within an AFA (HPW)	1(3) 2(3) 3(3) 4(3)	1(3) 2(3) 3(3) 4(3)	1(0) 2(0) 3(0) 4(0)	1(2) 2(2) 3(0) 4(0)	1(2) 2(2) 3(0) 4(0)	1(10) 2(10) 3(6) 4(6)	
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW	5(3)	5(3)	5(0)	5(0)	5(0)	5(6)	
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely. Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (ref. Table).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table 3-i: FSU Gauging station classification (from hydrologic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N15**	Length	48 km
Unit of Management		25/26	
AFAs	Newport and Cappamore		
IRRs	None		
River / Sub-Catchment / Catchment	River Mulkear, River Newport, River Small, River Kileenagarriff, River Bilboa / Lower Shannon / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☒ Fluvial tidal ☐ Coastal ☐		
Comments	Model N15 comprises the River Mulkear and tributaries (Rivers Newport, Small, Kileenagarriff and Bilboa). There are two AFAs in the model, namely Newport and Cappamore. River Mulkear flows through the Cappamore AFA whilst the River Newport flows through the Newport AFA. There are 6 gauging stations within the model extent which measure level and/or flow. There is an existing flood relief scheme implemented at Cappamore and Newport. (Refer to the Environmental Impact Statement under All/ General Verification in Appendix B).		

Completed by	Kieran Daly	Agnes Adjei	
Date	07/05/2013	04/02/2014	

Potential Flood Events to Consider for Calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	22/12/1993 staff gauging records available, (data prior to flood relief scheme constructed since 1996)	1	1+2+0+1+1=5	Not suitable for calibration /verification
2	11-12/08/1946 (flooded properties fall outside model extent)	1	0+0+0+0+1=1	Not suitable for calibration /verification
3	08/1986 (flood levels and locations not specified)	1	0+0+0+1+0=1	Not suitable for calibration /verification
4	Winter 1994/1995 (Limited information of dates or location).	1	2+0+0+1+1=4	Not suitable for calibration /verification
5	Gauge data only – In bank	1	To be identified in phase 2	Possible calibration/verification
6	Gauge data only – Out-of bank	1	To be identified in phase 2	Possible calibration/verification

*Appendix B for Event Details, **Appendix C for Quality Category and Quality Score (Score 0 (Poor) to 15(Good))
See attached spreadsheet for time series data

Gauging Station Information within Model Extent (or close to)					
Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
25002 Barrington's Bridge	01/06/1953 to present	Level and Flow	Gauge datum not found	A2	No Jacobs' rating review, Existing rating verified up to 1.04xQMED $_{obs}$
25003 Abington	01/09/1954 to present	Level and Flow	34.44	A1	Jacobs rating review completed up to 3xQMED $_{obs}$
25004 New Bridge	01/09/1954 to present	Level and Flow	Gauge datum not found	Not FSU Classified	No Jacobs' rating review. Two distinct trends observed at 25004 when check gaugings are plotted against stage. This would indicate a datum shift at this site after 1999. Existing rating verified up to 1.4xQMED$_{obs}$
25005 Sunville	01/09/1954 to present	Level and Flow	Gauge datum not found	A2 (2 records both A2)	No Jacobs' rating review Check gauging has minimum scatter 0.82xQmed$_{obs}$
25158 Cappamore	13/08/1982 to 02/07/1999	Level and Flow	Gauge datum not found	Not FSU Classified	Gauging station is inactive
25308 Waterpark Bridge	14/10/1999 to present	Level and Flow	Gauge datum not found	Not FSU Classified	No Jacobs rating review Existing rating verified up to 0.91x QMED$_{obs}$
25309 Clonsingle Bridge	14/10/1999	Level only	Gauge datum not found	Not FSU Classified	Very few check gauging is available at high flows. The highest gauged flow is 19.4m3/s. No Amax series available.
*See Appendix D for Key to FSU Station Classification (A1 (Good) to C (Poor))					

Control structures		
Reference	Type	Description
Weirs on River Bilboa	Weir	Decanting weir upstream on the River Bilboa
Bridges on River Mulkear	Bridges	Three road bridges and an arch bridge with six openings downstream of Cappamore on the River Mulkear.
Weirs on River Mulkear	Weir	Round nose weir on the River Mulkear.
Weirs on River Newport	Weir	Non uniform weir on the River Newport.
Bridges on River Newport	Bridge	Three road bridges and an arch bridge on the River Newport.
Bridges on River Small	Bridge	Road bridge on the River Small.

Conclusions from Phase 1

Phase 1 suggested:

- Observational data available for events 1 to 4.
- Event 1 consists of photographs and staff gauge readings of flood levels upstream and downstream of the Bridge in Cappamore on the Bilboa River during the December 1993 event. This event is not suitable for verification or calibration as this event occurred prior to the construction of a flood relief channel after 1996.
- Event 2 observational data consists of an Engineer's report and a newspaper article. However, this event is outside of the model extent and therefore cannot be used for verification or calibration.
- Event 3 observational data consists of a report which mentions extensive flooding in the Mulkear catchment. Some of the worst hit areas are reported to include Cappamore and Newport. Damages include breaches in embankment in some areas and roads, houses and shops in Cappamore were badly affected. Flood levels and locations of the properties are not specified. A flood relief scheme was implemented at Newport and Cappamore after 1996. As this event occurred prior to 1996 it is therefore not suitable for calibration or verification.
- Event 4 observational data consists of a report briefly mentioning extensive land flooding in the Cappamore village and surrounding areas. The flooding is considered to be recurring, occurring in December 1994, January 1995 and February 1995. A specific location of flooding was not indicated. This event is not suitable for calibration or verification as a flood relief scheme was implemented after 1996.
- Station 25308 is located on the River Newport about 4km downstream of the Newport AFA. This gauging station has not had a rating review completed by Jacobs. The existing rating is verified up to 0.9xQMED and the quality of the data at this station is unknown.
- Station 25309 is located on the River Annagh, a tributary of the Newport River. This station has only level data and limited check gaugings. Jacobs have established a rating equation from the check gaugings to derive flow from the water level data, which is verified up to 19.4m^3/s.
- Station 25002 is located on the River Kileenagarriff. The site has not had a rating review completed by Jacobs but the existing OPW rating is verified up to Qmed.
- Stations 25003, 25004, 25004 and 25158 all have level and flow data, with 25003 having had a Jacobs rating review. However, it is unlikely that these stations can be used for calibration as they are scattered across the model extent and between stations there are large inflows, so reliable calibration is not possible.

Phase 2

Gauging Station Information Used – Out of Bank*

Run	Tributary (River Newport)				
Type	Calibration				
Flood Event	5a) 12/12/2008	5a) 12/12/2008	5a) 12/12/2008		
GS Number	25308	25002	25309		
Station Name	Waterpark Bridge	Barrington Bridge	Clonsingle Bridge		
Recorded Start of flood	12/12/2008 (09:30)	12/12/2008 (11:30)	11/12/2008 (15:45)		
Recorded Finish of flood	16/12/2008 (10:00)	16/12/2008 (04:15)	12/12/2008 (08:15)		
Peak level (mAOD Malin)	X (2.98m)	X (2.44m)	X (2.59m)		
Peak flow (m^3/sec)	68.9	70.2	34.5		

Gauging Station Information Used – In Bank*

Run	Tributary (River Newport)				
Type	Verification				
Flood Event	6a) 14/11/2003	6a) 14/11/2003	6a) 14/11/2003		
GS Number	25308	25002	25309		
Station Name	Waterpark Bridge	Barrington Bridge	Clonsingle Bridge		
Recorded Start of peak level	14/11/2003 (05:30)	14/11/2003 (06:00)	13/11/2003 (17:45)		
Recorded Finish of peak level	15/11/2013 (09:45)	17/11/2003 (07:00)	16/11/2003 (01:15)		
Peak level (mAOD Malin)	X (1.87m)	X (1.37m)	X (2.33m)		
Peak flow (m^3/sec)	35.7	52.0	29.1		

X – no data available

Discussion and Strategy

Discussion

- Events 1, 2, 3 and 4 cannot be used for calibration or verification.
- There is insufficient gauged data to carry out reliable calibrations along the River Mulkear.
- There are flood relief schemes that have been implemented on Rivers Bilboa and Newport. The scheme on the River Bilboa was implemented after November 1996 and the one on the River Newport was implemented after March 1997. Calibration data prior to the scheme cannot be used to calibrate the area benefiting from the scheme.
- Calibration and verification may be attempted on the River Newport from Newport AFA to Kileenagarriff, between gauging station 25308 and 25002. The gauged data will be used for in-bank and out-of-bank calibration.
- Two events have have been taken forward to calibration, which include one in-bank event (14/11/2003) and one out-of-bank event (12/12/2008). As there is a large tributary joining between the two gauging station (River Annagh), an inflow has been created at this point and flow from the upstream tributary gauging station is added (25309 Closingle Bridge). One event will be used for calibration and the other for verification.

Calibration/Verification

- Out-of-bank tributary calibration between stations 25308, 25002 will be completed using the

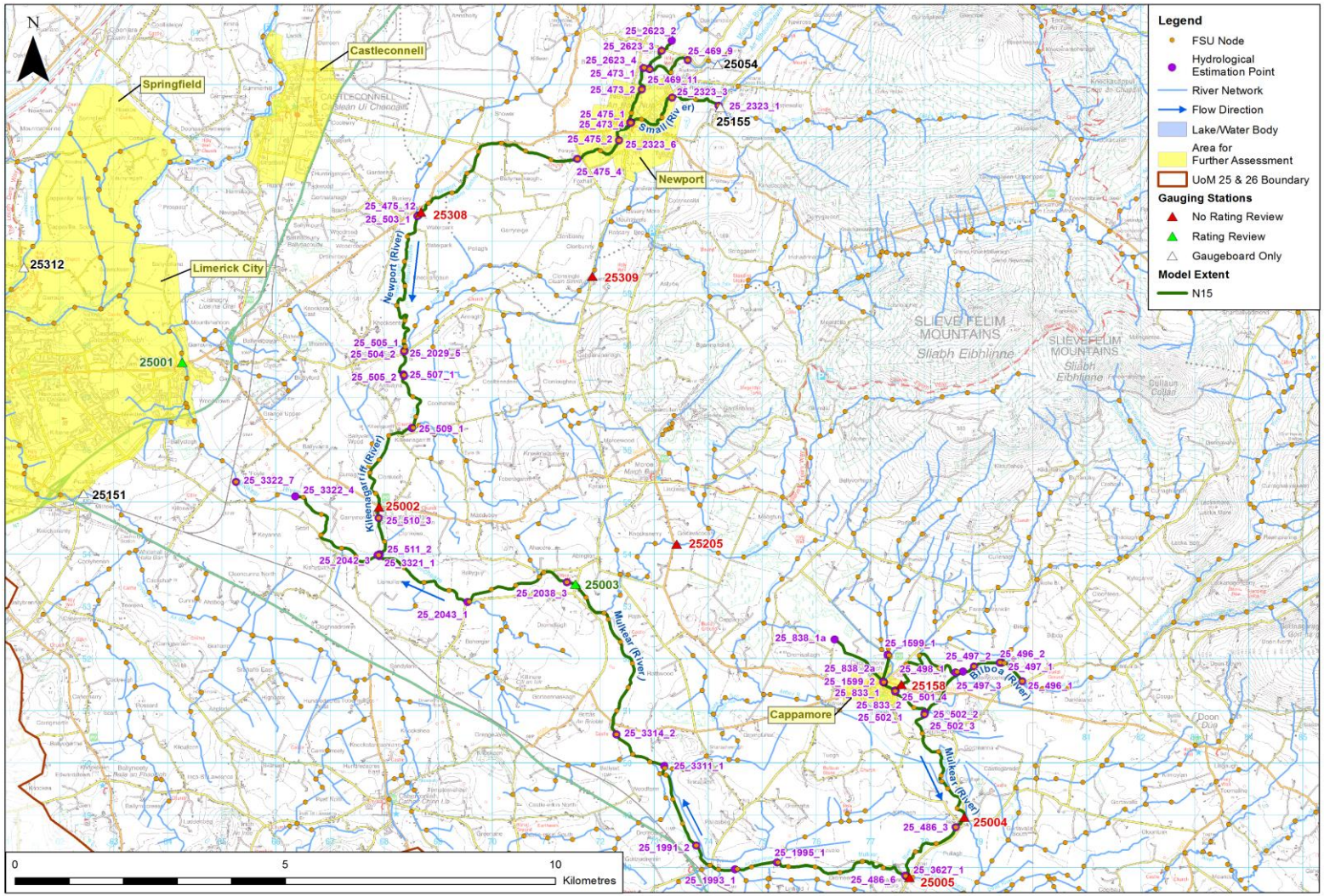
12/12/2008 event by inputting the recorded flows at GS25308 and GS25309 (to node 25_505_1), and comparing the modelled water levels with the downstream gauging station level at 25002.

- In-bank tributary verification between stations 25308, 25309 and 25002 will be completed using the 14/11/2003 event by inputting the recorded flows at GS25308 and GS25309 (to node 25_505_1), and comparing the modelled levels with the downstream gauging station level at 25002.

Post-Event Verification

- No suitable data

Appendix A – Plan of model N15



Appendix B – Details Flood Event Records			
Flood Event	Material type	Data location	Contains
	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 *Coverage: ☐ * No Coverage: ☒
All/ General Verification	GIS Layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☒ **No Coverage: ☐
	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☐ *No Coverage: ☒
	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☐ *No Coverage: ☒
1	Photograph	B-0063	15-2c 1.58m (staff gauge reading u/s of bridge).
1	Photograph	B-0063	15-2d 1.57m (staff gauge reading d/s of bridge)
2	Newspaper	B-0063	45-7q 16 to 17ft above normal level @ Port Ryan Bridge.
2	Report	B-0063	15-1a Embankment breached & 100 yards being washed out on left/ southern bank above Blackboy Bridge. 2 holdings in Dark Island badly damaged (by stripping topsoil to a depth of 1 to 2 ft) & 1 farmer's house was flooded.
3	Report	B-0063	15- 6d Overview of flooding on 5th/6th August 1986
3	Report	B-0063	15-7g Cappamore village was twice subjected to flooding. Houses, pub & shops flooded. One resident has 16 acres of land destroyed.
4	Report	B-0063	15-2a Q=50m^3/s @ Cappamore GS Cappamore Village & the surrounding areas were severely flooded on at least 3 occasions - 26-27 Dec 1994, 26-31 Jan 1995 & 22 Feb 1995.
All/ General Verification	Report	B-0063	15-2a Consultants Report. Environmental Impact Statement (EIS). Refers to flooding in the Mulkear catchment on the Bilboa and Glash Rivers in Co Limerick.
All/ General Verification	Report	B-0063	45-1b Consultants Report. Environmental Impact Statement (EIS). Refers to flooding in the Mulkear catchment on the Newport and Kileenagarriff Rivers in Co Limerick.
All/ General Verification	Report & map	B- 0063	15- 3d, 15-3a, 15- 3e Lands likely to benefit from flood alleviation

			scheme (prior to approval of scheme)
All/ General verification	ESB/ Limerick CoCo.	B- 0063	15-6e List of areas along N24 Limerick to Waterford Road that experienced repeat flooding (Dromkeen).
All/ General Verification	Photograph	B- 0063	15-6j Photograph of main street Cappamore which flood waters outside the Bridge Inn pub.
All/ General Verification	Application report	C-0130	Hydrological Risk Assessment with plans of the site/proposed development at Pond Street Newport. Extracts from a planning application (08/510773) for a development at Pound Street, Newport, Co. Tipperary.
All/ General Verification	Application report	C-0131	Appropriate Flood Risk Assessment (including historical maps and flood data), poor quality scanned photographs. Extracts from a planning application (09/51/0127) for a site at Tullow, Newport, Co. Tipperary. Includes changes to the proposals following the granting of planning permission.
All/ General Verification	FRR site visit	A-0148	Cappamore (CAR15) Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 08/06/2011
All/ General Verification	FRR site visit	A-0153	Newport (CAR45) Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 09/06/2011
All/ General Verification	Excel	B-0041	Inputs regarding potential sources of flood event calibration data
*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question. **The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.			

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment**
Category 1	Large gauged river within an AFA (HPW)	1(1) 2(0) 3(0) 4(2)	1(2) 2(0) 3(0) 4(0)	1(0) 2(0) 3(0) 4(0)	1(1) 2(0) 3(1) 4(1)	1(1) 2(1) 3(0) 4(1)	1(5) 2(1) 3(1) 4(4)	
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely. Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2).

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (ref. Table 3-i).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table 3-i: FSU Gauging station classification (from hydrologic 2006)

Phase 1			
Shannon CFRAM Study Calibration Information Refer to technical note TD041			
Model No.	**N16**	Length	188 km
Unit of Management		25/26	
AFA	Limerick		
IRRs	none		
River / Catchment / Sub-catchment	River Shannon and tributaries / Shannon		
Type of Flooding / Flood Risk	Fluvial non-tidal ☐ Fluvial tidal ☒ Coastal ☐		
Comments	Model extent N16 comprises of the River Shannon and 15 tributaries (Mulkear, Cappavilla, Crummeen, Blackwater, Shannakyle, Groody, Ballykeelaun, Head Race, Ballygrennan, Clonmacken, Ballincurra Creek, Crompaun, Gortatogher, Ashwood Drain and Abbey) and a few 2nd-order or 3rd-order tributaries (Thornfield, Towlerten, Coolnallira, Coolnallira, Parteen, Ballycannan, Ballynaclogh, Ballysheedy, Caherdavin West and East, Castle Park, Crompaun East and Pass, Moneennagliggin, Coonagh and Bulls Farm). The catchments u/s of N16 has three inline loughs (Lough Allen u/s of N01, Lough Ree in N10 and Lough Derg in N12). Flows from Lough Derg split into Head Race canal and River Shannon at Parteen weir, and about 4070m d/s of the weir, flows in the main river split into a by-pass canal and the old channel. N16 is linked to those three regulated watercourses: 1) Head Race in N16 starts at about 400m downstream of the hydro-power station on Head Race canal; 2) Tributary Crummeen in N16 is linked to the upstream by-pass canal; 3) Main River Shannon in N16 is linked to the upstream old channel. There is no gauging station along the River Shannon, but one station along the River Mulkear, one along River Groody, one along River Ballycannan, three along Ballincurra Creek, two along River Ballysheedy, and one (tidal) along River Abbey within the model extent. Gauging station Ardnacrusha (25055) sits along the Head Race canal, 0.44km to the upstream of the model extent on that tributary. Gauging station Parklock sits along the Shannon Canal, 0.82km upstream of the River Abbey. This N16 model has one large AFA and has a tidal d/s boundary. Fluvial calibration is not possible at Limerick. A cross model calibration of the River Mulkear is possible using the hydrographs at station 25001 in N16 mode and 25002 & 25003 in N15 model. Tidal calibration/ verification may be possible between station 25061 and stations 25047/ 25049. General verification of the model is possible given plenty indicative records and flood extent maps.		

Completed by	Kieran Daly	Yiwen Zhao		
Date	07/ 05 /13	13/05/2014		

Potential flood events to consider for calibration

No	Description*	Category **(TD041)	Score (TD041)	Calibration or verification
1	Winter 1999/ 2000 – Fluvial/Tidal flooding	1	3+3+0+3+3=12	General verification
2	20-26/ 11/ 2009 – Fluvial/Tidal flooding	1	3+3+0+3+3=12	General verification
3	Winter 2006/ 2007 – Fluvial flooding – Out of bank event – Observed data	1	3+3+0+2+0=8	General verification
4	30/01/1994- 01/02/1995 – Tidal flooding	1	3+3+0+1+1=8	Not suitable
5	Jan-Feb/ 2002 – Fluvial/Tidal flooding	1	3+3+0+1+1=8	Not suitable
6	Jan- Feb/ 1997 –Tidal flooding	1	3+3+0+1+1=8	Not suitable
7	22-23/10/ 1961 – Fluvial/Tidal flooding	1	3+3+0+2+0=8	Not suitable
8	31/12/ 1954 – unknown source	1	3+3+0+2+0=8	Not suitable
9	10-28/ 02/ 1990 – Fluvial flooding	1	3+3+0+2+0=8	General verification
10	26 Jan- 03 May 1994 – Fluvial flooding	1	3+3+0+1+0=7	Not suitable
11	24/ 10/ 1995 – Fluvial/ pluvial flooding	1	3+3+0+1+0=7	Not suitable
12	March 2006 – Tidal flooding (phase 2 only)			Calibration
13	October 2006 – Tidal flooding (phase 2 only)			Verification
14	August 1997 – Cross model fluvial flooding – out of bank – River Mulkear (phase 2 only)			Cross model calibration along Mulkear
15	November 2000 – Cross model fluvial flooding – out of bank – River Mulkear (phase 2 only)			Cross model verification along Mulkear
16	March 1998 – Cross model fluvial flooding – in bank – River Mulkear (phase 2 only)			Cross model Calibration along Mulkear
17	January 2005 – Cross model fluvial flooding – in bank – River Mulkear (phase 2 only)			Cross model verification along Mulkear

* See Appendix B for Event Details of events 1-2, ** See Appendix C for Quality Category and Quality Score
(Scoring - 0 (Not suitable for calibration) to 15(Suitable for calibration))

Gauging Station Information within Model Extent (or close to)

Station	Data Length	Type (flow, stage, both)	Gaugeboard Datum (mAOD Malin)	FSU Classification*	Comment
24047 Rossbrien Rly Br.	16/12/1998 to present	Level and Flow	1.046	Not FSU Classified	no rating review
24048 Ballinacurra D_S	18/12/1998 to present	Level	Missing	Not FSU Classified	no rating review
24049 Ballinacurra U_S	17/12/1998 to present	Level	-3.15	Not FSU Classified	no rating review
24050 Ballinacurra gardens	23/11/1998 to 09/06/2000	Level	Missing	Not FSU Classified	no rating review

24051 Huntsfield	23/11/1998 to 09/06/2000	Level	2.63	Not FSU Classified	no rating review
25001 Annacotty	01/09/1953 to present	Level and Flow	7.65	A2	Acceptable model fit cannot be achieved at high flows; OPW data remains unchanged.
25012 Groody Bridge	01/08/1972 to present	Level	Missing	Not FSU Classified	no rating review
25055 Ardnacrusha	unknown	Level and Flow	Missing	Not FSU Classified	no rating review; on tributary outside of model extent
25061 Ball's Br.	01/07/1957 to present	Level	0.04	Not FSU Classified	Tidal; no rating review
25076 Parklock	01/12/1980 to 25/11/2005	Level	Missing	Not FSU Classified	no rating review; on tributary outside of model extent
25310 Knockalisheen	09/07/2003 to 25/05/2004	Level	Missing	Not FSU Classified	no rating review

* See Appendix D for Key to FSU Station Classification A1 (Good) to C (Poor))

Control structures

Reference	Type	Description
25KEAR00361W 25KEAR00360X	Weir	Ballyclogh, South of the M7 crossing over Mulkear
25ABBY00005W 25ABBY00004X	Labyrinth Weir	At confluence of Shannon & River Abbey
25KEAR00227W 25KEAR00226W 25KEAR00225X	Crump weir	Woodstown, South of the r445 crossing over Mulkear
24CURA00413W 24CURA00412W 24CURA00412X	Weir	Dooradoyle
24CURA00406W 24CURA00405W 24CURA00405X	Weir	Dooradoyle
25SHAN08188W 25SHAN08185X 25SHAN08183X	Labyrinth Weir	Upstream of St. Thomas Island

Conclusions from Phase 1

Phase 1 suggested:

- Of all the stations listed above, only Station 25001 on the River Mulkear has 15min flow data available for this study. However due to a lack of observed historic flood data along the lower River Mulkear, calibration or verification of fluvial flooding is not possible.
- However, a cross model fluvial calibration could be possible for the Mulkear using the gauges 25001, 25002 & 25003 in N16 & N15 models.
- Levels at Station 25061, 24049/24047 have 15min level data available for tidal calibration of the Ballincurra branch of the N16 model. Levels at Station 24047 might be used with caution as they are unchecked imported water level data.
- General verification is possible given plenty indicative records and flood extent maps within Limerick City.

Phase 2			
Gauging Station Information Used – Tidal Calibration – Out of Bank*			
Type	Out of Bank Tidal Calibration	Out of Bank Tidal Verification	
Flood Event	12 (30/03/2006)	13 (26/12/1999)	
GS Number	25061	25061	
Station Name	Ball's Br.	Ball's Br.	
Approximate Start of peak level	23/03/2006 04:00:00	23/12/1999 11:45:00	
Approximate Finish of peak level	07/04/2006 05:45:00	31/12/1999 00:00:00	
Peak level** (mAOD Malin)	3.76 (3.72m)	3.71 (3.67m)	
Peak flow (m^3/sec)	N/A	N/A	
Other gauging stations for same event***	24049/ 24047	24049/ 24047	
Gauging Station Information Used – N16-N15 Cross Model Fluvial Calibration – Out of Bank*			
Type	Out of Bank Cross Model Calibration	Out of Bank Cross Model Verification	
Flood Event	14 (05/08/1997)	15 (06/11/2000)	
GS Number	25003	25003	
Station Name	Abington	Abington	
Approximate Start of peak level	02/08/1997 12:15:00	05/11/2000 04:15:00	
Approximate Finish of peak level	19/08/1997 03:15:00	10/11/2000 12:30:00	
Peak level** (mAOD Malin)	36.30 (1.86m)	36.48 (2.04m)	
Peak flow (m^3/sec)	72.37	83.3	
Other gauging stations for same event***	25002/ 25001	25002/ 25001	
Gauging Station Information Used – N16-N15 Cross Model Fluvial Calibration In Bank*			
Type	In Bank Cross Model Calibration	In Bank Cross Model Verification	
Flood Event	16 (06/03/1998)	17 (08/01/2005)	
GS Number	25003	25003	
Station Name	Abington	Abington	
Approximate Start of peak level	05/03/1998 22:00:00	07/01/2005 04:45:00	
Approximate Finish of peak level	24/03/1998 06:30:00	14/01/2005 20:30	
Peak level** (mAOD Malin)	36.40 (1.96m)	36.34 (1.90m)	
Peak flow	78.44	74.78	

(m^3/sec)			
Other gauging stations for same event***	25002/ 25001	25002/ 25001	

*Tidal calibration/verification may be possible between 25061 and 24047/24049. And N16-N15 cross model fluvial calibration/verification (for both out-of-bank and in-bank events) may be possible between 25003 and 25001. In-bank tidal calibration is not possible

Calibration events may include more than one gauging station but the table above indicates the details for the most upstream gauging station which will provide the level and flow data for the calibration/verification.

**Stage is converted to mAOD Malin with datum provided in the table above for station information. (Stage in brackets).
***Station 24047 data might be used with caution due to the limitation of data quality.

Discussion and Strategy – Fluvial Calibration

Discussion

- There is one AFA (Limerick) within the model extent, while model may only be generally verified at Limerick City due to the data availability.
- Station 25001 is the only one has 15min data available within this model. Yet, observed data of all flood events are not available.
- In-bank calibration or verification of fluvial flooding is not possible.
- Based on availability of 15min data along River Mulkear, station 25003, 25002 and 25001 can be used for N16-N15 cross model fluvial calibration.

Cross Model fluvial Calibration/Verification Strategy:

Model N16-N15 cross model fluvial calibration may be possible:
The event flow hydrographs at stations 25003 and 25002 (N15 model extent) are used to calibrate/verify the Mulkear model by comparing the level data of the corresponding events at Station 25001 (N16 model).
(i) Out-of-Bank calibration can be done with the August 1997 event
(ii) Out-of-Bank verification can be done with the November 2000 event
(iii) In-bank calibration can be done with the March 1998 event
(iv) In-bank verification can be done with the January 2005 event

Post-Design Event Modelling Verification:

- Verification may be possible on the Main Shannon by comparing model extent with historical flood maps (2009) and indicative records / photos of re-occurring flooding. This event was identified of having a rarity of about 1% AEP at Parteen Weir (fluvial).

Discussion and Strategy – Tidal/Coastal

Discussion

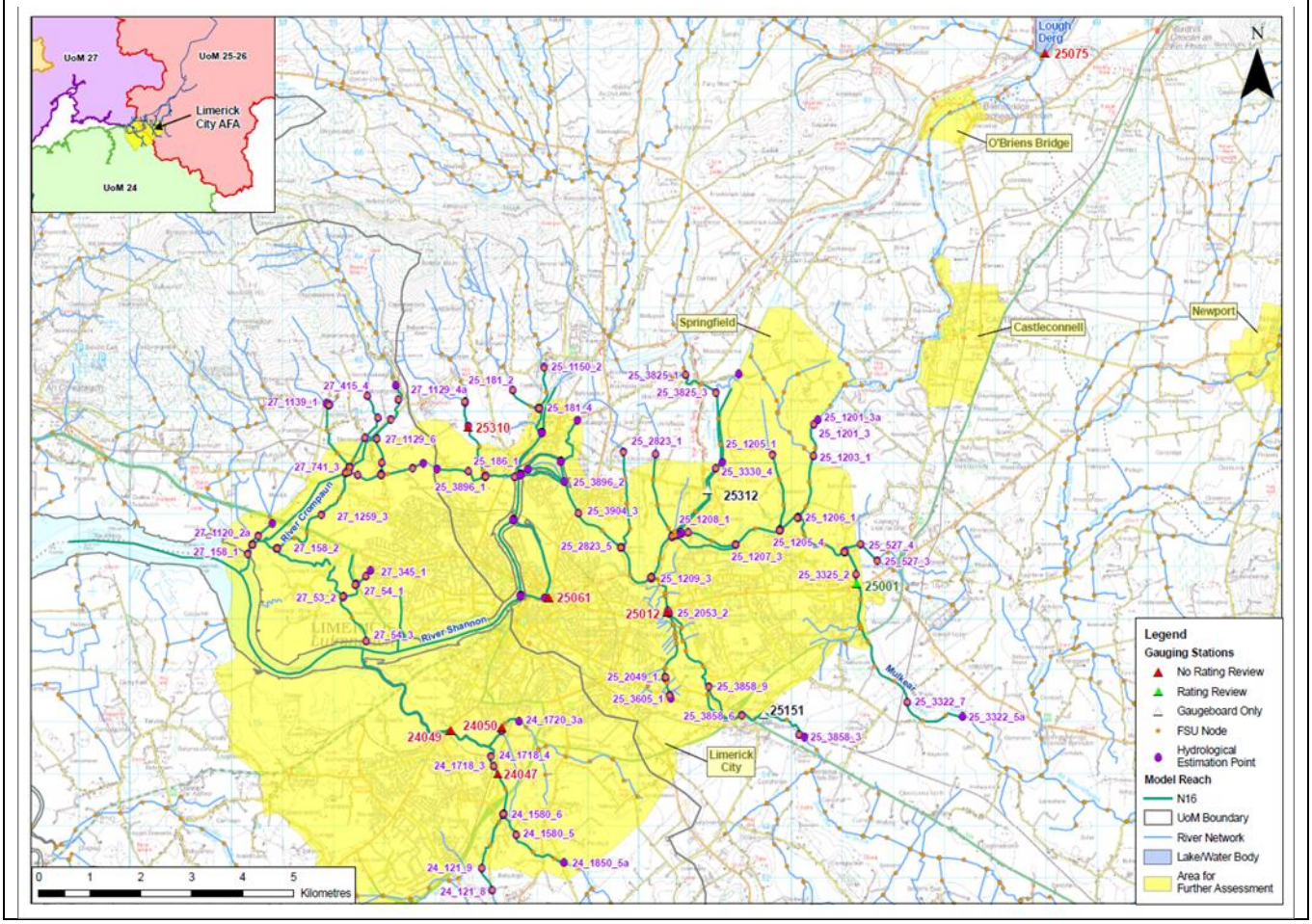
- Based on the availability of 15min interval level data, a tidal calibration/verification of the Ballincurra Creek Branch of the N16 model can be possible, using the tidal event data at Station 25061 and the corresponding level data at stations 24047 and 24049.

Calibration/Verification Strategy

(i) Calibration can be done with the March 2006 event, with the tidal hydrograph at Station 25061 and checking the levels at stations 24049/ 24047 (24047 level data to be used with caution)

(ii) Verification can be done with the October 2006 event, with the tidal hydrograph at Station 25061 and checking the levels at Station 24049/ 24047 (24047 level data to be used with caution)

Appendix A - Plan of model N16



Appendix B - Details Flood Event Records			
Flood Event	Material type	Data location	Contains
2/ General Verification	GIS shapefile	B-0006	SERTIT: Water bodies mapped from RADARSAT-2 data acquired the 5th of December 2009 Relevant: ☒ Not relevant: ☐
All / General verification	GIS Layer	A-0171	Revised GIS layers showing the areas of Benefiting lands. **Coverage: ☒ **No Coverage: ☐
8	GIS Layer	B-0020	Digitisation of 1954 flood event. *Coverage: ☒ *No Coverage: ☐
2	GIS Layer	B-0054	Jacobs digitisation of 2009 flood event. *Coverage: ☒ *No Coverage: ☐
1	Flooding Report Limerick CoCo	B-0063	37-18h, 19h Flood levels in Dec 1999 event recorded at St Mary's Pk in Limerick City Council Report Christmas day flood levels: 6" to 1ft @ Sir Harry's Mall, 4.4mOD @ Baal's Bridge, 4.2mAOD btw Thomond Bridge & Sarsfield Bridge. The roadway was 0.7m under water. Part of the road along Sir Harry's Mall & Athlunkard St - 3.5 to 3.8mAOD. 3.9 to 4.2mAOD on the Corbally side of O'Dwyer Bridge. 4.0mAOD at Merchant's Quay & Custome House Quay.
1 & 4	Report	B-0019	Two ESB International Report: River Shannon Flood of Winter 1994/95 and River Shannon Flood of Winter 1999/2000 The reports + Examines the extent of flooding. + Models the flood using the 'Shannon Flood Forecasting Model'.
1	Report & map	B-0063	37-44a Letter and map from an area engineer reported flood event of December 1999 at Quinspool, Parteen. 3 houses were flooded & not receded for over a week. White Hall basement was flooded also. The road (R464 near Quinspool South) in front of the houses was impassable. *Similar situation ~ 14 years ago.
1	Photograph	B-0063	37-41b 37-41c Photograph of flooding in Athlunkard St on 05/ 01/ 2000.
1	Flood study	B-0063	37-5e, 6c, 7c, 8c, 18g, 42c, 61b (duplicates) 9, 10, 11, 12, 16, 19, 20l , 43 Limerick flood study report of 28pages in the wake of the 1999/2000 event aimed at identifying areas at high risk of flooding and

			mitigation measures. 4.3mAOD. (4.1mAOD recorded by the Shannon Ports gauge @ Limerick docks - predicted 2.8mAOD). ~1.0m (road along Sir Harry's Mall) Considerable flooding in the Sir Harry's Mall (worst location of flooding) & Athlunkard St area. Flood water entered houses in Sir Harry's Mall, Athlunkard St & Corbally area. Flooding on Corbally Rd, Lower Park, Mill Rd, Condell Rd nr Barringtons Pier, Clancy Strand & St Mary's Park. Number of people were confined to their homes. "Worst in living memory".
2	Paragraph	B-0016	Paragraph from OPW hydrometric team regarding flooding during November 2009
2	Drawing	B-0031	Limerick City – November 2009 Flood Outline drawing
2	GIS shapefile	B-0036	Digitised estimated flood outlines of the November 2009 event in SE Clare (affecting UoM 25/26, plus some of UoM 27) and in Ennis (UoM 27)
3	GIS shapefile	B-0010	Flood polygons of the Dec 2006 flood event, River Shannon & Clare.
3	Photographs	B-0011	Flood photographs of the Dec 2006 flood event, River Shannon & Clare.
3	Photographs	B-0063	37-3b Aerial photographs of flooding.
3	Consultants ESB Report	B-0018	ESB International Report: River Shannon Flood of Winter 2006/07. The report +Examines the extent of flooding. + Models the flood using the 'Shannon Flood Forecasting Model'.
4	Newspaper extract	B-0063	37-62g Newspaper paragraphs A eight of 2ft at Sandmall was observed . Clancy's Strand and the Dock Rd, Longpavement, Rosbrien were also flooded.
4	Reports	B-0063	37-63a, 67a Short engineering reports on flooding Banks at top end of the Ballynaclogh River are tapered down to 22.5 ft. 25ft for the d/s embankment. A large housing estate did not suffer flooded (protected by banks that were overtopped) D/S embankment protected a large number of commercial properties.

4	Letter	B-0063	37-25a, 29a, 54a Letter describing flooding at various locations. 3.82mOD @ the harbour
5	Report	B-0063	37-26b, 27a 45 page Limerick City Council flood report describing the flood in Feb 2002 Water came to within ~ 150mm of the top of the quay walls (Bishops Quay to Honans Quay). 300mm of water at Custom House Quay.
5	Photograph	B-0063	37-26b, 27a, 31e, 32a, 34a, 36a, 37a (duplicates) A short report on 7 food identified areas of Limerick City, including Clancy Strand, O'Callaghan Strand, Sir Harrys Mall, Corbally Road Riverbank, St. Mary's Park, Condell Road Riverbank, Bishops Quay-Custom House Quay. It has been found that such flooding occurs two to three times a year. Photos of flood extent in Limerick City are included. Water depth ranging from 300 to 900mm was recorded. Yet, quality of the photos is poor, and no specific levels can be determined.
6	Report	B-0063	37-24c, 46c, 47, 48, 49, 50, 51, 62b 11 page report on the 1997 flooding in Limerick. Describes flooding in multiple locations. Yet, quality of the photos is poor, and no specific levels can be determined.
7	Handwritten note	B-0063	37-20n, 31g, 32c, 37b (duplicates) Highest recorded tides at Limerick Dock 1961 – 4.2mOD Malin (equivalent to 8.53m to Dock Gauge datum) 1999 – 4.27 mOD Malin (equivalent to 8.60m to Dock Gauge datum) 2002 – 4.37 mOD Malin (equivalent to 8.70m to Dock Gauge datum)
9	Photographs	B-0063	37-30a, 37-30b, 37-57a, 37-57b, 37-57c, 37-57d, 37-57e, 37-57f, 37-57g, 37-57h 10 photos of flooding near Sarsfields House/ Arthurs Quay Limerick on 28th Feb 1990. Levels may be estimated from the photos.
9	Newspaper article	B-0063	37-62e 10-13/ February 1990; 4 ft deep (flooding of roads) Farmers had to move their cows to higher ground as an area from Corbally to Crusheen along the river became far too dangerous to leave animals. Coolame National School closed due to flooding on nearby roads.

10	Photographs	B-0063	37-55a 37-55b 37-55c 37-55d 37-56a 37-56b 37-56c 37-56d 37-56e 37-56f 9 photos showing flood extent in Clancy's Strand. Levels may be estimated from the photos.
11	Letter and map	B-0063	37-52a This event appears to be pluvial and not fluvial. Letter describing flooding in the vicinity of Corrib drive. Appears to be a result of heavy rainfall and the extension of a culvert.
All/ General Verification	Consultants ESB Report	B-0017	Four Inundation Studies provided: Including ESBI Reports River Shannon Inundation Study - Parteen Weir to Limerick City and River Shannon - Inundation Study for Dams and Embankments on Lower Shannon.
All/ General Verification	FRR site visit	A-0152	Limerick (CAR37) Notes, photographs and videos (GIS-based) during UoM 25 & 26 Site Visit 09/06/2011

*The information is deemed relevant if land adjacent to the model extent is indicated as having flooded during the event in question.
**The information is deemed relevant if land adjacent to the model extent is indicated as at risk of flooding / could benefit from a flood defence scheme. The Office of Public Works has provided a map of lands that have benefited or would benefit from a flood relief scheme or drainage works. The designation of "benefiting lands" does not necessarily indicate that the respective sites are liable to flooding.

Appendix C – Event Category and Scoring								
1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions (1)**	**Supplementary known, useful flood levels(2)**	**Reliable flood history (levels, locations, dates) (3)**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment (with event number)**
Category 1	Large gauged river within an AFA (HPW)	1(3) 2(3) 3(3) 4(3) 5(3) 6(3) 7(3) 8(3) 9(3) 10(3) 11(3)	1(3) 2(3) 3(3) 4(3) 5(3) 6(3) 7(3) 8(3) 9(3) 10(3) 11(3)	1(0) 2(0) 3(0) 4(0) 5(0) 6(0) 7(0) 8(0) 9(0) 10(0) 11(0)	1(3) 2(3) 3(2) 4(1) 5(1) 6(1) 7(2) 8(2) 9(2) 10(1) 11(1)	1(3) 2(3) 3(0) 4(1) 5(1) 6(1) 7(0) 8(0) 9(0) 10(0) 11(0)	1(12) 2(12) 3(8) 4(8) 5(8) 6(8) 7(8) 8(8) 9(8) 10(7) 11(7)	
	Small gauged river within an AFA (HPW)							
Category 3	Large ungauged river within an AFA (HPW)							
	Small ungauged river within an AFA (HPW)							
Category 2	Gauged MPW							
Category 4	Ungauged MPW							

Key: 1(2) = Flood Event 1 (score = 2)

Table C.1 Event Category and Scoring

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely.

Total score in column 7 provides an overall guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2)

Appendix D – FSU Classification (Abstract from Interception Report)

Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (Table B.1).

FSU Classification		Definition
A	**Both**	Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood (Q_{med}) [HGF > 1.3 x Q_{med}] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events
	A1	Confirmed ratings for flood flows well above Q_{med} with the HGF > than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 x Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
	A2	Rating confirmed to measure Q_{med} and up to around 1.3 x Q_{med}. At least one gauging for confirmation and good confidence in the extrapolation.
B		Flows can be estimated up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.
C		Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least Q_{med}.

Table D.1 - FSU Gauging station classification (from Hydro-Logic 2006)

Appendix G Pooling Group Audit Trail

Table of Content

Gauging Stations

25003 Abington

25006 Ferbane

25014 Millbrook

25016 Rahan

25023 Milltown

25025 Ballyhooney

25040 Roscrea

26002 Rookwood

26005 Derrycahill

26006 Willsbrook

26007 Bellagill

26008 Johnston's Br

26016 Ballymurray

26019 Mullagh

26021 Ballymahon

26108 Boyle Abbey

26140 Ahascragh Pumping House

FSU Nodes

25_583_1

26_1470_1

26_3488_2

26_3824_10

26_3870_1

26_3975_3

26_3977_3

26_4022_8

26_59_3

26_695_1

Appendix G Pooling Group Audit Trail

Table of Content

Gauging Stations

25003 Abington

25004 New Bridge

25006 Ferbane

25014 Millbrook

25016 Rahan

25023 Milltown

25025 Ballyhooney

25027 Gourdeen

25029 Clarianna

25038 Tyone

25040 Roscrea

25308 Waterpark Bridge

26002 Rookwood

26005 Derrycahill

26006 Willsbrook

26007 Bellagill

26008 Johnston's Bridge

26016 Ballymurray

26019 Mullagh

26021 Ballymahon

26108 Boyle Abbey

26140 Ahascragh Pumping House

26221 Summerhill

25044 Coole

FSU Nodes

25_583_1

25_3560_6

25_3773b

25_709_4

25_1019_4

25_3708_4

25_3823_8b

25_1205_4

25_3329_2

25_833_2

26_1019_4

26_3977_3

26_4022_8

26_59_3

26_695_1

26_1459_4

26_2818_2

25_2616_4

26_1469_2

26_1470_1

26_3488_2

26_293_2

26_4030_4

26_3824_10

26_3870_1

26_3975_3

27_54_3

27_158_2

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: ABINGTON

Gauging station No: 25003

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N15 Mulkear\Pooled FloodFrequency Analysis_N15_v1.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_2038_3
Area	399.06
BFI	0.55
SAAR	1106.40
FARL	1.00
URBEXT	0.58
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.3 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
26006	Removed due to high FLATWET (> subject site + 0.1)
30005	Removed due to high FLATWET (> subject site + 0.1)
34005	Removed due to high FLATWET (> subject site + 0.1)
30037	Removed due to high FLATWET (> subject site + 0.1)
3051	Removed due to high URBEXT (> subject site + 2.5)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.4 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25003	51	0.229	399.062
24012	41	0.358	366.282
24013	36	0.179	438.788
24011	33	0.773	281.234
25001	27	0.663	647.558
24004	52	0.158	242.130
24030	25	0.382	258.880
15007	25	0.108	339.760
15003	51	0.982	299.166
14005	48	0.366	405.484
24001	28	0.106	770.230
15004	51	0.013	491.382
24082	28	0.267	762.836
16012	28	0.083	229.627

Total years of data	524

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.22	1.21	1.18
10	1.36	1.34	1.28
20	1.50	1.45	1.37
50	1.67	1.59	1.49
100	1.81	1.69	1.58
200	1.94	1.79	1.67
1000	2.24	2.01	1.88

Comments:

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name: New Bridge

Gauging station No: 25004

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N15 Mulkear\Pooled FloodFrequency Analysis_N15_v3.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_486_3
Area	122.26
BFI	0.57
SAAR	1336.49
FARL	1.00
URBEXT	0.15
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: Site is not in the set of stations for pooling.

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

The upper limit of FLATWET has been increase by 0.1 to improve pooling group.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
34011	Removed due to low FARL (< -10% subject site)
29071	Removed due to low FARL (< -10% subject site)
33070	Removed due to low FARL (< -10% subject site)
36071	Removed due to low FARL (< -10% subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.4 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
	N/A

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25158	18	0.638	109.547
25038	17	0.190	136.095
16013	33	0.301	93.583
25002	51	0.848	221.609
25044	40	0.169	92.546
30021	26	0.541	103.630
16012	28	0.035	229.627
26014	16	0.334	215.137
16007	51	0.144	273.260
34024	28	0.337	127.227
16005	30	0.267	84.000
19001	48	0.058	103.281
30037	21	0.487	210.196
20006	25	0.571	77.554
16003	27	0.301	243.202
30005	49	0.114	237.821

Total years of data	508

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.25	1.24	1.20
10	1.42	1.40	1.32
20	1.57	1.53	1.43
50	1.78	1.71	1.57
100	1.93	1.83	1.67
200	2.09	1.96	1.77
1000	2.44	2.24	2.01

Comments:

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Ferbane

Gauging station No: 25006

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\Brosna Catchment Model\UoM 25 26\Brosna Catchment Model\111102 - Pooled FloodFrequency Analysis -V3 - Brosna Main&Trib Final.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_608_1
Area	1185.46
BFI	0.76
SAAR	931.89
FARL	0.96
URBEXT	1.88
FLATWET	0.63

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 542

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
7041	7

STEP 3 Remove sites with high discordancy Di
Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
7012	3.893

STEP 4 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET
(to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	not greater than 2.5
FLATWET	

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed with explanation** + Reviewer initials if kept
26021	FARL value less than 10% of subject site
36016	FARL value less than 10% of subject site
36019	FARL value less than 10% of subject site
36010	FARL value less than 10% of subject site

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Station	**Removed with explanation** + Reviewer initials if kept
12001	SAAR value greater than 25% of subject site

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km^2)
25006	52	0.027	1162.76
25011	51	0.149	1180.21
7005	29	0.763	1332.17
7009	29	0.435	1658.19
14034	17	0.693	2057.36
14018	51	0.493	2419.40
15002	48	0.071	1644.07
14019	52	0.064	1697.28
14029	47	0.533	2778.15
15005	50	0.214	379.37
7010	19	0.532	699.75
7007	26	0.089	441.18
26005	51	0.271	1085.38

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	LN2	EV1	LO
2	1.00	1.00	1.00
5	1.23	1.23	1.29
10	1.37	1.39	1.45
20	1.50	1.54	1.61
50	1.65	1.73	1.80
100	1.77	1.88	1.95
200	1.88	2.02	2.09
1000	2.13	2.35	2.43

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.C2 - Pooled analysis site C

Site name: Millbrook

Gauging station No: 25014

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Brosna Catchment Model\N06\14032013 - Pooled FloodFrequency Analysis -V4_Millbrook Trib.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3806_3
Area	154.4
BFI	0.65
SAAR	1008.2
FARL	1
URBEXT	0.51
FLATWET(Formwet)	0.62

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years:

Is subject site in pooled group? (•) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data

STEP 3 Remove sites with high discordancy Di
Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy

STEP 4 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET
(to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	not greater than 2.5
FLATWET	

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed with explanation** + Reviewer initials if kept
26018	FARL variance is greater than 10% from the subject site
7004	FARL variance is greater than 10% from the subject site
36018	FARL variance is greater than 10% from the subject site
6070	FARL variance is greater than 10% from the subject site
6012	FARL variance is greater than 10% from the subject site

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Stations removed after first iteration

Station	**Removed with explanation** + Reviewer initials if kept
7011	FARL variance is greater than 10% from the subject site
6011	FARL variance is greater than 10% from the subject site
25016	URBEXT value greater than 2.5

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25014	54	0.030	164.41
25020	35	0.052	197.09
25027	43	0.070	118.86
7006	19	1.149	177.45
6026	46	0.230	148.48
16004	48	0.158	228.74
29004	32	0.134	121.44
36015	33	0.614	153.06
16001	33	0.139	135.05
25022	22	0.108	161.34
6025	30	0.394	175.98
25005	46	1.100	192.62
11001	33	0.316	155.11
26019	51	0.172	252.96

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	LN2	EV1	LO
2	1.00	1.00	1.00
5	1.20	1.21	1.26
10	1.33	1.35	1.41
20	1.44	1.49	1.55
100	1.67	1.79	1.86
200	1.77	1.92	1.99
1000	1.98	2.22	2.29

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: Rahan

Gauging station No: 25016

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Brosna Catchment Model\111102 - Pooled FloodFrequency Analysis -V3 - Brosna Main&Trib Prel_Update.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3612_2
Area	253.78
BFI	0.63
SAAR	952.60
FARL	1.00
URBEXT	2.85
FLATWET	0.61

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 504

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data

STEP 3 Remove sites with high discordancy Di
Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy

STEP 4 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	not greater than 2.5
FLATWET	

These criteria can be relaxed in some circumstances if agreed with reviewer. Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed with explanation** + Reviewer initials if kept
36018	FARL value less less 10% of subject site
18004	URBEXT value less than 25% of subject site
7004	FARL value less less 10% of subject site
36011	FARL value less less 10% of subject site
6025	URBEXT value less than 25% of subject site

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Station	**Removed with explanation** + Reviewer initials if kept
7011	FARL value less less 10% of subject site
15001	URBEXT value less than 25% of subject site
26008	FARL value less less 10% of subject site URBEXT value less than 25% of subject site

3rd iteration

Station	**Removed with explanation** + Reviewer initials if kept
25022	URBEXT value less than 25% of subject site

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25016	48	0.036	275.17
16004	48	0.179	228.74
6014	30	0.167	270.38
26019	51	0.195	252.96
7006	19	1.301	177.45
6013	30	0.400	309.15
24002	27	0.055	229.40
25014	54	0.033	164.41
6026	46	0.261	148.48
25020	35	0.058	197.09
11001	33	0.358	155.11
25005	46	1.246	192.62
16002	51	0.042	485.69

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	LN2	EV1	LO
2	1.00	1.00	1.00
5	1.23	1.24	1.29
10	1.38	1.40	1.46
20	1.51	1.55	1.62
100	1.79	1.89	1.97
200	1.90	2.04	2.12
1000	2.16	2.38	2.46

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.C2 - Pooled analysis site C

Site name: Milltown GS

Gauging station No: 25023

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N11 Little Brosna\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_N11_v4.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25023
Area	113.86
BFI	0.71
SAAR	922.49
FARL	1.00
URBEXT	0.25
FLATWET	0.60

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
26018	Removed due to low FARL (< -10% of subject site)
36018	Removed due to low FARL (< -10% of subject site)
6070	Removed due to low FARL (< -10% of subject site)
6012	Removed due to low FARL (< -10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
6011	Removed due to low FARL (< -10% of subject site)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
7001	18	0.233	151
14013	50	0.327	154
25025	31	0.358	161
25023	34	0.737	114
6026	46	0.504	148
25014	54	0.065	164
25027	43	0.152	119
25020	35	0.113	197
14009	25	0.136	68
26058	24	0.668	60
25022	22	0.237	161
14007	24	0.530	119
16001	33	0.304	135
6025	30	0.864	176
13002	19	0.088	63
7003	30	0.017	182

Total years of data	518

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.26	1.25	1.21
10	1.43	1.41	1.33
20	1.59	1.55	1.44
50	1.80	1.73	1.58
100	1.96	1.86	1.69
200	2.12	1.99	1.79
1000	2.49	2.29	2.04

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Ballyhooney

Gauging station No: 25025

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26 Lower Shannon\N13\120912 - Pooled FloodFrequency Analysis -V4_James.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25025
Area	182.80
BFI	0.71
SAAR	900.00
FARL	1.00
URBEXT	0.80
FLATWET	0.61

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 529

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 4 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET
(to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	not greater than 2.5
FLATWET	

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed with explanation** + Reviewer initials if kept
6011	FARL value less than 10% of the subject site
6012	FARL value less than 10% of the subject site
7004	FARL value less than 10% of the subject site
6070	FARL value less than 10% of the subject site
7011	FARL value less than 10% of the subject site
14011	URBEXT outside upper boundary
25016	URBEXT outside upper boundary
25124	FARL value less than 10% of the subject site
26059	FARL value less than 10% of the subject site
36011	FARL value less than 10% of the subject site
36012	FARL value less than 10% of the subject site
36018	FARL value less than 10% of the subject site

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Station	**Removed with explanation** + Reviewer initials if kept
N/A	N/A

Final pooling group

Table A4.5 Final pooling group summary

Station No	**Years of data**	**Discordancy**	**Area (km^2)**
25025	31	0.237	161.20
14013	50	0.217	154.40
7001	18	0.154	151.31
7002	26	0.289	284.97
25023	34	0.488	113.86
7006	19	1.667	177.45
25020	35	0.075	197.09
16004	48	0.230	228.74
15005	50	0.117	379.37
7003	30	0.011	181.51
25014	54	0.043	164.41
6014	30	0.214	270.38
6025	30	0.572	175.98
14007	24	0.351	118.59
6026	46	0.334	148.48

Pooled distributions for further consideration if different from EV1 and LN2:

EV1

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	LN2	EV1	LO
2	1.00	1.00	1.00
5	1.25	1.26	1.32
10	1.41	1.43	1.50
20	1.56	1.60	1.67
50	1.74	1.81	1.89
100	1.87	1.97	2.05
200	2.00	2.13	2.21
1000	2.30	2.50	2.58

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Gourdeen GS

Gauging station No: 25027

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ Lower Shannon\N14\Flood frequency curves\Pooled\Pooled Flood Frequency Analysis_TEMPLATE_17032014_25027.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25027
Area	118.86
BFI	0.651
SAAR	1021.15
FARL	1
URBEXT	0.62
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 504

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed
6012	FARL 0.831
26018	FARL 0.75
6070	FARL 0.83
7004	FARL 0.772
6011	FARL 0.874
36018	FARL 0.849

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25027	43	0.066	118.86
25014	54	0.019	164.41
25022	22	0.111	161.34
6026	46	0.707	148.48
25020	35	0.216	197.09
25023	34	0.391	113.86
29001	40	0.042	115.48
16001	33	0.190	135.05
26010	35	0.459	94.53
7001	18	0.429	151.31
19001	48	0.071	103.28
6025	30	0.988	175.98
26020	33	0.588	122.44
16006	33	0.391	75.80

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.24	1.24	1.20
10	1.40	1.38	1.31
20	1.56	1.52	1.42
50	1.76	1.68	1.55
100	1.91	1.80	1.65
200	2.06	1.92	1.75
1000	2.40	2.19	1.98

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The LN2 distribution is the selected distribution for GS 25027 given that the subject site is closest to the LN2 distribution according to the L-moment diagram in the pooling analysis spreadsheet for 25027

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Clarianna GS

Gauging station No: 25029

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ Lower Shannon\N14\Flood frequency curves\Pooled\Pooled Flood Frequency Analysis_TEMPLATE_17032014_25029.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25029
Area	292.65
BFI	0.58
SAAR	1108.69
FARL	0.997
URBEXT	1.34
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 520

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed
35001	FLATWET 0.72
30005	FLATWET0.71
34005	FLATWET 0.73
26008	FARL 0.855
25030	FARL 0.850
30037	FLATWET 0.710
26014	FLATWET 0.720
26006	FLATWET 0.710
7004	FARL 0.772
30007	FLATWET 0.70

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25029	33	0.643	292.67
15007	25	0.041	339.76
16003	27	0.284	243.20
29011	22	1.169	354.14
15004	51	0.056	491.38
18001	48	0.425	334.08
24030	25	0.283	258.88
26019	51	0.219	252.96
26002	53	0.264	641.45
25003	51	0.192	399.06
25016	48	0.032	275.17
16004	48	0.175	228.74
30004	38	0.551	699.25

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.20	1.20	1.17
10	1.34	1.31	1.26
20	1.46	1.42	1.35
50	1.63	1.55	1.46
100	1.76	1.64	1.55
200	1.88	1.73	1.63
1000	2.17	1.93	1.82

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The LN2 distribution has been selected as the pooled distribution for GS 25038 based on the fit of the L-moment diagram in the pooling analysis spreadsheet. Also, the LN2 distribution fits better to the at-site ranked Amax flows than the EV1 while also giving conservative growth factors for the site especially when compared to the LO distribution growth factors (GF1000 = 1.99 versus GF1000 = 2.20 (for LN2 distribution)).

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Tyone GS

Gauging station No: 25038

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ Lower Shannon\N14\Flood frequency curves\Pooled\Pooled Flood Frequency Analysis_TEMPLATE_17032014_25038.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3495_5
Area	136.28
BFI	0.604
SAAR	1248.84
FARL	1
URBEXT	0.24
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 522

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed
34011	FARL 0.867
29071	FARL 0.804
26014	FLATWET 0.72
30021	FLATWET 0.72
30037	FLATWET 0.71
3005	FLATWET 0.71
34024	FLATWET 0.73
35001	FLATWET 0.72
26006	FLATWET 0.71
34005	FLATWET 0.73
25030	FARL 0.850

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25038	17	0.197	136.10
25044	40	0.176	92.55
19001	48	0.037	103.28
25158	18	0.657	109.55
16012	28	0.024	229.63
19016	15	1.941	117.82
16005	30	0.205	84.00
29001	40	0.034	115.48
25002	51	0.794	221.61
16003	27	0.342	243.20
16007	51	0.080	273.26
19020	28	0.195	73.95
16006	33	0.215	75.80
19015	29	0.128	205.19
26010	35	0.189	94.53
29004	32	0.119	121.44

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.24	1.24	1.20
10	1.41	1.39	1.31
20	1.56	1.52	1.42
50	1.76	1.69	1.56
100	1.91	1.81	1.66
200	2.06	1.93	1.76
1000	2.41	2.20	1.99

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The LN2 distribution has been selected as the pooled distribution for GS 25038 based on the fit of the L-moment diagram in the pooling analysis spreadsheet. Also, the LN2 distribution fits better to the at-site ranked Amax flows than the EV1 while also giving conservative growth factors for the site especially when compared to the LO distribution growth factors (GF1000 = 1.99 versus GF1000 = 2.20 (for LN2 distribution)).

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Roscrea GS

Gauging station No: 25040

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N11 Little Brosna\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_N11_v4.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25040
Area	28.02
BFI	0.58
SAAR	989.64
FARL	1.00
URBEXT	6.18
FLATWET	0.60

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? (•) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

Standard limits of URBEXT, AREA and SAAR are relaxed as shown below

	FARL	URBEXT	FORMWET	AREA	BFI	SAAR
Inittial Limits	0.900	3.680	0.500	7	0.435	742.23
	1.100	8.680	0.700	112	0.725	1237.05

	FARL	URBEXT	FORMWET	AREA	BFI	SAAR
Final Limits	0.900	1.000	0.500	7	0.435	742.23
	1.100	11.360	0.700	300	0.725	1500

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
24022	Removed due to low URBEXT (<1)
26022	Removed due to low URBEXT (<1)
16051	Removed due to low URBEXT (<1)
16006	Removed due to low URBEXT (<1)
8002	Removed due to low URBEXT (<1)
8012	Removed due to low URBEXT (<1)
9010	Removed due to high URBEXT (> 11.36)
10022	Removed due to high URBEXT (> 11.36)
26010	Removed due to low URBEXT (<1)
10021	Removed due to high URBEXT (> 11.36)
30020	Removed due to low URBEXT (<1) and high FLATWET (> subject site +0.1)
26009	Removed due to low URBEXT (<1)
16005	Removed due to low URBEXT (<1)
9035	Removed due to high URBEXT (> 11.36)
14009	Removed due to low URBEXT (<1)
26020	Removed due to low URBEXT (<1)
13002	Removed due to low URBEXT (<1) and high BFI (> +25% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29001	Removed due to low URBEXT (<1)
19020	Removed due to low URBEXT (<1)
25044	Removed due to low URBEXT (<1)
25027	Removed due to low URBEXT (<1)
25023	Removed due to low URBEXT (<1)
30021	Removed due to low URBEXT (<1) and high FLATWET (> subject site +0.1)
19046	Removed due to low URBEXT (<1)
9002	Removed due to high URBEXT (> 11.36)
16001	Removed due to low URBEXT (<1)
26058	Removed due to high BFI (> +25% of subject site)

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25034	Removed due to low URBEXT (<1) and high BFI (> +25% of subject site)
35004	Removed due to low URBEXT (<1) and high FLATWET (> subject site +0.1)
25022	Removed due to low URBEXT (<1)
36071	Removed due to low FARL (< -10% subject site) and low URBEXT (<1)
6026	Removed due to low URBEXT (<1)
14033	Removed due to low URBEXT (<1)
14007	Removed due to low URBEXT (<1)
29071	Removed due to low FARL (< -10% subject site) and low URBEXT (<1)
34024	Removed due to low URBEXT (<1) and high FLATWET (> subject site +0.1)
26018	Removed due to low FARL (< -10% subject site) and low URBEXT (<1)
6030	Removed due to low URBEXT (<1)

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
7006	Removed due to low URBEXT (<1)
6025	Removed due to low URBEXT (<1)
25014	Removed due to low URBEXT (<1)
6012	Removed due to low FARL (< -10% subject site)
7001	Removed due to low URBEXT (<1)
25038	Removed due to low URBEXT (<1)
26006	Removed due to low URBEXT (<1) and high FLATWET (> subject site +0.1)

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
34011	Removed due to low FARL (< -10% subject site), low URBEXT (<1) and high FLATWET (> subject site +0.1)
14013	Removed due to low URBEXT (<1)
9011	Removed due to high URBEXT (> 11.36) and small AREA (<0.25 times subjext site)
25020	Removed due to low URBEXT (<1)

7033	Removed due to low FARL (< -10% subject site) and low URBEXT (<1)

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
19016	Removed due to low URBEXT (<1)
8005	Removed due to high URBEXT (> 11.36) and low SAAR (< -25% times subjext site)
24002	Removed due to low URBEXT (<1)
8007	Removed due to low BFI (> -25% of subject site)
6070	Removed due to low FARL (< -10% subject site) and high BFI (> +25% of subject site)
25025	Removed due to low URBEXT (<1) and high BFI (> +25% of subject site)

7th iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
8011	Removed due to low URBEXT (<1)
7004	Removed due to low FARL (< -10% subject site) and low URBEXT (<1)
25005	Removed due to low URBEXT (<1)
30037	Removed due to low URBEXT (<1) and high FLATWET (> subject site +0.1)
25158	Removed due to low URBEXT (<1)

8th iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
7003	Removed due to low URBEXT (<1)
33070	Removed due to low FARL (< -10% subject site), low URBEXT (<1) and high FLATWET (> subject site +0.1)
26014	Removed due to low URBEXT (<1) and high FLATWET (> subject site +0.1)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25040	19	0.041	28
6031	18	0.397	46
22009	24	0.030	35
6033	25	0.718	55
36031	30	0.414	64
8009	15	2.456	62
19001	48	0.023	103
29004	32	0.048	121
8003	18	0.546	84
23012	18	0.355	62
8008	25	0.229	108
11001	33	0.113	155
14011	25	0.039	162
16004	48	0.057	229
26019	51	0.062	253
24030	25	0.127	259

25016	48	0.011	275

Total years of data	502

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.30	1.30	1.24
10	1.50	1.49	1.38
20	1.69	1.67	1.51
50	1.94	1.89	1.68
100	2.12	2.06	1.80
200	2.30	2.23	1.92
1000	2.73	2.61	2.20

Comments:

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.F2 - Pooled analysis site E

Site name: Waterpark Bridge

Gauging station No: 25308

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N15 Mulkear\Pooled FloodFrequency Analysis_N15_v1.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_475_12
Area	97.30
BFI	0.540
SAAR	1366
FARL	1.00
URBEXT	0.39
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: Station not included in the list of gauging station suitable for pooing

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
35002	Removed due to high FLATWET (> subject site + 0.1)
33070	Removed due to low FARL (< -10% subject site) and high FLATWET (> subject site + 0.1)
34011	Removed due to low FARL (< -10% subject site) and high FLATWET (> subject site + 0.1)
29071	Removed due to low FARL (< -10% subject site)
31002	Removed due to low FARL (< -10% subject site)
34024	Removed due to high FLATWET (> subject site + 0.1)
30021	Removed due to high FLATWET (> subject site + 0.1)
30037	Removed due to high FLATWET (> subject site + 0.1)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
36071	Removed due to low FARL (< -10% subject site) and high FLATWET (> subject site + 0.1)
30005	Removed due to high FLATWET (> subject site + 0.1)
35011	Removed due to high FLATWET (> subject site + 0.1)
35004	Removed due to high FLATWET (> subject site + 0.1)
34009	Removed due to high FLATWET (> subject site + 0.1)

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
35071	Removed due to high FLATWET (> subject site + 0.1)
22009	Removed due to high URBEXT (> subject site + 2.5)
26006	Removed due to high FLATWET (> subject site + 0.1)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25158	18	0.656	109.547
16013	33	0.189	93.583
20006	25	0.276	77.554
25038	17	0.059	136.095
25044	40	0.055	92.546
25002	51	0.861	221.609
16012	28	0.082	229.627
16005	30	0.133	84.000
10002	46	0.490	230.893
16006	33	0.293	75.796
29001	40	0.087	115.480
16003	27	0.340	243.202
22003	10	1.171	271.290
26010	35	0.086	94.527
27003	48	0.037	166.418
27070	29	0.519	143.578

Total years of data	510

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.25	1.24	1.30
10	1.41	1.39	1.48
20	1.57	1.53	1.64
50	1.77	1.69	1.85
100	1.92	1.82	2.00
200	2.07	1.94	2.15
1000	2.42	2.21	2.50

Comments:

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: Rookwood GS

Gauging station No: 26002

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Suck Catchment Model\Final N08 N09\Pooled FloodFrequency Analysis_N08_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26002
Area	641.45
BFI	0.60
SAAR	1067.03
FARL	0.98
URBEXT	0.26
FLATWET	0.69

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 531

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
36010	Removed due to low FARL (<-10%)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	**Discordancy**
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26002	53	0.384	641
30004	38	0.735	699
15004	51	0.017	491
30007	31	0.041	470
30012	9	0.096	1073
14005	48	0.455	405
26005	51	0.136	1085
16008	51	0.699	1090
35005	55	0.122	640
29011	22	1.473	354
7010	19	0.267	700
26007	53	0.064	1207
15012	16	0.045	1057
15007	25	0.134	340

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.20	1.19	1.24
10	1.33	1.30	1.38
20	1.45	1.40	1.51
50	1.61	1.52	1.67
100	1.73	1.61	1.79
200	1.85	1.70	1.91
1000	2.13	1.89	2.19

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.C2 - Pooled analysis site C

Site name: Derrycahill GS

Gauging station No: 26005

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Suck Catchment Model\Final N08 N09\Pooled FloodFrequency Analysis_N08_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26005
Area	1085.38
BFI	0.63
SAAR	1054.40
FARL	0.98
URBEXT	0.23
FLATWET	0.68

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 538

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
36019	Removed due to low FARL (< 0.9)
36010	Removed due to low FARL (< 0.9)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
12001	Removed due to low FLATWET (< -0.1)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26005	51	0.160	1085
16008	51	0.827	1090
16009	52	0.995	1583
30012	9	0.113	1073
15012	16	0.053	1057
26007	53	0.076	1207
30004	38	0.869	699
26002	53	0.454	641
15002	48	0.042	1644
7010	19	0.315	700
16011	51	0.264	2144
35005	55	0.144	640
15004	51	0.020	491

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.24	1.23	1.29
10	1.40	1.37	1.46
20	1.55	1.50	1.62
50	1.74	1.66	1.82
100	1.89	1.78	1.96
200	2.03	1.89	2.11
1000	2.37	2.15	2.45

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Willsbrook GS

Gauging station No: 26006

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Suck Catchment Model\Final N08 N09\Pooled FloodFrequency Analysis_N08_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26006
Area	184.76
BFI	0.49
SAAR	1120.64
FARL	0.97
URBEXT	0.55
FLATWET	0.71

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 539

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
3051	Removed due to high URBEXT (> +/- 2.5)
16012	Removed due to low FLATWET (<-0.1)
25002	Removed due to low FLATWET (<-0.1)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

16005	Removed due to low FLATWET (<-0.1)
29071	Removed due to low FARL (<-10%)

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

14033	Removed due to low FLATWET (<-0.1)
25003	Removed due to low FLATWET (<-0.1)

4th iteration

Table A4.6 Stations with outlying catchment descriptors

34011	Removed due to low FARL (<-10%)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26006	53	1.148	185
35004	14	0.437	117
24011	33	0.592	281
34024	28	0.300	127
7033	25	0.049	125
24012	41	0.274	366
24030	25	0.292	259
24004	52	0.121	242
30005	49	0.081	238
24013	36	0.137	439
30037	21	0.383	210

34009	33	0.037	117
26009	35	0.128	98
22003	10	0.910	271
26020	33	0.245	122
30021	26	0.199	104

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.23	1.22	1.28
10	1.38	1.35	1.44
20	1.52	1.48	1.59
50	1.71	1.63	1.78
100	1.85	1.73	1.92
200	1.98	1.84	2.06
1000	2.31	2.08	2.38

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.F2 - Pooled analysis site F

Site name: Bellagill GS

Gauging station No: 26007

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Suck Catchment Model\Final N08 N09\Pooled FloodFrequency Analysis_N09_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26007
Area	1207.22
BFI	0.58
SAAR	1045.62
FARL	0.98
URBEXT	0.21
FLATWET	0.68

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 549

Is subject site in pooled group? (●) Yes ( ) No at ranked position:

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
36019	Removed due to low FARL (< -10% of subject site)
36010	Removed due to low FARL (< -10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26007	53	0.070	1207
30012	9	0.105	1073
16008	51	0.766	1090
26005	51	0.149	1085
15012	16	0.049	1057
16009	52	0.921	1583
30004	38	0.805	699
26002	53	0.420	641
16011	51	0.244	2144
15002	48	0.039	1644
24008	30	0.149	806
14006	51	0.281	1064

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.22	1.21	1.27
10	1.36	1.34	1.42
20	1.50	1.45	1.56
50	1.68	1.59	1.74
100	1.81	1.70	1.88
200	1.94	1.79	2.01
1000	2.25	2.02	2.32

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: JOHNSTON'S BR.

Gauging station No: 26008

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\NO1 & NO2 folder\NO2 Hydrology\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N02_v6.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26008
Area	280.31
BFI	0.59
SAAR	1035.47
FARL	0.86
URBEXT	0.26
FLATWET	0.68

Catchment descriptors listed from "RBD……." spreadsheet

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25029	Removed due to high FARL (> +10% of subject site)
15007	Removed due to high FARL (> +10% of subject site)
29011	Removed due to high FARL (> +10% of subject site)
25016	Removed due to high FARL (> +10% of subject site)
16004	Removed due to high FARL (> +10% of subject site)
26019	Removed due to high FARL (> +10% of subject site)
15004	Removed due to high FARL (> +10% of subject site)
24030	Removed due to high FARL (> +10% of subject site)
24002	Removed due to high FARL (> +10% of subject site)
25022	Removed due to high FARL (> +10% of subject site)
30005	Removed due to high FARL (> +10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd Iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
18001	Removed due to high FARL (> +10% of subject site)
26006	Removed due to high FARL (> +10% of subject site)
25020	Removed due to high FARL (> +10% of subject site)
7006	Removed due to high FARL (> +10% of subject site)
30037	Removed due to high FARL (> +10% of subject site)
25021	Removed due to high FARL (> +10% of subject site)
30007	Removed due to high FARL (> +10% of subject site)
26014	Removed due to high FARL (> +10% of subject site)
18004	Removed due to high FARL (> +10% of subject site)

3rd Iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
16003	Removed due to high FARL (> +10% of subject site)
26002	Removed due to high FARL (> +10% of subject site)
6025	Removed due to high FARL (> +10% of subject site)
16002	Removed due to high FARL (> +10% of subject site)
25014	Removed due to high FARL (> +10% of subject site)

26020	Removed due to high FARL (> +10% of subject site)
6013	Removed due to high FARL (> +10% of subject site)

4th Iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29001	Removed due to high FARL (> +10% of subject site)
14005	Removed due to high FARL (> +10% of subject site)
16001	Removed due to high FARL (> +10% of subject site)
30004	Removed due to high FARL (> +10% of subject site)

5th Iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
15001	Removed due to high FARL (> +10% of subject site)
25027	Removed due to high FARL (> +10% of subject site)
25003	Removed due to high FARL (> +10% of subject site)

6th Iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29004	Removed due to high FARL (> +10% of subject site)
24004	Removed due to high FARL (> +10% of subject site)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26008	50	0.190	280
7004	23	1.493	246
35001	29	0.495	299
6014	30	0.236	270
7011	22	0.135	282
34005	13	0.132	309
25030	48	0.128	280
6012	47	0.116	163
36018	50	0.292	234
6011	48	0.233	229
6026	46	0.422	148
36016	14	0.595	507
26010	35	0.118	95
36010	50	0.084	772

Total years of data	505

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.23	1.23	1.19
10	1.39	1.36	1.30
20	1.53	1.49	1.40
50	1.72	1.65	1.53

100	1.87	1.76	1.63
200	2.01	1.87	1.72
1000	2.34	2.12	1.94

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Ballymurray

Gauging station No: 26016

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\Inny\NO4 Roscommon\ 111102 - Pooled FloodFrequency Analysis -V3 – Roscommon_prelim_update.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_3595_7
Area	62.30
BFI	0.65
SAAR	1007.65
FARL	1.00
URBEXT	4.66
FLATWET	0.67

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group.

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: Gauging station is not in the list of stations for pooling

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.3 Stations with outlying catchment descriptors

Station	Removed with explanation
6026	URBEXT of 0.90 outside the acceptable range of +/- 2.5
19046	URBEXT of 0.25 outside the acceptable range of +/- 2.5
26010	URBEXT of 0.00 outside the acceptable range of +/- 2.5
26018	FARL of 0.756 outside the acceptabe range of +/- 10%

STEP 4 Remove sites with high discordancy Di
Discordancy limit used: 3

Table A4.4 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
13002	19	0.066	62.959
26058	24	0.501	59.977
24022	20	0.112	41.212
25027	43	0.114	118.865
26022	33	0.278	61.880
16006	33	0.456	75.796
29004	32	0.221	121.435
19020	28	0.460	73.955
25023	34	0.553	113.859
25014	54	0.049	164.415
16001	33	0.228	135.055
19001	48	0.108	103.281
29001	40	0.135	115.480
16051	13	0.940	34.186
14009	25	0.102	68.353
36015	33	1.010	153.058

Total years of data	512

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.24	1.23	1.29
10	1.39	1.37	1.46
20	1.55	1.5	1.62
50	1.74	1.66	1.82
100	1.89	1.78	1.96
200	2.03	1.89	2.11
1000	2.37	2.15	2.45

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: MULLAGH

Gauging station No: 26019

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\NO1 & NO2 folder\NO2 Hydrology\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N02_v6.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26019
Area	253
BFI	0.60
SAAR	980
FARL	0.99
URBEXT	1.29
FLATWET	0.67

Catchment descriptors listed from "RBD……." spreadsheet

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: Removed as the site is not considered reliable for entire period of record

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
7004	Removed due to low FARL (< -10% of subject site)
26008	Removed due to low FARL (< -10% of subject site)
7011	Removed due to low FARL (< -10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25016	48	0.007	275
16004	48	0.036	229
24002	27	0.019	229
6014	30	0.338	270
25022	22	0.097	161
6025	30	0.204	176
7006	19	0.763	177
6013	30	0.193	309
25020	35	0.172	197
29011	22	1.786	354
25029	33	0.326	293
25021	44	0.583	479
16001	33	0.018	135
18004	45	0.426	310
25014	54	0.032	164

Total years of data	520

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.21	1.20	1.17
10	1.35	1.33	1.27
20	1.49	1.44	1.37
50	1.66	1.57	1.48
100	**1.79**	**1.67**	**1.57**
200	1.92	1.77	1.66
1000	**2.22**	**1.98**	**1.86**

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: BALLYMAHON

Gauging station No: 26021

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Inny\NO3 Inny\Pooled FloodFrequency Analysis_NO3_v5.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26021
Area	1098.78
BFI	0.75
SAAR	945.25
FARL	0.81
URBEXT	0.41
FLATWET	0.66

Catchment descriptors listed from "RBD……." spreadsheet

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.73	-2.09	0.56	275	0.56	709
0.89	2.91	0.76	4395	0.94	1182

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.73	-2.09	0.56	**200**	0.56	709
0.90	2.91	0.76	4395	0.94	**1400**

Initial threshold [see in table (1)] derived from the standard criteria, results in 291 years of records suitable for pooling. It is concerned that so many stations have been removed that the remaining may not be hydrologically similar. By relaxing FARL, AREA and SAAR [see in table (2)], revised limits for pooling result in 549 years of records with a maximum discordancy value of 0.403.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
25006	FARL value larger than 0.9 (+12% of subject site).
25011	FARL value larger than 0.9 (+12% of subject site).
7005	FARL value larger than 0.9 (+12% of subject site).
7041	FARL value larger than 0.9 (+12% of subject site).
7009	FARL value larger than 0.9 (+12% of subject site).
7012	FARL value larger than 0.9 (+12% of subject site).
14034	FARL value larger than 0.9 (+12% of subject site).
15002	FARL value larger than 0.9 (+12% of subject site).
12001	FARL value larger than 0.9 (+12% of subject site) and FLATWET value less than 0.56 (subject site - 0.1).
7010	FARL value larger than 0.9 (+12% of subject site).

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	**Discordancy**
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
14018	FARL value larger than 0.9 (+12% of subject site).
15005	FARL value larger than 0.9 (+12% of subject site).
26005	FARL value larger than 0.9 (+12% of subject site).
14019	FARL value larger than 0.9 (+12% of subject site).
16008	FARL value larger than 0.9 (+12% of subject site).
7007	FARL value larger than 0.9 (+12% of subject site).
15012	FARL value larger than 0.9 (+12% of subject site).
14029	FARL value larger than 0.9 (+12% of subject site).

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
14006	FARL value larger than 0.9 (+12% of subject site).
7002	FARL value larger than 0.9 (+12% of subject site).
16009	FARL value larger than 0.9 (+12% of subject site).
16002	FARL value larger than 0.9 (+12% of subject site).
15006	FARL value larger than 0.9 (+12% of subject site).

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
15001	FARL value larger than 0.9 (+12% of subject site).
26002	FARL value larger than 0.9 (+12% of subject site).
25016	FARL value larger than 0.9 (+12% of subject site).
30004	FARL value larger than 0.9 (+12% of subject site).
30012	FARL value larger than 0.9 (+12% of subject site).

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
18001	FARL value larger than 0.9 (+12% of subject site).
26007	FARL value larger than 0.9 (+12% of subject site).
25124	URBEXT value larger than 2.91 (subject site +2.5).
16011	FARL value larger than 0.9 (+12% of subject site).

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
29011	FARL value larger than 0.9 (+12% of subject site).
29007	FARL value larger than 0.9 (+12% of subject site).
6013	FARL value larger than 0.9 (+12% of subject site).
15004	FARL value larger than 0.9 (+12% of subject site).

7th iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
25021	FARL value larger than 0.9 (+12% of subject site).
30007	FARL value larger than 0.9 (+12% of subject site).

8th iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
6014	FARL value larger than 0.9 (+12% of subject site).

9th iteration

Table A4.12 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
18004	FARL value larger than 0.9 (+12% of subject site).

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26021	30	0.653	1099
36016	14	0.373	507
36010	50	0.054	772
36019	47	0.434	1492
26108	15	0.741	527
26012	14	0.409	520
36012	47	0.159	262
26059	23	0.129	257
36011	49	0.688	321
7011	22	0.065	282
6011	48	0.146	229
7004	23	0.725	246
36018	50	0.155	234
35005	55	0.113	640
34001	31	0.153	1975

Total years of data	518

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.19	1.19	1.24
10	1.32	1.30	1.38
20	1.45	1.40	1.50
50	1.61	1.52	1.67
100	1.72	1.61	1.79
200	1.84	1.69	1.91
1000	2.12	1.88	2.18

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on ~500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: Boyle Abbey Bridge GS

Gauging station No: 26108

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\NO1 & NO2 temporary folder\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N01 revised_Rev 1.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26108
Area	511.13
BFI	0.70
SAAR	1139.08
FARL	0.82
URBEXT	0.53
FLATWET	0.71

Catchment descriptors listed for 26108 from "RBD Shannon Data summary.xls" spreadsheet

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
18005	FARL 1.00
30007	FARL 0.989
18001	FARL 1.00
29011	FARL 0.976
12001	FARL 0.999
30004	FARL 0.992
26002	FARL 0.979
15004	FARL 0.998
18004	FARL 0.999
15007	FARL 0.997
19015	FARL 0.997
35001	FARL 0.923
26007	FARL 0.983
16008	FARL 0.999
7010	FARL 0.911
15012	FARL 0.998
36027	FARL 0.720
25029	FARL 0.997
25020	FARL 0.999
16002	FARL 1.00

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26108	15	0.782	527.3
26012	14	0.510	519.9
35005	55	0.168	639.7
36016	14	0.578	506.9
27002	51	0.151	564.3
7011	22	0.126	281.7
6011	48	0.106	229.2
26008	50	0.135	280.3

36010	50	0.094	771.7
36011	49	0.769	320.5
36012	47	0.143	262.0
34005	13	0.163	309.1
7004	23	0.830	245.7
36018	50	0.113	234.4

Total years of data	501

Pooled distributions for further consideration if different from EV1 and LN2:

EV1

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)
2	1.00	1.00
5	1.20	1.19
10	1.33	1.31
20	1.46	1.41
50	1.62	1.54
100	1.74	1.63
200	1.87	1.71
1000	2.15	1.91

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

With regards to the pooling group for 26108 all sites in the final pooling group satisfied the bounds for catchment descriptors including AREA, BFIsoil, AREA, SAAR, FLATWET and URBEXT. Please note that the AREA bounds are 25% of the subject site and 4 times that of the subject site. Therefore this represents bounds of 132 km^2 to 2108 km^2 for AREA.

CALCULATION AUDIT TRAIL

PART A4.H2 - Pooled analysis site H

Site name: Ahascragh Pump Hse

Gauging station No: 26140

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Suck Catchment Model\Final N08 N09\Pooled FloodFrequency Analysis_N09_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26140
Area	100.50
BFI	0.59
SAAR	1092.11
FARL	1.00
URBEXT	0.57
FLATWET	0.65

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 523

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: level only guaging station

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
29071	Removed due to low FARL (< -10% of subject site)
26018	Removed due to low FARL (< -10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
7033	Removed due to low FARL (< -10% of subject site)
34011	Removed due to low FARL (< -10% of subject site)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
29001	40	0.119	115
26010	35	0.118	95
16006	33	0.405	76
30021	26	0.354	104
36015	33	0.896	153
25044	40	0.076	93
29004	32	0.196	121
25027	43	0.102	119
26020	33	0.436	122
16005	30	0.183	84
26009	35	0.227	98
25022	22	0.158	161
25005	46	1.606	193
25038	17	0.081	136
25014	54	0.043	164

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here

for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.21	1.20	1.25
10	1.34	1.32	1.40
20	1.47	1.42	1.53
50	1.64	1.55	1.70
100	1.77	1.65	1.83
200	1.89	1.74	1.96
1000	2.18	1.94	2.25

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The catchment draining towards this station has no significant karst effects. Pooled analysis is considered as an appropriate aproach.

According to the L-Moment Ratio Diagram (see in pooled analysis spreadsheet v2), EV1 is the best fit.

CALCULATION AUDIT TRAIL

PART A4.F2 - Pooled analysis site F

Site name: Summerhill

Gauging station No: GS 26221

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N10\Gauged tributary hydrology\River Cross\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_River Cross GFs.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_4018_4
Area	103.28
BFI	0.795
SAAR	933
FARL	1.00
URBEXT	0.26
FLATWET	0.65

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 540

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: This gauging site is not in the pooling database of stations

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(2) Standard Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-2.24	0	25.82	0.596	700
1.10	2.76	1	413.12	0.994	1166

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
26018	FARL 0.756
6070	FARL 0.830
25124	FARL 0.782
36012	FARL 0.756
36018	FARL 0.849
6012	FARL 0.831
6011	FARL 0.874
36011	FARL 0.792
26059	FARL 0.730
7011	FARL 0.798

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26058	24	0.542	60.0
25025	31	0.290	161.2
7001	18	0.189	151.3
14013	50	0.265	154.4
13002	19	0.071	63.0
7002	26	0.354	285.0
25023	34	0.598	113.9
6026	46	0.409	148.5
25014	54	0.053	164.4
25027	43	0.124	118.9
14009	25	0.110	68.4
25020	35	0.092	197.1
14007	24	0.430	118.6
25022	22	0.192	161.3
18004	45	0.597	310.3
16051	13	1.017	34.2

Total years of data	509

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.26	1.26	1.21
10	1.43	1.41	1.33
20	1.60	1.56	1.45
50	1.81	1.74	1.59
100	1.97	1.88	1.70
200	2.13	2.01	1.80
1000	2.50	2.31	2.05

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

JACOBS

CALCULATION AUDIT TRAIL

PART A4.E2 - Pooled analysis site E

Site name: Coole

Gauging station No: 25044

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N12\N12 Growth curves\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N12.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3881_9
Area	102.26
BFI	0.582
SAAR	1185
FARL	1.00
URBEXT	0.00
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 503

Is subject site in pooled group? (●) Yes ( ) No at ranked position: 1

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-2.5	0.49	25.6	0.437	889
1.10	2.5	0.69	409.0	0.728	1481

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
30021	FLATWET 0.72
29071	FARL 0.804
34011	FARL 0.867
34024	FLATWET 0.73
26014	FLATWET 0.72
26006	FLATWET 0.71
30037	FLATWET 0.71
36071	FARL 0.823
30005	FLATWET 0.710

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25044	40	0.166	92.5
16005	30	0.188	84.0
16006	33	0.248	75.8
25038	17	0.173	136.1
29001	40	0.033	115.5
19001	48	0.028	103.3
26010	35	0.176	94.5
29004	32	0.112	121.4
19020	28	0.221	74.0
25158	18	0.622	109.5
26009	35	0.202	98.2
26020	33	0.249	122.4
16003	27	0.302	243.2
19016	15	1.823	117.8
25027	43	0.031	118.9
25002	51	0.761	221.6

Total years of data	525

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.23	1.22	1.18
10	1.38	1.35	1.29
20	1.52	1.47	1.39
50	1.71	1.62	1.52
100	1.84	1.73	1.61
200	1.98	1.84	1.70
1000	2.30	2.08	1.92

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:
Pooled LN2 distribution selected for the River Killmastulla.

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name:	HEP node 25_583_1 at the confluence of Clodiah and Gorragh
Gauging station No:	N/A

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Brosna Catchment Model\N07\Pooled FloodFrequency Analysis_25_583_1_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_583_1
Area	26.512
BFI	0.342
SAAR	1490
FARL	1
URBEXT	1.09
FLATWET(Formwet)	0.61

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: Ungauged site

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
34029	7

STEP 3 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 4 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET
(to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	not greater than 2.5
FLATWET	?

These criteria can be relaxed in some circumstances if agreed with reviewer.

Initial limits

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.900	-1.410	0.510	6.6	0.257	1118
1.100	3.590	0.710	106.0	0.428	1863

Final limits

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.900	-1.410	0.510	6.6	0.257	1000
1.100	3.590	0.730	260.0	0.489	2000

Table A4.4 Stations with outlying catchment descriptors

Station	Removed with explanation
39008	FARL value is less than 10% from the subject site
39009	FARL value is less than 10% from the subject site
31002	FARL value is less than 10% from the subject site BFIsoil value is greater than 0.489

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Stations removed after 2nd iteration

Station	Removed with explanation
10004	BFIsoil value is greater than 0.489
19014	FARL value is less than 10% from the subject site SAAR value is greater than 2000
35002	BFIsoil value is greater than 0.489

Stations removed after 3rd iteration

Station	Removed with explanation
25158	BFIsoil value is greater than 0.489
33070	FARL value is less than 10% from the subject site BFIsoil value is greater than 0.489
22006	AREA greater than 260

Stations removed after 4th iteration

Station	Removed with explanation
16013	BFIsoil value is greater than 0.489
1055	FARL value is less than 10% from the subject site BFIsoil value is greater than 0.489
22003	AREA greater than 260
34010	AREA greater than 260
23002	AREA greater than 260

Stations removed after 5th iteration

Station	Removed with explanation
34024	BFIsoil value is greater than 0.489

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
36021	27	0.054	23
27001	9	0.102	47
32011	25	0.068	70
39001	31	0.101	51
33001	25	0.036	76
18016	20	0.164	117
1041	32	0.056	116
38001	33	0.063	111
34007	53	0.038	152
23012	18	0.480	62
28001	17	1.293	169
18050	24	0.118	249
30001	18	0.481	121
14033	9	0.696	79
34009	33	0.021	117
23001	33	0.036	192
35004	14	0.257	117
3051	15	1.756	143
26006	53	0.675	185
24030	25	0.172	259

Total no. of years 514

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	LN2	EV1	LO
2	1.00	1.00	1.00
5	1.24	1.25	1.30
10	1.39	1.41	1.48
20	1.53	1.57	1.64
100	1.82	1.92	2.00
200	1.94	2.07	2.15
1000	2.22	2.43	2.51

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The growth factors for FSU 25_583_1 have been compared with the growth curve factors at gauging station 25016 Rahan. These are comparatively similar. The Growth factors for Rahan has therefore been selected and applied to the enitre catchment.

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Benedin Tributary

Gauging station No: Ungauged

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ Lower Shannon\N14\Flood frequency curves\Pooled\Pooled Flood Frequency Analysis_TEMPLATE_17032014_Benedin.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3560_6
Area	3.48
BFI	0.60
SAAR	930.7
FARL	1
URBEXT	28.98
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 215

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1:

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed t
	Refer to comments below

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
10022	17	0.362	12.94
8005	18	0.067	9.17
25040	19	0.125	28.02
10021	24	0.202	32.51
9035	9	0.016	37.14
22009	24	0.254	35.40
9002	25	0.132	34.95
8009	15	1.701	61.64
36031	30	0.309	63.77
8007	15	0.321	37.94
9010	19	0.178	94.26

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.48	1.50	1.37
10	1.79	1.86	1.59
20	2.10	2.22	1.79
50	2.49	2.70	2.04
100	2.78	3.09	2.23
200	3.08	3.48	2.42
1000	3.75	4.47	2.85

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The gauging stations listed in Table A4.5 above are the only stations retained in the pooling analysis spreadsheet for the Benedin tributary. All other gauging stations within the pooling spreadsheet gauging station database have been eliminated as they are different from the subject site. The Benedin tributary site is a very small catchment (< 4km^2) with a relatively high URBEXT value (29%). The sites with relatively high to high URBEXT are retained as a best estimate of the growth factors for the site given the limited amount of stations available in the pooled database.

CALCULATION AUDIT TRAIL

PART A4.A2 - Pooled analysis site A

Site name: Moyroe Stream

Gauging station No: Ungauged

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ Lower Shannon\N14\Flood frequency curves\Pooled\Pooled Flood Frequency Analysis_TEMPLATE_17032014_Moyroe Stream.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3773_5b
Area	8.68
BFI	0.65
SAAR	991.45
FARL	1
URBEXT	16.89
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 215

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Subject site is an ungauged watercourse

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed
	Refer to comments below

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
10022	17	0.362	12.94
25040	19	0.125	28.02
22009	24	0.254	35.40
10021	24	0.202	32.51
9035	9	0.016	37.14
9002	25	0.132	34.95
8005	18	0.067	9.17
9010	19	0.178	94.26
8009	15	1.701	61.64
36031	30	0.309	63.77
8007	15	0.321	37.94

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.48	1.50	1.37
10	1.79	1.86	1.59
20	2.10	2.22	1.79
50	2.49	2.70	2.04
100	2.78	3.09	2.23
200	3.08	3.48	2.42
1000	3.75	4.47	2.85

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The gauging stations listed in Table A4.5 above are the only stations retained in the pooling analysis spreadsheet for the Moyroe Stream. All other gauging stations within the pooling spreadsheet gauging station database have been eliminated as they are different from the subject site. The Moyroe Stream site is a very small catchment (< 9km^2) with a relatively high URBEXT value (17%). Instead the sites with relatively high to high URBEXT are retained as a best estimate of the growth factors for the site given the limited amount of stations available in the pooled database.

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: River Killooly

Gauging station No: 25_709_4

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	Projects\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Brosna Catchment Model\N06\Prelimnary Inflows\Pooled Flood Frequency Analysis_17032014_S Pollagh Trib_Final

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_709_4
Area	36.22
BFI	0.55
SAAR	864.27
FARL	1.00
URBEXT	0.00
FLATWET	0.63

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 511

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: Ungauged site

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
None	

STEP 3 Remove sites with high discordancy Di
Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
None	

STEP 4 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site

BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	not greater than 2.5
FLATWET	

These criteria can be relaxed in some circumstances if agreed with reviewer.

Initial limits

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.900	-2.500	0.530	9.1	0.410	648
1.100	2.500	0.730	144.9	0.684	1080

Final limits

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.900	-2.500	0.530	9.1	0.410	648
1.100	2.810	0.730	181.8	0.684	1116

Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed with explanation** + Reviewer initials if kept
8009	URBEXT outwith threshold.
36031	URBEXT outwith threshold.
10021	URBEXT outwith threshold.
9010	URBEXT outwith threshold.
25040	URBEXT outwith threshold.
10022	URBEXT outwith threshold.
9035	URBEXT outwith threshold.
8003	URBEXT outwith threshold.
8008	URBEXT outwith threshold.
9002	URBEXT outwith threshold.

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration - Not required

Final pooling group

Table A4.5 Final pooling group summary

Station No	**Years of data**	**Discordancy**	**Area (km2)**
6031	18	0.791	46.17
24022	20	0.021	41.21
8012	19	0.518	25.95
8002	21	0.167	33.43
6033	25	1.368	55.23
26022	33	0.095	61.88
16051	13	0.411	34.19

14009	25	0.082	68.35
26009	35	0.125	98.22
26020	33	0.249	122.44
16001	33	0.121	135.05
26010	35	0.060	94.53
14007	24	0.145	118.59
25023	34	0.224	113.86
16006	33	0.152	75.80
14011	25	0.097	162.30
11001	33	0.257	155.11
7006	19	0.876	177.45
8011	23	0.575	181.77

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	LN2	EV1	LO
2	1.00	1.00	1.00
5	1.30	1.30	1.24
10	1.49	1.50	1.38
20	1.67	1.69	1.51
100	2.06	2.12	1.80
200	2.23	2.31	1.92
1000	2.61	2.73	2.20

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 501-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

JACOBS

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name: Drumbane tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N12\N12 Growth curves\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N12.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_1019_4
Area	1.78
BFI	0.596
SAAR	1247
FARL	1.00
URBEXT	30.45
FLATWET	0.60

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 528

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	27.95	0.5	0.4	0.447	935
1.10	32.95	0.7	7.1	0.745	1558

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation	+ Reviewer initials if kept
	Refer to comment below Table A4.4	

Comment:
The Drumbane tributary has an AREA of 1.778 km2 and is also a largely urbanised catchment (URBEXT = 30.45 %). Therefore, the critical event for this catchment is likely to be an urban flooding event where sewers are exceeded in capacity and flow directly into the receiving watercourse (i.e. the urban area falls towards Drumbane tributary). Therefore, the most urbanised pooling sites in the pooling spreadsheet are retained to apoproximate the most appropriate growth factors for this site with the limited pooled data available. All pooling sites with URBEXT greater than 5 % were retained in the pooling group for the Drumbane tributary site with all other sites with URBEXT less than 5 % removed.

STEP 4 Remove sites with high discordancy Di

Discordancy limit used:	3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
10022	17	0.362	12.9
22009	24	0.254	35.4
25040	19	0.125	28.0
8005	18	0.067	9.2
10021	24	0.202	32.5
9035	9	0.016	37.1
9002	25	0.132	35.0
36031	30	0.309	63.8
9010	19	0.178	94.3
8007	15	0.321	37.9
8009	15	1.701	61.6

Total years of data	215

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.48	1.50	1.37
10	1.79	1.86	1.59
20	2.10	2.22	1.79
50	2.49	2.70	2.04
100	2.78	3.09	2.23
200	3.08	3.48	2.42
1000	3.75	4.47	2.85

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:
Pooled EV1 distribution selected for the Drumbane tributary.

JACOBS

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: Fairyhill tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N12\N12 Growth curves\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N12.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3708_4
Area	1.64
BFI	0.721
SAAR	885
FARL	1.00
URBEXT	34.95
FLATWET	0.62

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 526

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(2) Standard Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	32.45	0.52	0.4	0.541	664
1.10	37.45	0.72	6.5	0.901	1107

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
	Refer to comment below Table A4.4

Comment:
The Fairyhill tributary has an AREA of 1.635 km2 and is a largely urbanised catchment (URBEXT = 34.92 %) Therefore, the critical event for this catchment is likely to be an urban flooding event where sewers are are exceeded in capacity and flow directly into the receiving watercourse (i.e. the urban area falls towards Fairyhill tributary). Therefore, the most urbanised pooling sites in the pooling spreadsheet are retained to apoproximate the most appropriate growth factors for this site with the limited pooled data available. All pooling sites with URBEXT greater than 5 % were retained in the pooling group for the Fairyhill tributary site with all other sites with URBEXT less than 5 % removed.

STEP 4 Remove sites with high discordancy Di

Discordancy limit used:	3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
10022	17	0.362	12.9
8005	18	0.067	9.2
25040	19	0.125	28.0
10021	24	0.202	32.5
9002	25	0.132	35.0
9035	9	0.016	37.1
22009	24	0.254	35.4
8009	15	1.701	61.6
36031	30	0.309	63.8
9010	19	0.178	94.3
8007	15	0.321	37.9

Total years of data	215

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.48	1.50	1.37
10	1.79	1.86	1.59
20	2.10	2.22	1.79
50	2.49	2.70	2.04
100	2.78	3.09	2.23
200	3.08	3.48	2.42
1000	3.75	4.47	2.85

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:
Pooled EV1 distribtion selected for the Fairyhill tributary.

JACOBS

CALCULATION AUDIT TRAIL

PART A4.F2 - Pooled analysis site F

Site name: Stradbally East tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N12\N12 Growth curves\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N12.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3823_8b
Area	3.05
BFI	0.500
SAAR	1025
FARL	1.00
URBEXT	3.50
FLATWET	0.60

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 513

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	1	0.5	0.8	0.375	769
1.10	6	0.7	12.2	0.625	1282

Initial threshold values (see table in Step 3) needed to be widened to retain sufficient pooled stations, due to the small catchment area (3.05 km^2) and low BFI value.
Revised thresholds are:

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR

0.90	0	0.5	0.8	**0.325**	769
1.10	3.5	0.7	**122.0**	**0.675**	1282

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
9011	URBEXT 68.33
10022	URBEXT 29.72
8005	URBEXT 25.01
25034	BFI 0.759
25040	URBEXT 6.18
30020	BFI 0.684
22009	URBEXT 5.75
8007	URBEXT 6.49
16051	BFI 0.676
10021	URBEXT 24.21
36031	URBEXT 6.00
9035	URBEXT 33.37
9002	URBEXT 20.97
36071	FARL 0.823
8009	URBEXT 7.54
25040	URBEXT 6.18
16051	BFI 0.676
9010	URBEXT 24.04
8003	URBEXT 4.56
10004	SAAR 1700.39 mm
19046	BFI 0.698
13002	BFI 0.733
1055	SAAR 1975.76 mm
36021	SAAR 1569.64 mm

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	**Discordancy**
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	**Years of data**	**Discordancy**	**Area (km2)**
6030	27	0.315	10.4
8012	19	0.725	26.0
24022	20	0.038	41.2
6031	18	0.580	46.2
8002	21	0.104	33.4
6033	25	1.141	55.2
26022	33	0.183	61.9
23012	18	0.545	61.6
14033	9	1.454	78.9
16006	33	0.268	75.8
16005	30	0.081	84.0
26009	35	0.111	98.2
26010	35	0.022	94.5
25044	40	0.011	92.5
19020	28	0.309	74.0
14009	25	0.064	68.4

30021	26	0.110	103.6
35004	14	0.318	117.0
29004	32	0.149	121.4
29001	40	0.138	115.5

Total years of data	528

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.31	1.31	1.25
10	1.52	1.51	1.39
20	1.71	1.69	1.53
50	1.97	1.93	1.70
100	2.16	2.11	1.82
200	2.35	2.28	1.95
1000	2.79	2.69	2.24

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:
Pooled EV1 distribution selected for the Stradbally East tributary and nearby Cederwood tributary. The pooled EV distribution at this site was also adopted for the Grange tributary and the unnamed tributary to the River Killmastulla. This was done so as the pooling analysis at Grange and the Killmastulla tributary resulted in similar growth factors as those derived at Stradbally East, although the Stradbally East growth curve is slightly steeper. Both the Grange tributary and tributary to River Killmastulla are steep catchments (i.e. S1085 ~ 25 m/km) and so the steep growth curve derived at Stradbally East was deemed suitable for both these sites.

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name: Tributary Cappavilla

Gauging station No: NONE
ungauged

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Lower Shannon\N16\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N16_v4.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_1205_4	***@ bottom of the Tributary Cappavilla***
Area	1.757	
BFI	0.544046	
SAAR	1016.71	
FARL	1	
URBEXT	0	
FLATWET	0.59	

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group.

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged site.

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Using the recommended thresholds there is no record for pooling. Therefore the limits of URBEXT, AREA and SAAR are revised to improve pooling group.

AREA	between 0.25 and 55 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	- 25% / +75% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 6
FLATWET	(FORMWET) - 0.10/ +0.1 (half of total range)

Table A4.3 Stations with outlying catchment descriptors

Station	Removed with explanation
9011	URBEXT greater than URBEXT(subject site) + 6.
10022	URBEXT greater than URBEXT(subject site) + 6.
8005	URBEXT greater than URBEXT(subject site) + 6; SAAR less than -25% of subject site
25034	BFI greater than +25% of subject site.
30020	FLATWET greater than FLATWET(subject site) +0.1; BFI greater than +25% of subject site.
25040	URBEXT greater than URBEXT(subject site) + 6.
10021	URBEXT greater than URBEXT(subject site) + 6.
9035	URBEXT greater than URBEXT(subject site) + 6.
9002	URBEXT greater than URBEXT(subject site) + 6; SAAR less than -25% of subject site
8007	URBEXT greater than URBEXT(subject site) + 6; BFI less than -25% of subject site.
8009	URBEXT greater than URBEXT(subject site) + 6.
36071	FARL less than -10% of subject site; FLATWET greater than FLATWET(subject site) +0.1

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.4 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
19046	BFI greater than +25% of subject site.
13002	BFI greater than +25% of subject site.
26058	BFI greater than +25% of subject site.
1055	FARL less than -10% of subject site; SAAR greater than +75% of subject site
9010	URBEXT greater than URBEXT(subject site) + 6.
26009	AREA greater than 55 times of subject site.

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
30021	FLATWET greater than FLATWET(subject site) +0.1; AREA greater than 55 times of subject site

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29001	AREA greater than 55 times of subject site

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
19001	AREA greater than 55 times of subject site

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
26020	AREA greater than 55 times of subject site

7th iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
35004	FLATWET greater than FLATWET(subject site) +0.1; AREA greater than 55 times of subject site
29004	AREA greater than 55 times of subject site

8th iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
31002	FARL less than -10% of subject site

9th iteration

Table A4.12 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
33070	FARL less than -10% of subject site; FLATWET greater than FLATWET(subject site) +0.1

10th iteration

Table A4.13 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25023	AREA greater than 55 times of subject site

11th iteration

Table A4.14 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25027	AREA greater than 55 times of subject site

12th iteration

Table A4.15 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
36021	BFI less than -25% of subject site.

13th iteration

Table A4.16 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
8008	AREA greater than 55 times of subject site

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
6030	27	0.155	10.400
8012	19	0.754	25.953
22009	24	0.091	35.397
24022	20	0.072	41.212
16051	13	0.103	34.186
8002	21	0.090	33.428
6031	18	0.296	46.174
6033	25	0.696	55.227
26022	33	0.271	61.880
36031	30	0.421	63.769
16006	33	0.349	75.796
23012	18	0.294	61.631
16005	30	0.106	84.000
14009	25	0.080	68.353
19020	28	0.407	73.955
14033	9	1.445	78.892
26010	35	0.034	94.527
25044	40	0.023	92.546
10004	14	0.778	30.567
8003	18	0.494	83.595
20006	25	0.041	77.554

Total years of data	505

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.34	1.35	1.27
10	1.57	1.58	1.44
20	1.79	1.79	1.58
50	2.07	2.07	1.77
100	2.29	2.28	1.91
200	2.50	2.49	2.05
1000	2.99	2.99	2.37

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

30 of the selected catchments were removed as they were not deemed appropriate - this amounts to 15% of the dataset. The resultant pooling group will be less hydrologically similar to the study site.

CALCULATION AUDIT TRAIL

PART A4.E2 - Pooled analysis site E

Site name: Tributary Blackwater

Gauging station No: NONE
ungauged

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Lower Shannon\N16\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N16_v4.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_3329_2
Area	61.288
BFI	0.385396
SAAR	1181.62
FARL	1
URBEXT	0.22
FLATWET	0.60

@ bottom of the Tributary Blackwater

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group.

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged site.

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

Using the recommended thresholds there are only 138 years of records, which is not enough for pooling. Therefore the upper limits of FLATWET, AREA and SAAR are revised to improve pooling group.

AREA	between 0.25 and 10 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	- 25% / +60% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) - 0.15/ +0.15 (half of total range)

Table A4.3 Stations with outlying catchment descriptors

Station	Removed with explanation
3051	URBEXT greater than URBEXT(subject site) + 2.5
7033	FARL less than -10% of subject site
35004	BFI greater than +25% of subject site.
36071	FARL less than -10% of subject site; BFI greater than +25% of subject site.
34024	BFI greater than +25% of subject site.
29004	BFI greater than +25% of subject site.
36031	URBEXT greater than URBEXT(subject site) + 2.5; BFI greater than +25% of subject site.
8007	URBEXT greater than URBEXT(subject site) + 2.5; SAAR less than -25% of subject site.

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.4 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
33070	FARL less than -10% of subject site; BFI greater than +25% of subject site.
39009	FARL value less than -10% of subject site.
30021	BFI greater than +25% of subject site.
6030	AREA value less than 0.25 times of subject site.

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
33001	BFI less than -25% of subject site.
26009	BFI greater than +25% of subject site.
16005	BFI greater than +25% of subject site.

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
11001	BFI greater than +25% of subject site.
27001	BFI less than -25% of subject site.

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29001	BFI greater than +25% of subject site.

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29071	FARL less than -10% of subject site; BFI greater than +25% of subject site.

Final pooling group

Table A4.10 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
34009	33	0.012	117.114
1041	32	0.021	116.180
14033	9	0.588	78.892
35002	34	0.040	88.820
23012	18	0.911	61.631
36015	33	0.625	153.058
18016	20	0.191	116.728
23001	33	0.150	191.744
29007	22	0.087	271.482
24011	33	0.223	281.234
25005	46	0.391	192.616
34029	7	1.190	226.834
18050	24	0.047	248.829
22003	10	0.838	271.290
24012	41	0.075	366.282
36021	27	0.179	23.406
34007	53	0.114	151.710
15003	51	0.317	299.166

Total years of data	526

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.21	1.20	1.17
10	1.35	1.33	1.27
20	1.48	1.44	1.36
50	1.66	1.57	1.48
100	1.79	1.67	1.57
200	1.91	1.76	1.65
1000	2.21	1.97	1.85

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

According to the L-moment ratio diagram, LN2 provides the best fit and will be taken forward for flood frequency analysis.

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name: River Bilboa

Gauging station No: Ungauged

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N15 Mulkear\Pooled FloodFrequency Analysis_N15_v3.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_833_2
Area	9.59
BFI	0.450
SAAR	997
FARL	1.00
URBEXT	1.57
FLATWET	0.59

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: Site is ungauged

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

To improve the homogenity of the final pooling group, the upper limits of the catchment descriptiors listed below have been increased.

AREA	between 0.25 and 10.4 times the area of the subject site
BFIsoil	step interval of 1.25
URBEXT	+10/- 2.5

Table A4.4 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
10022	Removed due to high URBEXT (> subject site +10)
9011	Removed due to high URBEXT (> subject site +10)
8005	Removed due to high URBEXT (> subject site +10)
23012	Removed due to high SAAR (> +25% of subject site)
30020	Removed due to high FLATWET (> +0.10 subject site)
36071	Removed due to high FARL (> +10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.4 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
9010	Removed due to high FLATWET (> +0.10 subject site)
10021	Removed due to high FLATWET (> +0.10 subject site)
7033	Removed due to high FARL (> +10% of subject site)
35004	Removed due to high FLATWET (> +0.10 subject site)

3rd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
8008	Removed due to high AREA (> +10.4 of subject site)
29004	Removed due to high AREA (> +10.4 of subject site)
30021	Removed due to high AREA (> +10.4 of subject site)

4th iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed with explanation + Reviewer initials if kept
3051	Removed due to high AREA (> +10.4 of subject site)
9035	Removed due to high URBEXT (> subject site +10)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
6030	27	0.098	10.400
8012	19	0.489	25.953
24022	20	0.039	41.212
8007	15	0.226	37.936
6031	18	0.222	46.174
36031	30	0.342	63.769
6033	25	0.482	55.227
25040	19	0.025	28.022
22009	24	0.082	35.397
14033	9	1.028	78.892
8002	21	0.078	33.428
26022	33	0.180	61.880
8003	18	0.340	83.595
26009	35	0.115	98.221
8009	15	2.286	61.644
16051	13	0.088	34.186
16006	33	0.224	75.796
16005	30	0.089	84.000
26010	35	0.032	94.527
25034	26	0.521	10.770
25044	40	0.014	92.546

Total years of data	505

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here

for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.36	1.37	1.29
10	1.60	1.61	1.46
20	1.83	1.85	1.61
50	2.13	2.15	1.81
100	2.36	2.38	1.96
200	2.58	2.61	2.10
1000	3.09	3.16	2.44

Comments:

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

JACOBS

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name: Drumbane tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N12\N12 Growth curves\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N12.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_1019_4
Area	1.78
BFI	0.596
SAAR	1247
FARL	1.00
URBEXT	30.45
FLATWET	0.60

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 528

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	27.95	0.5	0.4	0.447	935
1.10	32.95	0.7	7.1	0.745	1558

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation	+ Reviewer initials if kept
	Refer to comment below Table A4.4	

Comment:
The Drumbane tributary has an AREA of 1.778 km2 and is also a largely urbanised catchment (URBEXT = 30.45 %). Therefore, the critical event for this catchment is likely to be an urban flooding event where sewers are exceeded in capacity and flow directly into the receiving watercourse (i.e. the urban area falls towards Drumbane tributary). Therefore, the most urbanised pooling sites in the pooling spreadsheet are retained to apoproximate the most appropriate growth factors for this site with the limited pooled data available. All pooling sites with URBEXT greater than 5 % were retained in the pooling group for the Drumbane tributary site with all other sites with URBEXT less than 5 % removed.

STEP 4 Remove sites with high discordancy Di

Discordancy limit used:	3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4
The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
10022	17	0.362	12.9
22009	24	0.254	35.4
25040	19	0.125	28.0
8005	18	0.067	9.2
10021	24	0.202	32.5
9035	9	0.016	37.1
9002	25	0.132	35.0
36031	30	0.309	63.8
9010	19	0.178	94.3
8007	15	0.321	37.9
8009	15	1.701	61.6

Total years of data	215

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.48	1.50	1.37
10	1.79	1.86	1.59
20	2.10	2.22	1.79
50	2.49	2.70	2.04
100	2.78	3.09	2.23
200	3.08	3.48	2.42
1000	3.75	4.47	2.85

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:
Pooled EV1 distribution selected for the Drumbane tributary.

CALCULATION AUDIT TRAIL

PART A4.I2 - Pooled analysis site I

Site name: Tributary Deerpark

Gauging station No: N/A HEP node 26_3977_3

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Suck Catchment Model\Final N08 N09\Pooled FloodFrequency Analysis_N09_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_3977_3
Area	61.03
BFI	0.64
SAAR	1064.62
FARL	0.99
URBEXT	1.10
FLATWET	0.64

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 512

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged tributary

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
26018	Removed due to low FARL (< -10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
22009	Removed due to low FARL (< -10% of subject site)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
13002	19	0.074	63
16006	33	0.512	76
26058	24	0.563	60
19020	28	0.517	74
29004	32	0.248	121
25027	43	0.129	119
24022	20	0.126	41
26010	35	0.150	95
19046	9	0.697	63
19001	48	0.121	103
29001	40	0.151	115
26022	33	0.313	62
25044	40	0.097	93
36015	33	1.135	153
30021	26	0.448	104
25014	54	0.055	164

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.26	1.25	1.32
10	1.43	1.41	1.50
20	1.59	1.55	1.67
50	1.80	1.74	1.89
100	1.96	1.87	2.05
200	2.12	2.00	2.20
1000	2.49	2.29	2.57

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The catchment draining towards this station has no significant karst effects. Pooled analysis is considered as an appropriate aproach.

According to the L-Moment Ratio Diagram (see in pooled analysis spreadsheet v2), EV1 is the best fit.

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name: ungauged

Gauging station No: 26_4022_8

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\NO1 & NO2 folder\NO2 Hydrology\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N02_v6.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_4022_8
Area	69.60
BFI	0.64
SAAR	1061.97
FARL	0.87
URBEXT	0.00
FLATWET	0.69

Catchment descriptors listed from "RBD……." spreadsheet

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

Upper limit of AREA is adjusted to 5 times the area of the subject site in order to get sufficient year of data for pooling.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
16006	Removed due to high FARL (> +10% of subject site)
25027	Removed due to high FARL (> +10% of subject site)
19020	Removed due to high FARL (> +10% of subject site)
19001	Removed due to high FARL (> +10% of subject site)
29001	Removed due to high FARL (> +10% of subject site)
13002	Removed due to high FARL (> +10% of subject site); and low FLATWET (< subject site -0.1)
25044	Removed due to high FARL (> +10% of subject site)
19046	Removed due to high FARL (> +10% of subject site)
16005	Removed due to high FARL (> +10% of subject site)
26018	Removed due to high FARL (> +10% of subject site)
25023	Removed due to high FARL (> +10% of subject site)
22009	Removed due to high FARL (> +10% of subject site); and high URBEXT (> subject site +2.5)
9010	Removed due to high FARL (> +10% of subject site); high URBEXT (> subject site +2.5); and low FLATWET (< subject site -0.1)
26022	Removed due to high FARL (> +10% of subject site)
26020	Removed due to high FARL (> +10% of subject site)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd Iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25022	Removed due to high FARL (> +10% of subject site)
25014	Removed due to high FARL (> +10% of subject site)
25040	Removed due to high FARL (> +10% of subject site) and high URBEXT (> subject site +2.5)

30021	Removed due to high FARL (> +10% of subject site)
6031	Removed due to high FARL (> +10% of subject site)
16001	Removed due to high FARL (> +10% of subject site) and low FLATWET (< subject site -0.1)
25020	Removed due to high FARL (> +10% of subject site)
25038	Removed due to high FARL (> +10% of subject site)
26058	Removed due to high FARL (> +10% of subject site)
19016	Removed due to high FARL (> +10% of subject site)
16051	Removed due to high FARL (> +10% of subject site) and low FLATWET (< subject site -0.1)
29004	Removed due to high FARL (> +10% of subject site)

3rd Iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
7001	Removed due to high FARL (> +10% of subject site)
24022	Removed due to high FARL (> +10% of subject site)
6025	Removed due to high FARL (> +10% of subject site)
14009	Removed due to high FARL (> +10% of subject site)
7004	Removed due to low FARL (< -10% of subject site)
26006	Removed due to high FARL (> +10% of subject site)
14013	Removed due to high FARL (> +10% of subject site) and low FLATWET (< subject site -0.1)

4th Iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
19015	Removed due to high FARL (> +10% of subject site)
7006	Removed due to high FARL (> +10% of subject site)
30020	Removed due to high FARL (> +10% of subject site)
25025	Removed due to high FARL (> +10% of subject site)

5th Iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
30037	Removed due to high FARL (> +10% of subject site)
16004	Removed due to high FARL (> +10% of subject site)

6th Iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25158	Removed due to high FARL (> +10% of subject site) and high SAAR (> +25% of subject site)
30005	Removed due to high FARL (> +10% of subject site)

7th Iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
14007	Removed due to high FARL (> +10% of subject site) and low FLATWET (< subject site -0.1)
24002	Removed due to high FARL (> +10% of subject site)

8th Iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
35004	Removed due to high FARL (> +10% of subject site)
25016	Removed due to high FARL (> +10% of subject site) and high URBEXT (> subject site +2.5)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26010	35	0.191	95
6012	47	0.141	163
26009	35	0.227	98
6026	46	0.515	148
6070	27	0.042	162
29071	26	0.055	124
34011	30	0.220	143
34024	28	0.867	127
6011	48	0.166	229
26014	16	0.425	215
36018	50	0.223	234
26008	50	0.261	280
7011	22	0.218	282
36071	20	1.145	68
6014	30	0.303	270

Total years of data	510

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.21	1.21	1.17
10	1.35	1.33	1.27
20	1.49	1.44	1.37
50	1.66	1.58	1.49
100	1.79	1.68	1.57
200	1.92	1.77	1.66
1000	2.22	1.99	1.86

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: Aghagrania River

Gauging station No: HEP 26_59_3

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ NO1 & NO2 temporary folder\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N01 revised_Rev 1.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_59_3
Area	11.93
BFI	0.48
SAAR	1281.16
FARL	0.89
URBEXT	3.26
FLATWET	0.70

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse so it is not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.80	0.76	0.6	2.982	0.36	961
0.98	5.76	0.8	47.712	0.60	1601

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.80	0.26	**0.5**	2.982	**0.26**	**769**
0.98	6.26	**0.9**	**357.84**	**0.69**	**1794**

Initial threshold [see in table (1)] derived from the standard criteria. The fact that the Aghagrania River has such a small catchment area (11.93 km2) and low BFI value made amednments to the standard boundary conditions necessary to obtain a pooling group.

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
6030	URBEXT 0.00
23012	FARL 0.999
22009	FARL 0.995
10004	FARL 0.986
36071	URBEXT 0.00
14033	FARL 1.00
30020	FARL 1.00
31002	FARL 0.632
24022	FARL 1.00
33070	FARL 0.677
35002	FARL 0.986
16005	FARL 1.00
25040	FARL 1.00
16006	FARL 0.994
16013	FARL 0.993
1055	FARL 0.737
6031	FARL 1.00
36021	FARL 0.995
25044	FARL 0.997
30021	FARL 0.994
35004	FARL 0.994
29071	URBEXT 0.00
34009	FARL 1.00
29004	FARL 0.993
26010	URBEXT 0.00
26009	URBEXT 0.00
19020	FARL 1.00
20006	FARL 1.00
1041	FARL 1.00
10022	FARL 1.00
26022	FARL 1.00
39008	FARL 0.781
25158	FARL 1.00
6033	FARL 0.996
19046	FARL 1.00
8012	FARL 0.999
29001	FARL 0.998
8007	FARL 1.00
19001	FARL 1.00
9010	URBEXT 24.04

25038	FARL 1.00
36015	URBEXT 0.02
26020	FARL 1.00
16051	FARL 1.00
25034	FARL 1.00
34018	FARL 0.732
18016	FARL 1.00
9011	FARL 1.00
26006	AREA 184.76 km2
30001	URBEXT 0.00
8002	FARL 1.00
19016	FARL 1.00
13002	FARL 1.00
25002	FARL 0.999
8003	FARL 1.00
30037	FARL 0.987
25005	FARL 0.999
25027	FARL 1.00
11001	FARL 1.00
27070	URBEXT 0.00
8005	FARL 1.00
10021	FARL 0.997
16003	FARL 0.998
27001	FARL 0.987
22003	FARL 1.00
30005	FARL 0.985
10002	URBEXT 0.17
8009	FARL 1.00
27003	URBEXT 0.15
16001	FARL 1.00
18050	FARL 0.998
7006	FARL 0.990
8008	FARL 1.00
32012	URBEXT 0.00
25030	URBEXT 0.13
25022	FARL 1.00
9035	FARL 0.993
25023	FARL 1.00
24030	FARL 1.00
16012	FARL 0.998
16007	FARL 0.998
26058	FARL 0.995
39001	FARL 0.987
26018	FARL 0.756
34029	FARL 0.980
24004	FARL 1.00
14009	FARL 1.00
33001	FARL 0.998
24011	FARL 1.00
21001	FARL 0.665
25014	FARL 1.00
26019	FARL 0.986
34007	FARL 0.987
25029	FARL 0.997
19031	FARL 0.999
9002	FARL 1.00
19015	FARL 0.997
6025	URBEXT 0.22
16004	FARL 1.00
25020	FARL 0.999
7004	FARL 0.772
23001	FARL 1.00

24002	FARL 1.00
6070	BFI 0.733
25003	FARL 0.998
24012	FARL 1.00
15007	FARL 0.997
8011	FARL 0.999
14007	FARL 1.00
7001	FARL 0.996
12013	FARL 0.999
19014	URBEXT 0.00
18001	URBEXT 0.00
35011	FARL 0.978
25016	FARL 0.999
14005	FARL 1.00
14011	FARL 1.00
36027	FARL 0.72
28001	URBEXT 0.05
14013	FARL 0.999
6011	BFI 0.708
15003	FARL 0.997
24013	FARL 1.00
34010	FARL 0.988
32011	FARL 0.986
9001	FARL 1.00
20002	FARL 0.987
14004	FARL 0.999
7011	FARL 0.798
25025	FARL 0.995

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
36031	30	0.579	63.8
34024	28	0.591	127.2
7033	25	0.002	124.9
34011	30	0.082	143.0
3051	15	2.501	143.2
26014	16	0.012	215.1
39009	33	0.047	206.8

29007	22	0.012	271.5
6012	47	0.127	162.8
6026	46	0.204	148.5
34005	13	0.002	309.1
35001	29	0.338	299.5
26008	50	0.066	280.3
29011	22	0.559	354.1
6014	30	0.114	270.4
38001	33	0.117	111.2
36018	50	0.314	234.4

Total years of data	519

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)
2	1.00	1.00
5	1.22	1.22
10	1.37	1.35
20	1.51	1.47
50	1.70	1.62
100	1.84	1.72
200	1.97	1.83
1000	2.29	2.06

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.E2 - Pooled analysis site E

Site name: ungauged

Gauging station No: 26_695_1

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\NO1 & NO2 folder\NO2 Hydrology\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N02_v6.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_695_1
Area	11.77
BFI	0.47
SAAR	1034.47
FARL	1.00
URBEXT	6.06
FLATWET	0.69

Catchment descriptors listed from "RBD……." spreadsheet

Number of pooled years required: 400 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	3.56	0.59	3	0.35	776
1.10	8.56	0.79	47	0.59	1293

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	0.50	0.50	1.2	0.31	724
1.10	30.00	0.79	117.7	0.64	1345

Initial threshold [see in table (1)] derived from the standard criteria results in no records suitable for pooling. By relaxing URBEXT, FORMWET, AREA, BFI and SAAR [see in table (2)], revised limits for pooling result in 535 years of records with a maximum discordancy value of 1.76.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
6030	Removed due to low URBEXT (< 0.5)
24022	Removed due to low URBEXT (< 0.5)
25040	Removed due to high BFI (> 0.64)
9011	Removed due to high URBEXT (> 30)
8005	Removed due to low SAAR (< 724)
30020	Removed due to low URBEXT (< 0.5) and high BFI (> 0.64)
16006	Removed due to low URBEXT (< 0.5)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd Iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
36071	Removed due to low FARL (< -10% of subject site) and low URBEXT (< 0.5)
26009	Removed due to low URBEXT (< 0.5)
16005	Removed due to low URBEXT (< 0.5)
16051	Removed due to low URBEXT (< 0.5) and high BFI (> 0.64)
35004	Removed due to low URBEXT (< 0.5)

3rd Iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
26010	Removed due to low URBEXT (< 0.5)
7033	Removed due to low FARL (< -10% subject site) and high AREA (>117.7)
10021	Removed due to high BFI (> 0.64)
30021	Removed due to low URBEXT (< 0.5)

4th Iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29004	Removed due to high AREA (>117.7)
25044	Removed due to low URBEXT (< 0.5)
25034	Removed due to low URBEXT (< 0.5) and high BFI (>0.64)
26020	Removed due to low URBEXT (< 0.5) and high AREA (>117.7)

5th Iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
34024	Removed due to high AREA (>117.7)
3051	Removed due to high AREA (>117.7)

6th Iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
9035	Removed due to high URBEXT (> 30) and high BFI (> 0.64)
35002	Removed due to low URBEXT (< 0.5) and high SAAR (> 1345)

7th Iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29071	Removed due to low FARL (< -10% subject site), low URBEXT (< 0.5) and high AREA (>117.7)
36015	Removed due to low URBEXT (< 0.5) and high AREA (>117.7)

8th Iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation

11001	Removed due to high AREA (>117.7)
19020	Removed due to low URBEXT (< 0.5) and high BFI (> 0.64)

9th Iteration

Table A4.12 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
33070	Removed due to low FARL (< -10% subject site), low URBEXT (< 0.5) and high SAAR (> 1345)

10th Iteration

Table A4.13 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
9002	Removed due to high BFI (> 0.64)

11th Iteration

Table A4.14 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
19046	Removed due to low URBEXT (< 0.5) and high BFI (> 0.64)

12th Iteration

Table A4.15 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
14009	Removed due to low URBEXT (< 0.5) and high BFI (> 0.64)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
8012	19	0.459	26
6031	18	0.146	46
10022	17	0.174	13
22009	24	0.093	35
8007	15	0.214	38
36031	30	0.261	64
6033	25	0.344	55
23012	18	0.174	62
14033	9	0.949	79
26022	33	0.195	62
8002	21	0.080	33
8003	18	0.232	84
9010	19	0.305	94
8009	15	1.783	62
29001	40	0.183	115
8008	25	0.068	108
34009	33	0.165	117
19001	48	0.176	103

Total years of data	427

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.37	1.37	1.29
10	1.61	1.62	1.46
20	1.85	1.86	1.62
50	2.15	2.17	1.82
100	2.37	2.41	1.97
200	2.60	2.65	2.12
1000	3.12	3.21	2.45

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). Yet, there is not sufficient data available for small catchment pooling. In this instance the pooling group is based on 400-years of AMAX event data, four times the target return period, a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 4T the estimates will be less certain and should be treated

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CALCULATION AUDIT TRAIL

PART A4.G2 - Pooled analysis site G

Site name: Cuilglass tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N10\Ungauged tributary hydrology\River Cuilglass\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_River Cuilglass GFs.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_1459_4
Area	16.35
BFI	0.585
SAAR	923
FARL	1.00
URBEXT	0.00
FLATWET	0.65

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 514

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**
(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-2.5	0.55	4.09	0.439	692
1.10	2.5	0.75	65.40	0.731	1154

Initial threshold values (see table in Step 3) needed to be widened to retain sufficient pooled stations, due to the small catchment area (16.35 km2). Revised thresholds are:

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-2.5	0.55	4.09	0.439	**692**
1.10	2.5	0.75	**130.80**	0.731	**1181**

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
10022	URBEXT 29.72
25040	URBEXT 6.18
10021	URBEXT 24.21
9035	URBEXT 33.37
25034	BFI 0.759
9011	URBEXT 68.33
22009	URBEXT 5.75
9002	URBEXT 20.97
6033	URBEXT 2.78
30020	SAAR 1190.7 mm
8005	URBEXT 25.01
8009	URBEXT 7.54
36021	URBEXT 6.00
9010	URBEXT 24.04
13002	BFI 0.733
26058	BFI 0.773
8003	URBEXT 4.56
16001	AREA 135.1 km2
19046	SAAR 1196.5 mm

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
24022	20	0.068	41.2
8012	19	0.793	26.0
6031	18	1.114	46.2
16051	13	0.573	34.2
8002	21	0.226	33.4
26022	33	0.170	61.9
14009	25	0.062	68.4
16006	33	0.278	75.8
6030	27	0.699	10.4
26010	35	0.081	94.5
26009	35	0.156	98.2
16005	30	0.126	84.0
25023	34	0.337	113.9
26020	33	0.299	122.4
19020	28	0.280	74.0
25027	43	0.070	118.9

Total years of data	447

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.30	1.30	1.24
10	1.50	1.49	1.38
20	1.69	1.67	1.51
50	1.94	1.90	1.68
100	2.13	2.07	1.80
200	2.31	2.24	1.92
1000	2.74	2.62	2.21

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

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CALCULATION AUDIT TRAIL

PART A4.C2 - Pooled analysis site C

Site name: Culiaghy tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N10\Ungauged tributary hydrology\River Culiaghy\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_Culiaghy trib GFs_Rev1.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_2818_2
Area	5.32
BFI	0.468
SAAR	952
FARL	1.00
URBEXT	1.00
FLATWET	0.67

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 511

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**
(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-1.5	0.57	1.3	0.351	714
1.10	3.5	0.77	21.3	0.585	1190

Initial threshold values (see table in Step 3) needed to be widened to retain sufficient pooled stations, due to the small catchment area (5.3 km^2) and low BFI value.
Revised thresholds are:

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-1.5	0.57	1.3	**0.281**	714
1.10	3.5	0.77	**127.7**	**0.655**	1190

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
6030	URBEXT 0.00
9011	URBEXT 68.33
8005	URBEXT 25.01
10022	URBEXT 29.72
8012	URBEXT 0.60
24022	URBEXT 0.33
25040	BFI 0.641
6031	URBEXT 1.54
6033	URBEXT 2.78
8002	URBEXT 0.54
22009	BFI 0.600
25034	URBEXT 0.00
10021	URBEXT 24.21
30020	URBEXT 0.99
16051	URBEXT 0.00
26022	URBEXT 0.56
25034	BFI 0.758
16051	BFI 0.676
23012	SAAR 1264
9035	URBEXT 33.37
9002	URBEXT 20.97
9010	URBEXT 24.04
36071	FARL 0.823
8008	AREA 107.00
35004	AREA 116.96
7033	FARL 0.893
14009	BFI 0.667
29004	AREA 121.43
26020	AREA 122.40

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
6030	27	0.503	10.4
8012	19	0.570	26.0
24022	20	0.049	41.2
6031	18	0.801	46.2
6033	25	1.447	55.2
8002	21	0.163	33.4
26022	33	0.122	61.9
14033	9	1.039	78.9
16006	33	0.200	75.8
26009	35	0.112	98.2
16005	30	0.090	84.0
26010	35	0.058	94.5
30021	26	0.175	103.6
29004	32	0.097	121.4
26020	33	0.215	122.4
25044	40	0.038	92.5
29001	40	0.059	115.5
34024	28	0.263	127.2

Total years of data	504

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.30	1.30	1.24
10	1.50	1.49	1.38
20	1.69	1.66	1.51
50	1.93	1.89	1.68
100	2.12	2.06	1.80
200	2.30	2.22	1.92
1000	2.73	2.61	2.20

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

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CALCULATION AUDIT TRAIL

PART A4.C2 - Pooled analysis site C

Site name: Deerpark tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N12\N12 Growth curves\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N12.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	25_2616_4
Area	8.77
BFI	0.657
SAAR	913
FARL	1.00
URBEXT	1.68
FLATWET	0.62

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 526

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**
(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-0.82	0.52	2.2	0.493	684
1.10	4.18	0.72	35.1	0.821	1141

Initial threshold values (see table in Step 3) needed to be widened to retain sufficient pooled stations, due to the small catchment area (8.77 km^2).
Revised thresholds are:

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-0.82	0.52	2.2	0.493	684
1.10	4.18	0.72	**131.5**	0.821	1141

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
10022	URBEXT 29.72
25040	URBEXT 6.18
9011	URBEXT 68.33
10021	URBEXT 24.21
9035	URBEXT 33.37
30020	SAAR 1190.71 mm
9002	URBEXT 20.97
8005	URBEXT 25.01
22009	URBEXT 5.75
8009	URBEXT 7.54
6030	BFI 0.447
19046	SAAR 1196.50 mm
19020	SAAR 1179.10 mm
9010	URBEXT 24.04
36031	URBEXT 6.00
16005	SAAR 1153.60 mm
26018	FARL 0.756
16001	AREA 135.06 km2
25044	SAAR 1186.86 mm
19001	SAAR 1175.68 mm

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25034	26	0.699	10.8
16051	13	0.427	34.2
8002	21	0.149	33.4
8012	19	0.738	26.0
6031	18	0.871	46.2
24022	20	0.031	41.2
26022	33	0.124	61.9
14009	25	0.124	68.4

26058	24	0.171	60.0
13002	19	0.048	63.0
6033	25	1.530	55.2
16006	33	0.203	75.8
25023	34	0.310	113.9
26010	35	0.045	94.5
25027	43	0.111	118.9
14007	24	0.113	118.6
26009	35	0.123	98.2
26020	33	0.410	122.4
29001	40	0.108	115.5

Total years of data	520

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.31	1.31	1.25
10	1.51	1.50	1.39
20	1.70	1.68	1.52
50	1.96	1.92	1.69
100	2.14	2.09	1.81
200	2.33	2.26	1.94
1000	2.77	2.66	2.22

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:
Pooled EV1 distribution selected for the Deerpark tributary

CALCULATION AUDIT TRAIL

PART A4.D2 - Pooled analysis site D

Site name: Derryloughbannow tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N10\Ungauged tributary hydrology\River Derryloughbannow\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_Derryloughbannow GFs.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_1469_2
Area	38.53
BFI	0.419
SAAR	901
FARL	1.00
URBEXT	0.84
FLATWET	0.67

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 524

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**
(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-1.66	0.57	9.63	0.314	676
1.10	3.34	0.77	154.12	0.524	1126

Initial threshold values (see table in Step 3) needed to be widened to retain sufficient pooled stations, due to the small catchment area (38.53 km2) and low BFI value. Revised thresholds are:

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-1.66	0.57	9.63	**0.314**	676
1.10	3.34	0.77	**231.18**	**0.566**	1261

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
8007	URBEXT 6.48
36031	URBEXT 6.00
8003	URBEXT 4.56
7033	FARL 0.893
8008	URBEXT 4.10
8009	URBEXT 7.54
26022	BFI 0.578
9010	URBEXT 24.04
26022	BFI 0.578
23012	SAAR 1264
8002	BFI 0.597
24004	AREA 242.00
26010	BFI 0.578
15003	AREA 299.17

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
6033	25	0.852	55.2
24022	20	0.029	41.2
8012	19	0.336	26.0
14033	9	0.611	78.9
6031	18	0.471	46.2
11001	33	0.134	155.1
3051	15	1.541	143.2
36015	33	0.260	153.1
35004	14	0.226	117.0
26009	35	0.066	98.2
25005	46	0.466	192.6
6030	27	0.296	10.4
29004	32	0.057	121.4
8011	23	0.303	181.8
26020	33	0.127	122.4
34009	33	0.019	117.1
9001	25	0.179	209.6
7006	19	0.487	177.5
16005	30	0.053	84.0
34024	28	0.155	127.2

Total years of data	517

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.28	1.28	1.23
10	1.47	1.46	1.36
20	1.65	1.62	1.49
50	1.89	1.83	1.64
100	2.06	1.99	1.76
200	2.24	2.14	1.87
1000	2.64	2.49	2.14

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: Guiltyconeen River

Gauging station No: HEP 26_1470_1

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ NO1 & NO2 temporary folder\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N01 revised_Rev 1.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_1470_1
Area	7.24
BFI	0.50
SAAR	1037.50
FARL	1.00
URBEXT	1.43
FLATWET	0.70

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Not a gauged site & thus not in the pooled database

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-1.07	0.6	1.81	0.38	778
1.10	3.93	0.8	28.96	0.63	1297

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-1.07	0.5	1.81	0.38	778
1.10	3.93	0.9	130.34	0.63	1297

Initial threshold [see in table (1)] derived from the standard criteria. The fact that the Ballinamore River/Ballyconnell Canal has a small catchment area (7.24 km2) made amednments to the standard boundary conditions necessary to obtain a suitable pooling group.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
10022	URBEXT 29.72
9011	URBEXT 68.33
25040	URBEXT 6.18
22009	URBEXT 5.75
8005	URBEXT 25.01
30020	BFI 0.684
25034	BFI 0.759
36031	URBEXT 6.00
16051	BFI 0.676
8007	URBEXT 6.48
10021	URBEXT 24.21
36071	FARL 0.823
9035	URBEXT 33.37
9010	URBEXT 24.04
8009	URBEXT 7.54
9002	URBEXT 20.97
8003	URBEXT 4.56
19020	BFI 0.664
19046	BFI 0.698

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
6030	27	0.304	10.4
24022	20	0.036	41.2
8012	19	0.680	26.0
6031	18	0.553	46.2
8002	21	0.102	33.4
6033	25	1.089	55.2
26022	33	0.174	61.9
23012	18	0.518	61.6
14033	9	1.356	78.9
16006	33	0.254	75.8
16005	30	0.078	84.0
26009	35	0.106	98.2
26010	35	0.022	94.5
25044	40	0.009	92.5
30021	26	0.102	103.6
35004	14	0.297	117.0
29004	32	0.141	121.4
29001	40	0.129	115.5
26020	33	0.382	122.4

Total years of data	508

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)
2	1.00	1.00
5	1.31	1.31
10	1.51	1.50
20	1.70	1.68
50	1.96	1.92
100	2.14	2.09
200	2.33	2.26
1000	2.77	2.66

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:
Growth factor determined for the Guiltyconeem/Mullaghmore River also applied to the small tributaries within Carrick-on-Shannon AFA (i.e. the Lisnabrak, Drummagh and Keenaghban tributaries).

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B

Site name: Ballinamore/Ballyconnell canal

Gauging station No: HEP 26_3488_2

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\ NO1 & NO2 temporary folder\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N01 revised_Rev 1.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_3488_2
Area	31.48
BFI	0.61
SAAR	1111.51
FARL	0.90
URBEXT	0.13
FLATWET	0.70

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Not a gauged site & thus not in the pooled database

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.81	-2.37	0.6	7.87	0.46	834
0.99	2.63	0.8	125.92	0.76	1389

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.81	-2.37	0.6	7.87	0.46	834
0.99	2.63	0.8	**251.84**	0.76	1389

Initial threshold [see in table (1)] derived from the standard criteria. The fact that the Ballinamore River/Ballyconnell Canal has a small catchment area (31.48 km2) made amednments to the standard boundary conditions necessary to obtain a suitable pooling group.

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
22009	FARL 0.995
25040	FARL 1.00
30020	FARL 1.00
16006	FARL 0.994
19020	FARL 1.00
19046	FARL 1.00
16005	FARL 1.00
6031	FARL 1.00
24022	FARL 1.00
25044	FARL 0.997
13002	FARL 1.00
26022	FARL 1.00
19001	FARL 1.00
16051	FARL 1.00
29001	FARL 0.998
30021	FARL 0.994
9010	URBEXT 24.04
25027	FARL 1.00
26020	FARL 1.00
29071	FARL 0.804
26058	FARL 0.995
29004	FARL 0.993
25038	FARL 1.00
19016	FARL 1.00
26018	FARL 0.756
25023	FARL 1.00
25158	FARL 1.00
23012	FARL 0.999
20006	FARL 1.00
25034	FARL 1.00
35004	FARL 0.994
10021	FARL 0.997
25022	FARL 1.00
36031	URBEXT 6.00
14009	FARL 1.00
16001	FARL 1.00

8002	FARL 1.00
14033	FARL 1.00
25014	FARL 1.00
10022	FARL 1.00
33070	FARL 0.677
6033	FARL 0.996
9035	FARL 0.993
8012	FARL 0.999
16013	FARL 0.993
25020	FARL 0.999
6030	BFI 0.447
31002	FARL 0.632
7001	FARL 0.996
7006	FARL 0.990
19015	FARL 0.997
9002	FARL 1.00
14013	FARL 0.999
34018	FARL 0.732
14007	FARL 1.00
7004	FARL 0.772
8009	FARL 1.00
16003	FARL 0.999
11001	FARL 1.00
25025	FARL 0.995
16004	FARL 1.00
16012	FARL 0.999
25002	FARL 0.999
26008	AREA 280.31 km2
7033	BFI 0.439
24002	FARL 1.00
25029	FARL 0.997
24030	AREA 258.88 km2

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/S	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
26010	35	0.116	94.5
26009	35	0.148	98.2
36071	20	0.510	68.0

34024	28	0.364	127.2
34011	30	0.096	143.0
6012	47	0.082	162.8
6026	46	0.285	148.5
26006	53	1.877	184.8
6070	27	0.027	162.0
26014	16	0.215	215.1
30037	21	0.583	210.2
6025	30	0.432	176.0
30005	49	0.095	237.8
6011	48	0.080	229.2
36018	50	0.090	234.4

Total years of data	535

Pooled distributions for further consideration if different from EV1 and LN2:

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)
2	1.00	1.00
5	1.23	1.22
10	1.38	1.35
20	1.52	1.48
50	1.71	1.62
100	1.84	1.73
200	1.98	1.84
1000	2.30	2.08

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.H2 - Pooled analysis site H

Site name: Fardrum tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N10\Ungauged tributary hydrology\River Fardrum\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_Fardrum GFs.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_293_2
Area	19.90
BFI	0.697
SAAR	915
FARL	0.99
URBEXT	1.70
FLATWET	0.65

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 518

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Ungauged watercourse and therefore not ranked

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**
(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.89	-0.8	0.55	4.98	0.523	686
1.09	4.2	0.75	79.60	0.871	1199

Initial threshold values (see table in Step 3) needed to be widened to retain sufficient pooled stations, due to the small catchment area (19.9 km2). Revised thresholds are:

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.89	-0.8	0.55	4.98	0.523	686
1.09	4.2	0.75	**119.40**	0.871	1199

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
25040	URBEXT 6.18
10021	URBEXT 24.21
9035	URBEXT 33.37
10022	URBEXT 29.72
9002	URBEXT 20.97
22009	URBEXT 5.75
26018	FARL 0.756
9010	URBEXT 24.04
8009	URBEXT 7.54
7001	AREA 151.30
6026	AREA 148.50
16001	AREA 135.06
14013	AREA 154.4
6033	BFI 0.496
25025	AREA 161.20
8005	URBEXT 25.01

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
16051	13	0.644	34.2
25034	26	0.704	10.8
8002	21	0.254	33.4
26058	24	0.343	60.0
14009	25	0.070	68.4
13002	19	0.045	63.0
30020	16	0.077	21.4
6031	18	1.251	46.2
26022	33	0.190	61.9
24022	20	0.077	41.2
8012	19	0.891	26.0
25023	34	0.379	113.9
19046	9	0.425	63.2
19020	28	0.315	74.0
25027	43	0.078	118.9
16006	33	0.312	75.8
14007	24	0.272	118.6

26010	35	0.091	94.5
19001	48	0.074	103.3
26009	35	0.175	98.2

Total years of data	523

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.29	1.28	1.23
10	1.48	1.46	1.37
20	1.66	1.63	1.49
50	1.90	1.84	1.65
100	2.07	2.00	1.77
200	2.25	2.15	1.88
1000	2.66	2.51	2.15

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.E2 - Pooled analysis site E

Site name: Garrycastle tributary

Gauging station No: N/A - Ungauged watercourse

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\N10\Ungauged tributary hydrology\River Garrycastle\Pooled FloodFrequency Analysis_TEMPLATE_03032014 JC_Garrycastle GFs.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_4030_4
Area	3.14
BFI	0.547
SAAR	900
FARL	1.00
URBEXT	30.36
FLATWET	0.65

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 509

Is subject site in pooled group? ○ Yes ◉ No at ranked position: N/A

Give reason if not at position 1: Not a gauged site & thus not in the pooled database

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	N/A

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(2) Standard Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	27.86	0.55	0.79	0.41	675
1.10	32.86	0.75	12.56	0.68	1125

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation	+ Reviewer initials if kept
	Refer to the comment below Table A4.4	

Comment:
Given that the Garrycastle site is such a small catchment area (3.14 km2) and highly urbanised (30.36 %) a suitable pooling group was not possible. The smallest site in the pooling database of stations is 5 km2 and there are very few sites with high urbanisation that are similarly small in terms of catchment area. Therefore, the most representative sites were retained which were those with a high degree of urbanisation in additon to being relatively small in area terms thereby resulting in the documented pooling group for the Garrycastle tributary.

STEP 4 Remove sites with high discordancy Di

Discordancy limit used:	3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	N/A

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

Insert additional iterations of Steps 1-4 here

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
9011	19	0.445	5.5
10022	17	0.070	12.9
8005	18	0.228	9.2
10021	24	0.070	32.5
9035	9	0.301	37.1
9002	25	0.570	35.0
9010	19	0.650	94.3

Total years of data	131

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

Insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.60	1.66	1.46
10	1.99	2.16	1.72
20	2.37	2.69	1.97
50	2.86	3.43	2.28
100	3.23	4.04	2.51
200	3.60	4.70	2.74
1000	4.45	6.40	3.27

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

CALCULATION AUDIT TRAIL

PART A4.J2 - Pooled analysis site J

Site name: Tributary Mackney

Gauging station No: N/A HEP node 26_3824_10

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Suck Catchment Model\Final N08 N09\Pooled FloodFrequency Analysis_N09_v2.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_3824_10
Area	8.41
BFI	0.74
SAAR	961.45
FARL	1.00
URBEXT	4.03
FLATWET	0.64

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group with (many) more years than required. Give initial number of years: 526

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged tributary

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
N/A	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.
Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	1.53	0.54	2.10	0.55	721
1.10	6.53	0.74	33.64	0.92	1202

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	**0.80**	0.54	2.10	**0.48**	**673**
1.10	**70.00**	0.74	**201.84**	**1.00**	**1250**

Initial threshold [see in table (1)] derived from the standard criteria, results in 19 years of records suitable for pooling (i.e only one station in the final group). By relaxing URBEXT, AREA, BFI and SAAR [see in table (2)], revised limit for pooling result in 517 years of records with a maximum discordancy value of 2.48

Table A4.4 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25034	Removed due to low URBEXT (< 0.8)
6030	Removed due to low URBEXT (< 0.8)
24022	Removed due to low URBEXT (< 0.8)
16051	Removed due to low URBEXT (< 0.8)
13002	Removed due to low URBEXT (< 0.8)
8002	Removed due to low URBEXT (< 0.8)
19046	Removed due to low URBEXT (< 0.8)
26022	Removed due to low URBEXT (< 0.8)
19020	Removed due to low URBEXT (< 0.8)
14009	Removed due to low URBEXT (< 0.8)
25023	Removed due to low URBEXT (< 0.8)
16006	Removed due to low URBEXT (< 0.8)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	Discordancy
N/A	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
36071	Removed due to low FARL (< -10% of subject site); low URBEXT (< 0.8); high SAAR (> 30% of subject site)
26018	Removed due to low FARL (< -10% of subject site); low URBEXT (< 0.8)
25027	Removed due to low URBEXT (< 0.8)
26010	Removed due to low URBEXT (< 0.8)
14007	Removed due to low URBEXT (< 0.8)
7001	Removed due to low URBEXT (< 0.8)

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
14013	Removed due to low URBEXT (< 0.8)
16001	Removed due to low URBEXT (< 0.8)
6070	Removed due to low FARL (< -10% of subject site)
6012	Removed due to low FARL (< -10% of subject site)

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
19016	Removed due to low URBEXT (< 0.8); high SAAR (> 30% of subject site)
25044	Removed due to low URBEXT (< 0.8)
29001	Removed due to low URBEXT (< 0.8)

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
25014	Removed due to low URBEXT (< 0.8)
30021	Removed due to low URBEXT (< 0.8)
16005	Removed due to low URBEXT (< 0.8)

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
26009	Removed due to low URBEXT (< 0.8)
7006	Removed due to low URBEXT (< 0.8)

7th iteration

Table A4.10 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
26020	Removed due to low URBEXT (< 0.8)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
10022	17	0.072	13
8005	18	0.234	9
10021	24	0.072	33
30020	16	0.025	21
25040	19	0.041	28
26058	24	0.110	60

9035	9	0.309	37
9011	19	0.458	5
9002	25	0.586	35
22009	24	0.030	35
6031	18	0.401	46
6033	25	0.725	55
19001	48	0.024	103
29004	32	0.048	121
8009	15	2.480	62
25025	31	0.059	161
6026	46	0.083	148
9010	19	0.668	94
14011	25	0.039	162
36031	30	0.419	64
11001	33	0.114	155

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.35	1.36	1.43
10	1.58	1.59	1.68
20	1.81	1.81	1.91
50	2.10	2.10	2.21
100	2.31	2.32	2.43
200	2.53	2.54	2.64
1000	3.03	3.06	3.14

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

The catchment draining towards this station has no significant karst effects. Pooled analysis is considered as an appropriate aproach.

According to the L-Moment Ratio Diagram (see in pooled analysis spreadsheet v2), EV1 is the best fit. EV1 values will also be used for growth factors along Tributary Ballyhugh as the catchment is hydrologically similar.

CALCULATION AUDIT TRAIL

PART A4.B2 - Pooled analysis site B for Tributary Ballindadny

Site name: Tributary Ballindadny

Gauging station No: N/A HEP node 26_3870_1

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Inny\NO3 Inny\Pooled FloodFrequency Analysis_NO3_v5.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_3870_1
Area	9.97
BFI	0.60
SAAR	989.79
FARL	1.00
URBEXT	4.37
FLATWET	0.67

Catchment descriptors listed from "RBD……." spreadsheet

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	1.87	0.57	2.49275	0.45	742
1.10	6.87	0.77	39.884	0.75	1237

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	**1.00**	**0.53**	2	**0.42**	**693**
1.10	**70.00**	0.77	**200**	**0.78**	**1287**

Initial threshold [see in table (1)] derived from the standard criteria, results in 43 years of records suitable for pooling. It is concerned that so many stations have been removed that the remaining may not be hydrologically similar. By relaxing URBEXT, FORMWET, AREA, BFI and SAAR [see in table (2)], revised limits for pooling result in 515 years of records with a maximum discordancy value of 2.004

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
6030	URBEXT value less than 1 (subject site -3.37).
25034	URBEXT value less than 1 (subject site -3.37).
30020	URBEXT value less than 1 (subject site -3.37).
16051	URBEXT value less than 1 (subject site -3.37).
24022	URBEXT value less than 1 (subject site -3.37).
8002	URBEXT value less than 1 (subject site -3.37).
26022	URBEXT value less than 1 (subject site -3.37).
13002	URBEXT value less than 1 (subject site -3.37).
16006	URBEXT value less than 1 (subject site -3.37).
14009	URBEXT value less than 1 (subject site -3.37).
8012	URBEXT value less than 1 (subject site -3.37).

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	**Discordancy**
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
26010	URBEXT value less than 1 (subject site -3.37).
19046	URBEXT value less than 1 (subject site -3.37).
16005	URBEXT value less than 1 (subject site -3.37).
19020	URBEXT value less than 1 (subject site -3.37).
26009	URBEXT value less than 1 (subject site -3.37).
25044	URBEXT value less than 1 (subject site -3.37).
36071	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37) and SAAR value larger than 1287 (+30% of subject site).
25027	URBEXT value less than 1 (subject site -3.37).

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
29001	URBEXT value less than 1 (subject site -3.37).
30021	URBEXT value less than 1 (subject site -3.37).
26020	URBEXT value less than 1 (subject site -3.37).
26018	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37).

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
16001	URBEXT value less than 1 (subject site -3.37).
7033	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37).
25023	URBEXT value less than 1 (subject site -3.37).
14007	URBEXT value less than 1 (subject site -3.37).

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
6026	URBEXT value less than 1 (subject site -3.37).
29071	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37).

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
36015	URBEXT value less than 1 (subject site -3.37).
25022	URBEXT value less than 1 (subject site -3.37).
35004	URBEXT value less than 1 (subject site -3.37).

7th iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
34024	URBEXT value less than 1 (subject site -3.37).
25014	URBEXT value less than 1 (subject site -3.37).

8th iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
25038	URBEXT value less than 1 (subject site -3.37).
20006	URBEXT value less than 1 (subject site -3.37) ; SAAR value larger than 1287 (+30% of subject site).
14033	URBEXT value less than 1 (subject site -3.37).

9th iteration

Table A4.12 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
19016	URBEXT value less than 1 (subject site -3.37).
35002	URBEXT value less than 1 (subject site -3.37) ; SAAR value larger than 1287 (+30% of subject site).

10th iteration

Table A4.13 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
6025	URBEXT value less than 1 (subject site -3.37).
7006	URBEXT value less than 1 (subject site -3.37).

11th iteration

Table A4.14 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
34011	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37).
14013	URBEXT value less than 1 (subject site -3.37).

12th iteration

Table A4.15 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
25005	URBEXT value less than 1 (subject site -3.37).

13th iteration

Table A4.16 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
25025	URBEXT value less than 1 (subject site -3.37).
6070	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37)

14th iteration

Table A4.17 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
33070	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37) and SAAR value larger than 1287 (+30% of subject site).
6012	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37)

15th iteration

Table A4.18 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
7001	URBEXT value less than 1 (subject site -3.37).

16th iteration

Table A4.19 Stations with outlying catchment descriptors

Station	Removed or kept with explanation + Reviewer initials if kept
25020	FARL value less than 0.9 (-10% of subject site); URBEXT value less than 1 (subject site -3.37)

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
25040	19	0.033	28

10022	17	0.058	13
9011	19	0.370	5
22009	24	0.025	35
6031	18	0.324	46
10021	24	0.058	33
9035	9	0.250	37
8005	18	0.189	9
9002	25	0.474	35
6033	25	0.586	55
26058	24	0.089	60
8007	15	0.165	38
36031	30	0.338	64
8009	15	2.004	62
9010	19	0.540	94
8003	18	0.446	84
29004	32	0.039	121
19001	48	0.019	103
11001	33	0.092	155
8008	25	0.186	108
23012	18	0.290	62
14011	25	0.032	162
3051	15	1.060	143

Total years of data	515

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.40	1.42	1.49
10	1.67	1.70	1.78
20	1.93	1.97	2.05
50	2.26	2.34	2.39
100	2.51	2.62	2.64
200	2.76	2.90	2.89
1000	3.33	3.59	3.46

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on ~500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

According to the L-Moment Ratio Diagram (see in pooled analysis spreadsheet), EV1 is the best fit.

CALCULATION AUDIT TRAIL

PART A4.C2 - Pooled analysis site C for Tributary Tipper

Site name: Tributary Tipper

Gauging station No: N/A HEP node 26_3975_3

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Inny\NO3 Inny\Pooled FloodFrequency Analysis_NO3_v5.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	26_3975_3
Area	20.60
BFI	0.61
SAAR	902.88
FARL	1.00
URBEXT	2.04
FLATWET	0.66

Catchment descriptors listed from "RBD……." spreadsheet

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10

These criteria can be relaxed in some circumstances if agreed with reviewer.

Add reviewer initials to the table below for deviations from the criteria above.

*** NOTES:**

(1) Initial Threshold

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-0.46	0.56	0.25	0.45	677
1.10	4.54	0.76	82.42	0.76	1129

(2) Threshold Applied

FARL	URBEXT	FORMWET	AREA	BFI	SAAR
0.90	-0.46	0.56	0.25	0.45	677
1.10	4.54	0.76	**206.04**	0.76	1129

Initial threshold [see in table (1)] derived from the standard criteria, results in 257 years of records suitable for pooling. It is concerned that so many stations have been removed that the remaining may not be hydrologically similar. By relaxing AREA[see in table (2)], revised limit for pooling result in 540 years of records with a maximum discordancy value of 1.813

Table A4.4 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
25040	URBEXT value larger than 4.54 (subject site +2.5).
10022	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
10021	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
9035	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
9002	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
30020	SAAR value larger than 1129 (+25% subject site).
6030	SAAR value larger than 1129 (+25% subject site).
22009	URBEXT value larger than 4.54 (subject site +2.5);SAAR value larger than 1129 (+25% subject site).
8005	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
8009	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
36031	URBEXT value larger than 4.54 (subject site +2.5)
9011	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
8007	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.3 Stations removed due to discordancy

Station No	**Discordancy**
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group

has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

insert additional iterations of Steps 1-4 here

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
9010	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)
8012	FLATWET value less than (subject site -0.1)
8003	URBEXT value larger than 4.54 (subject site +2.5); FLATWET value less than (subject site -0.1)

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	**Removed or kept with explanation** + Reviewer initials if kept
26018	FARL value less than 0.9 (-10% of subject site).

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
16051	13	0.516	34
24022	20	0.061	41
8002	21	0.204	33
6031	18	1.003	46
26022	33	0.153	62
6033	25	1.813	55
25034	26	0.565	11
14009	25	0.056	68
26058	24	0.275	60
13002	19	0.036	63
16006	33	0.250	76
26010	35	0.073	95
26009	35	0.140	98
25027	43	0.063	119
14007	24	0.218	119
16001	33	0.125	135
26020	33	0.269	122
25023	34	0.304	114
6026	46	0.208	148

Total years of data	540

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.28	1.27	1.34
10	1.46	1.45	1.54
20	1.64	1.60	1.72
50	1.86	1.80	1.95
100	2.03	1.95	2.12
200	2.20	2.10	2.29
1000	2.60	2.43	2.69

Comments: The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on ~500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

According to the L-Moment Ratio Diagram (see in pooled analysis spreadsheet), EV1 is the best fit.

CALCULATION AUDIT TRAIL

PART A4.I2 - Pooled analysis site I

Site name: Tributary Clonmacken

Gauging station No: NONE
ungauged

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Lower Shannon\N16\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N16_v4.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	27_54_3
Area	4.1
BFI	0.54
SAAR	983
FARL	1
URBEXT	46.99
FLATWET	0.59

@ bottom of the Tributary Clonmacken

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group.

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged site.

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

Due to small catchment size the limits of AREA and UREXT needed to be revised to have suficient pooled sites.

AREA	between 0.25 and 50 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	-/+ 25%% of subject site
FARL	+/- 10% of subject site
URBEXT	- 46.4 / +50
FLATWET	(FORMWET) -/+ 0.10 (half of total range)

Table A4.3 Stations with outlying catchment descriptors

Station	Removed with explanation
6030	URBEXT less than URBEXT (subject site) -46.4.
8005	SAAR less than -25% of subject site
25034	URBEXT less than URBEXT (subject site) -46.4; BFI greater than +25% of subject site
30020	FLATWET greater than FLATWET(subject site) + 0.1
24022	URBEXT less than URBEXT (subject site) -46.4.
8002	URBEXT less than URBEXT (subject site) -46.4.
16051	URBEXT less than URBEXT (subject site) -46.4.
26022	URBEXT less than URBEXT (subject site) -46.4.
8007	BFI less than -25% of subject site
16006	URBEXT less than URBEXT (subject site) -46.4.
23012	SAAR greater than +25% of subject site.
16005	URBEXT less than URBEXT (subject site) -46.4.

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.4 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
14009	URBEXT less than URBEXT (subject site) -46.4.
13002	URBEXT less than URBEXT (subject site) -46.4.
26009	URBEXT less than URBEXT (subject site) -46.4.
26010	URBEXT less than URBEXT (subject site) -46.4.
36071	FARL less than -10% of subject site; URBEXT less than URBEXT (subject site) -46.4; FLATWET greater than FLATWET(subject site) + 0.1; SAAR greater than +25% of subject site.
19046	URBEXT less than URBEXT (subject site) -46.4; BFI greater than +25% of subject site.
19020	URBEXT less than URBEXT (subject site) -46.4; BFI greater than +25% of subject site.
26058	BFI greater than +25% of subject site.
25044	URBEXT less than URBEXT (subject site) -46.4.

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
30021	URBEXT less than URBEXT (subject site) -46.4; FLATWET greater than FLATWET(subject site) + 0.1
26020	URBEXT less than URBEXT (subject site) -46.4
35004	URBEXT less than URBEXT (subject site) -46.4; FLATWET greater than FLATWET(subject site) + 0.1

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25023	URBEXT less than URBEXT (subject site) -46.4

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
16001	URBEXT less than URBEXT (subject site) -46.4

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
34024	FLATWET greater than FLATWET(subject site) + 0.1

7th iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
29071	FARL less than -10% of subjest site; URBEXT less than URBEXT (subject site) -46.4

8th iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
7033	FARL less than -10% of subject site

9th iteration

Table A4.12 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
33070	FARL less than -10% of subject site; URBEXT less than URBEXT (subject site) -46.4; FLATWET greater than FLATWET(subject site) + 0.1; SAAR greater than +25% of subject site.

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
9011	19	0.214	5.460
10022	17	0.209	12.938
25040	19	0.047	28.022
8012	19	0.539	25.953
22009	24	0.128	35.397
6031	18	0.147	46.174
10021	24	0.105	32.506
9035	9	0.070	37.139
6033	25	0.338	55.227
9002	25	0.241	34.954
36031	30	0.303	63.769
8009	15	1.927	61.644
9010	19	0.300	94.260
14033	9	1.151	78.892
8003	18	0.232	83.595
29001	40	0.232	115.480
29004	32	0.225	121.435
8008	25	0.054	107.921
19001	48	0.227	103.281
25027	43	0.228	118.865
14007	24	0.083	118.591

Total years of data	502

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.39	1.40	1.31
10	1.65	1.67	1.49
20	1.90	1.93	1.66
50	2.22	2.28	1.87
100	2.46	2.54	2.03
200	2.70	2.81	2.18
1000	3.26	3.45	2.54

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

Due to the limited availability of small gauged catchments within the pooling database a more heterogenius pooling group has to be accepted.

According to the L-moment ratio diagram, EV1 provides the best fit and will be taken forward for flood frequency analysis.

CALCULATION AUDIT TRAIL

PART A4.I2 - Pooled analysis site I

Site name: Tributary Crompaun

Gauging station No: NONE
ungauged

Table A4.1 Pooled analysis file location

Description	File path
Pooled analysis	P:\32103000 - Shannon CFRAMS Study\Hydrological Assessment\A) Modelling\UoM 25 26\Lower Shannon\N16\Pooled Flood Frequency Analysis_TEMPLATE_17032014_N16_v4.xls

FSU location details from pooled flood frequency analysis spreadsheet:

Site no.	27_158_2
Area	18.481
BFI	0.43996
SAAR	1025.3
FARL	1
URBEXT	3.45
FLATWET	0.59

@ bottom of the Tributary Crompaun

Number of pooled years required: 500 years

STEP 1 Use OPW pooled flood frequency spreadsheet to generate pooled group.

Is subject site in pooled group? ○ Yes ◉ No at ranked position:

Give reason if not at position 1: ungauged site.

Then move the subject gauging station to number 1 by setting distance measure Dij to 0.

STEP 2 Remove sites with record lengths of 8 years or less.

Table A4.2 Stations removed due to short record

Station No	No of years of data
NA	

STEP 3 Remove sites with outlying AREA, BFIsoil, FARL, URBEXT or FLATWET (to ensure homogeneity of the pooling group)

AREA	between 0.25 and 4 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	+/- 25% of subject site
FARL	+/- 10% of subject site
URBEXT	+/- 2.5
FLATWET	(FORMWET) +/- 0.10 (half of total range)

These criteria can be relaxed in some circumstances if agreed with reviewer. Add reviewer initials to the table below for deviations from the criteria above.

Using the recommended thresholds there is only one record for pooling. Therefore the limits of URBEXT, AREA and SAAR are revised to improve pooling group.

AREA	between 0.25 and 25 times the area of the subject site
BFIsoil	+/- 25% of subject site
SAAR	- 25% / +75% of subject site
FARL	+/- 10% of subject site
URBEXT	- 2.9 / +50
FLATWET	(FORMWET) -/+ 0.10 (half of total range)

Table A4.3 Stations with outlying catchment descriptors

Station	Removed with explanation
6030	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
24022	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
6031	BFI greater than +25% of subject site.
22009	BFI greater than +25% of subject site.
7033	FARL less than -10% of subject site.
35004	URBEXT less than URBEXT (subject site) -2.9; FLATWET greater than FLATWET(subject site) + 0.1.
26022	BFI greater than +25% of subject site.
26009	URBEXT less than URBEXT (subject site) -2.9
25040	BFI greater than +25% of subject site.
10022	BFI greater than +25% of subject site.
36071	FARL less than -10% of subject site; URBEXT less than URBEXT (subject site) -2.9; FLATWET greater than FLATWET(subject site) + 0.1; BFI greater than +25% of subject site.
16005	URBEXT less than URBEXT (subject site) -2.9
9010	BFI greater than +25% of subject site.
16006	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.

STEP 4 Remove sites with high discordancy Di

Discordancy limit used: 3

Table A4.4 Stations removed due to discordancy

Station No	Discordancy
NA	

STEP 5 Revisit STEPS 1 to 4

The pooling group may need to be revised several times until a pooling group has been developed that is suitably homogeneous.

Copy the tables from steps 1-4 to below Step 5 to record removed sites in additional iterations of the process.

Note that the nature of the subject site may mean that the pooling group will always be heterogeneous in which case the use of pooled analysis will need to be reconsidered in agreement with the reviewer.

2nd iteration

Table A4.5 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
36015	URBEXT less than URBEXT (subject site) -2.9
8002	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
26010	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
34009	FLATWET greater than FLATWET(subject site) + 0.1.
30021	URBEXT less than URBEXT (subject site) -2.9; FLATWET greater than FLATWET(subject site) + 0.1; BFI greater than +25% of subject
35002	URBEXT less than URBEXT (subject site) -2.9; FLATWET greater than FLATWET(subject site) + 0.1
8005	BFI greater than +25% of subject site; SAAR less than -25% of subject site
8009	SAAR less than -25% of subject site
34024	FLATWET greater than FLATWET(subject site) + 0.1.
26020	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.

3rd iteration

Table A4.6 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
9011	URBEXT greater than URBEXT(subject site) +50
25044	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
29001	BFI greater than +25% of subject site.
29071	FARL less than -10% of subject site; URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
16051	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
30020	FLATWET greater than FLATWET(subject site) + 0.1; BFI greater than +25% of subject site.
33070	FARL less than -10% of subject site;URBEXT less than URBEXT (subject site) -2.9; FLATWET greater than FLATWET(subject site) +
10021	BFI greater than +25% of subject site.

4th iteration

Table A4.7 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
26006	FLATWET greater than FLATWET(subject site) + 0.1.
7006	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
19020	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.
16001	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.

5th iteration

Table A4.8 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
31002	FARL less than -10% of subject site; URBEXT less than URBEXT (subject site) -2.9.
34011	FARL less than -10% of subject site; FLATWET greater than FLATWET(subject site) + 0.1; BFI greater than +25% of subject site.
10004	URBEXT less than URBEXT (subject site) -2.9
9035	BFI greater than +25% of subject site.
36021	URBEXT less than URBEXT (subject site) -2.9; BFI less than -25% of subject site
16013	URBEXT less than URBEXT (subject site) -2.9

6th iteration

Table A4.9 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
19001	BFI greater than +25% of subject site.
14009	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.

7th iteration

Table A4.10 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
25027	BFI greater than +25% of subject site.
25038	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.

8th iteration

Table A4.11 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
30037	FLATWET greater than FLATWET(subject site) + 0.1; BFI greater than +25% of subject site.
25023	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.

9th iteration

Table A4.12 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
9002	BFI greater than +25% of subject site; SAAR less than -25% of subject site.

10th iteration

Table A4.13 Stations with outlying catchment descriptors

Station	Removed or kept with explanation
19046	URBEXT less than URBEXT (subject site) -2.9; BFI greater than +25% of subject site.

Final pooling group

Table A4.5 Final pooling group summary

Station No	Years of data	Discordancy	Area (km2)
8007	15	0.239	37.936
36031	30	0.381	63.769
14033	9	0.711	78.892
6033	25	0.638	55.227
8012	19	0.357	25.953
23012	18	0.310	61.631
8003	18	0.452	83.595
3051	15	1.231	143.195
29004	32	0.110	121.435
8008	25	0.178	107.921
11001	33	0.073	155.110
25005	46	0.601	192.616
1041	32	0.098	116.180
24004	52	0.056	242.130
8011	23	0.377	181.774
29007	22	0.019	271.482
24011	33	0.412	281.234
24030	25	0.135	258.880
18016	20	0.217	116.728
26019	51	0.073	252.961

Total years of data	543

Pooled distributions for further consideration if different from EV1 and LN2:

LO

Final pooled growth factors

insert growth factor table from pooled analysis spreadsheet here
for the following RPs

RP	GF (EV1)	GF (LN2)	GF (LO)
2	1.00	1.00	1.00
5	1.31	1.30	1.24
10	1.51	1.50	1.39
20	1.70	1.68	1.52
50	1.95	1.91	1.69
100	2.14	2.08	1.81
200	2.33	2.25	1.93
1000	2.76	2.65	2.22

The FSU recommends a pooling-group size that is five times the target return period (the 5T rule). In this instance the pooling group is based on 500-years of AMAX event data, corresponding to a 100-year target return period. Growth curves have been extended to include estimates for the 200-year and 1000-year return periods, but due to the number of AMAX events being less than 5T the estimates will be less certain and should be treated with caution.

Comments:

50 of the selected catchments were removed as they were not deemed appropriate - this amounts to 18% of the datase. The resultant pooling group will be less hydrologically similar to the study site.

According to the L-moment ratio diagram, EV1 appears to be the best and and will be used for further analysis of extreme inflows estimation as a conservative approach.

Appendix H Geomorphology Assessment

JACOBS

SHANNON CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

Shannon Catchment-based Flood Risk Assessment and Management Study

Office of Public Works

Geomorphology Assessment

Final Report

JACOBS

July 2016

Executive Summary

The Office of Public Works (OPW) has commissioned Jacobs to undertake a geomorphological assessment to help inform the Catchment Flood Risk and Management Strategy (CFRAMS) for the River Shannon in the Republic of Ireland. This requires information to be provided on both erosion and sedimentation risks in the catchment.

Given the uncertainties of working at a strategic level with limited data and information two complementary geomorphological approaches have been used independently to increase confidence in the observations made:

- Approach One: a 'top-down' approach founded largely on an existing British River typology; and,
- Approach Two: a 'bottom-up' approach using catchment level information.

The first approach (Approach One) classified the catchment by using variables including the altitude, historic channel activity and geology. Using this information a high level understanding of river channel types and associated potential risks of erosion and deposition has been developed. The key deliverables obtained through this approach are maps showing river channel type, risk of erosion and risk of deposition.

The second approach (Approach Two) used various data and information sources to obtain measurements of slope, stream power, sinuosity, land use, soil type, bedrock, historical change, structures and waterfall locations for the catchment, albeit at a strategic level. From this a series of scenarios has been created using the variables to create three outputs highlighting risks of erosion and deposition and a specific output focusing solely on stream power and soil type.

Both approaches identified key parts of the catchment that could potentially be at risk of erosion and/or deposition or more generally of morphological change. It should be noted that both approaches are strategic and that at this level the data/ information is not focused on individual channels. No site work was undertaken to ground truth the strategic findings and the analyses drawn from this report need to be caveated accordingly.

The two approaches did lead to similar findings, suggesting some form of validity in the information/data used. In particular two key areas of the Shannon catchment have been highlighted to be at potential risk of deposition and/or erosion, namely the northern and south western areas. The two approaches have allowed the potential for geomorphological change to be assessed across the entire Shannon catchment and specifically for the management units used in the wider hydrological study. From this strategic study it has been found (overall) that the hydrological sites are located in areas of medium to high risk of either erosion and/or deposition. This would indicate a potential for future management intervention such as repeated dredging and/or bank reinforcement (dependent on the solutions adopted for tackling flood risk).

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Appendix A Gauging Station Information Sheets

1 Introduction

As part of a hydrological study of the Shannon catchment, The Office of Public Works (OPW) in Ireland has commissioned Jacobs to carry out a high level geomorphological assessment to establish sites/areas susceptible to erosion/deposition risks and to determine the potential for morphological change more generally. This information should potentially help inform the types of flood risk management solution recommended for a site.
Given the uncertainties of working at a strategic level with limited data and information two complementary geomorphological approaches have been used independently to try to increase confidence in the observations made:

- Approach One: a 'top-down' approach founded largely an existing British River typology; and,
- Approach Two: a 'bottom-up' approach using catchment level information.

1.1 Aims and Objectives

The primary aim of this geomorphological study is to identify sites/areas (management units) at risk of change through erosion and/or deposition. This additional data/information should help inform the suitability of particular flood risk management options proposed.

1.2 Study Area

This report focuses on the Shannon catchment, with a catchment area of over 18,000km2 and consists of the River Shannon and a network of major and minor tributaries and sub-catchments. The River Shannon is approximately 360.5km in length. For the purposes of the hydrological assessment, which this geomorphological study feeds into, the Shannon catchment has been subdivided into units of management. Figure 1.1 shows the study area and the units of management adopted.

1.3 What is Fluvial Geomorphology?

This study concerns fluvial geomorphology which is the study of landforms associated with river channels and the processes that form them. It considers the process of sediment transfer (erosion, transport and deposition) in river systems and also the relationship between channel forms and processes.

The geomorphological form of a river channel and valley floor is complex and influenced by many different factors and inter-related processes. Controls influencing the river system include external controls and internal controls. External controls include catchment geology, topography, soil type, climatic trends and land management practices. Internal controls may include bed and bank materials, vegetation characteristics, gradient, cross-sectional morphology and flow conditions. These controls interact to determine fluvial processes, such as flow and sediment transport, which in turn, influence channel form.

As a natural system, a river evolves in response to natural influences. However, rivers are often significantly affected by human activities. Artificial structures in the river, alterations to the channel dimensions and land management around it can have major implications for river forms and processes. Changes in one part of the

river catchment either through natural or human activity can result not only in geomorphological adjustment over time at that point, but also in changes upstream and downstream. An understanding of the controls on channel morphology is required before an action to enhance conditions or reduce and mitigate the impacts of current or future activities is decided upon.

Hydromorphology is a specific term coined by the Water Framework Directive (Directive 2000/60/EC). It refers to the relationship between hydrological processes and the morphological effects and encompasses key factors such as river width and depth, riparian zone, longitudinal profile, lateral profile, groundwater connectivity and bed substrate. Within this report hydromorphology and fluvial geomorphology are taken to be synonymous.

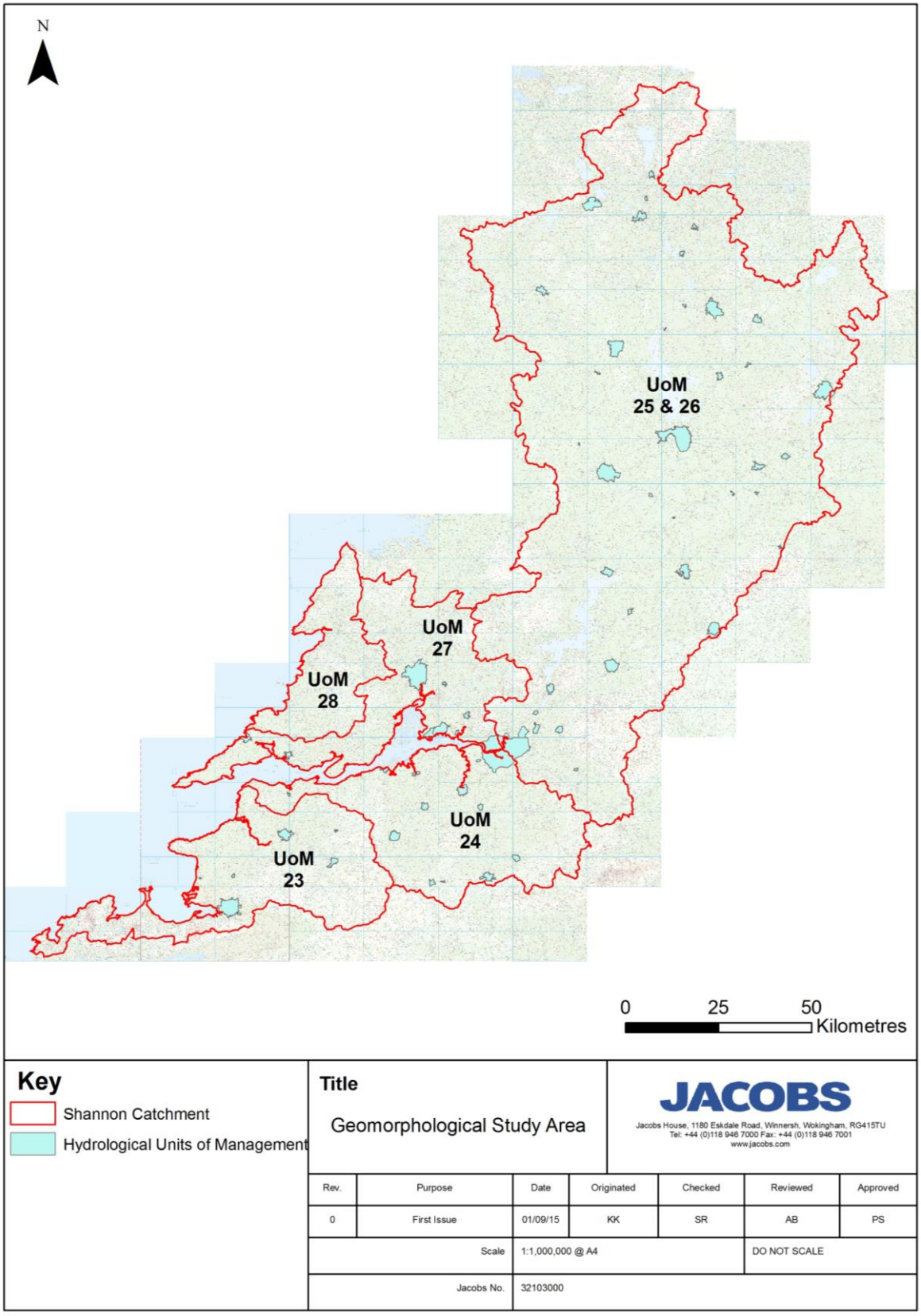

Figure 1.1 Geomorphological assessment study area

2 Methodology

To assess the risk of erosion and deposition, two distinct approaches have been followed. The first (Approach One) has used a 'top-down' method to create a crude typology of channels, using a combination of informed professional judgement and aerial photography. Approach Two has collected a database of information and data which has been variously combined to develop a score, providing an indication of potential risk for erosion and/or deposition (subsequently mapped at the catchment scale). Both approaches allow outputs to be displayed at a catchment scale, showing areas at potential risk of erosion and deposition. These outputs have then subsequently been compared to the hydrological units of management identified in the overarching hydrological study to establish any potential risk of geomorphological change.

2.1 Approach One

2.1.1 Classification

Channels have been classified into five broad river typologies, outlined in Table 2.1. These correlate approximately to the channel types identified for British Rivers in general in Ferguson (1986). The humid-temperate climate and glaciated landscape of Britain is assumed in this study to translate across to the Shannon Catchment. This typology has been applied to the catchment using desk study information on geology and altitude, channel pattern and stream power, photographs previously gathered from the previous hydrological site visits to the Shannon and aerial photography, together with informed professional judgement. This has led to the broad typing of channels at a catchment scale.

2.1.2 Mapping River Channel Types

River channel types have been assigned based on the specific altitudes of the catchment (see Table 2.1) and an overview assessment of historical channel change (using maps) indicating potential natural adjustment. The following briefly summarises the definition of each of the types:

- Type 1 river channels - below the 40m contour;
- Type 2 river channels - inactive channels between the 40m and 300m contours;
- Type 3 river channel - between the 40m and 60m contours and active;
- Type 4 river channels - between the 60m and 300m contours; and,
- Type 5 river channels - above the 300m contour.

A GIS platform was used to generate the different types

Channel Type	Description	Potential River Management Issues	Key Features	Comments
Type 1	Lower catchment channels: • Those having not perceptibly changed their courses (naturally); • Low to very low energy; • Predominantly sediment sinks; • Likely to have regular to irregular sinuosity (note: straight channels extremely rare in nature); • Tree-lined gravely channels to clay bound channels; • Sinuosity could have been inherited from early Holocene times; and, • Includes clay channels found locally on glacio-lacustrine and glacio-marine sediments.	Maintenance of flood schemes (e.g. involving widening and/or deepening) probably concentrating on the need to remove accumulated finer sediments (from point and diffuse sources upstream).	• Less than 40m contour; and, • Alluvium as shown on drift geology map.	None.
Type 2	Inactive alluvial channels: • Narrow valleys of the main stem of the Shannon and its tributaries; • Little scope for meander development; • Confined channel patterns; • Likely to be a legacy from the Ice Age (i.e. palaeohydrological origin); river terraces could be present; and, • Could be locally cut into rock sides.	Due to the confined flood risk could be low, obviating the need for flood risk management solutions such as intervention. However, if settlements located in the valley bottom then could be localised issues of migration of channels. Sedimentation of artificially enlarged channels likely to occur.	• Areas between the 40m and 300m contours; and, • Alluvium as shown on drift geology map.	None.
Type 3	Self-formed alluvial channels: • Moderate energy; • Predominantly a sediment exchange (transfer); • Can be described as an active mobile gravel bed river; • Presence of active meandering; • Bedload likely to be a mix of coarse and fine gravels to coarse gravels carried from upstream; and, • Well defined pools and riffles and bar features; mature floodplain with a fining upwards sequence of sediments.	Lower risk of erosion than Type 4 but probably a higher risk of sediment issues than Type 4. Generally a moderate to high risk of erosion of embankments. Local modifications to the channel morphology through flood works could cause a sediment sink (e.g. excavation through a town or an arterial drainage scheme). Over-deep and over-wide channels could attempt to adjust to a more natural cross-section through sediment deposition (in the absence of maintenance). Previously straightened channels could have partially recovered sinuosity.	• Areas between the 40m and 60m contours; • Alluvium as shown on drift geology map; and • Historically active.	Field drains in Piedmont alluvial floodplain not included. Tributaries on floodplain of main stem may exhibit some of the characteristics of Type 4 channels.

Type 4	Self-formed alluvial channels: Piedmont • High energy; • Predominantly a sediment exchange (transfer); • Can be described as an active mobile gravel bed river; • Presence of active meandering; • Bedload likely to be coarse gravels carried down from Type 1 channels and deposited on less steep slopes; • Exposed point bars; and • Could be some fine silt from diffuse pollution sources such as agriculture.	Higher risk of erosion of embankments (i.e. would require embankments to be located outside of the meander belt to avoid erosion). Local modifications to the channel morphology through flood works could cause a sediment sink (e.g. excavation through a town or an arterial drainage scheme). Previously straightened channels could have partially or fully recovered their sinuosity.	• Areas between the 60m and 300m contours; • Alluvium as shown on drift geology map; and, • Historically active.	Field drains in Piedmont alluvial floodplain not included. Tributaries on floodplain of main stem could exhibit some of the characteristics of Type 4 channels.
Type 5	Bedrock channels: • High energy; • Inherently stable; and, • Predominantly sediment sources.	Assumed little need for flood risk management. Erosion and deposition not likely to be relevant management issue. Areas of low population in uplands; relatively stable bed and banks; predominantly erosion (sediment sources).	• Areas above the 300m contour.	Peat bogs/peat channels and local field drains could be present but not included at this scale.

Table 2.1 River channel typology

2.2 Approach Two

A Geographic Information System (GIS) has been used to develop a database of information and desk based data, subsequently manipulated to inform this high level geomorphological assessment. The overall outputs are three key maps highlighting areas potentially at risk of erosion and deposition and another plan taking into account the two key variables, soil type and stream power. The following data sources were used:

- Contemporary OS maps (Magic, 2015);
- Aerial photography (Bing, 2015);
- Flood maps (OPW, 2015);
- Historic maps (OSI, 2015); and,
- Hydrology data (CEH, 2015).

2.2.1 Variables

To establish the potential for erosion and deposition at a catchment scale, the relationships between multiple variables were assessed, including both natural and anthropogenic factors. These included historical change, stream power, sinuosity, soils, land use and slope. The following provides a brief description of each variable.

Stream Power

Stream power (Ω) represents the potential energy loss rate per unit length of the channel. Stream power is the product of gravitational acceleration (g = 9.8m/s2), discharge (Q, m3/s), water surface slope (S), and the density of water (ρ =1000kg/m3) (Eq. 1). As stream power increases, the risk of erosion increases, and (generally) the risk of long-term deposition decreases. The risk ratings for each output are shown in Tables 2.2, 2.3, and 2.4. Stream power has been classified into five categories: <10Wm-2; 10-35 Wm-2; 35-100 Wm-2; 100-300 Wm-2; and over 300 Wm-2.

$$\Omega = \rho g Q S \qquad \text{(Eq. 1)}$$

Soil

Soil type can affect the rate at which the surrounding land is eroded and the likelihood of a specific area being susceptible to erosion. Soil type, derived from the Irish Soil Information System (EPA, 2015), has been mapped and put into five categories. These are bedrock at the surface; made ground; peat; glacial till and alluvium. The more resistant the soil type, the smaller the risk of erosion and deposition. Therefore, bedrock and made ground have been classed as low risk, peat has been judged to be medium risk, and glacial tills and alluvium have been classed as high risk.

Sinuosity

The channel planform is reflected by the sinuosity index (Si); this is the ratio between the actual length of the main channel and tributaries, and the straight length of the main channel and its tributaries. The more variable the channel planform, i.e. the more sinuous, it has been assumed that there is a higher the potential for erosion and/or deposition to occur. Sinuosity was used for both the assessment of the potential risk of erosion and deposition. Sinuosity has been mapped and classified into five categories: less than 1.05; 1.05-1.3; 1.3-1.6; 1.6-2;

and greater than 2. A sinuosity value less than 1.05 is typically indicative of an artificially straightened channel. As the sinuosity of the channel increases, the risk of erosion or deposition also increases. Therefore for this study a sinuosity greater than 1.3 has been taken as low risk, a sinuosity of 1.3-1.6 w taken as medium risk, and sinuosity of greater than 1.6 as high risk.

Land Use

Land use potentially impacts sediment movement and therefore the extent of erosion and deposition mapped. Land use has been mapped and then put into eight categories. These are artificial land; plantation; arable land; woodland; pasture; open space; wetland; and shrubs and herbs. Different land uses potentially affect the hydrology of an area, impacting flashiness of flood events, runoff rates, infiltration rates and erosion rates.

Slope

The slope of a channel affects sediment transport and the potential for erosion and deposition. Slope was mapped and then classed into five categories. These are s=0-0.2; 0.2-10; 10-100; 100-200; and 200+. As the slope of a river channel increases, so risk of erosion increases, risk of deposition decreases and stream power increases.

Historical Channel Change

Some historical analysis of the Shannon catchment has been undertaken, and any evidence of historical change recorded. This variable has been divided into five categories: naturally migrating; realigned and sinuous; channelized; newly built field drains; and newly built canals. This data layer has only been used to assess the risk of erosion. The erosion risk of each category has been identified: naturally migrating channels potentially at high risk of erosion, realigned channels and channelized channels at medium risk of erosion, and any built channels at low risk of erosion.

Other Factors

Various other factors have been mapped but not used in any of the reported output calculations. These have been deemed as potentially important and could have local risks associated with them. Structures have been mapped as they could impact on sediment regime. These included various types of weirs, sluices and embankments. Locations of waterfalls have also been mapped, as these could have indicated active migration if not within areas of bedrock.

2.2.2 Variables

All data layers have been converted from vector to raster, to a resolution of 1km. This resolution has been chosen as it suitably reflects the precision needed.
For each of the three outputs, different weightings have been applied to each variable, as shown in Tables 2.2, 2.3 and 2.4. These weights have been used to combine the raster datasets in the weighted overlay process to create a corresponding output map. Once completed, the output raster dataset has been converted back into a vector dataset for ease of data handling.

Parameter	Ranking	Categories	Risk of Erosion	Notes
Historical change (evidence of change)	1	Canals (created)	Low	Low risk as likely reinforcement prevents erosion.
	2	Created field drains	Low	Low risk as low discharges and straight planforms indicate a relatively inactive channel with little erosion.
	3	Channelized	Medium	Medium risk as influenced by humans and possibly dynamic.
	4	Realigned (sinuous)	High	High risk as recovering back to a sinuous state, and therefore an active channel readily eroding.
	5	Naturally migrating	High	High risk as indication of an active channel, therefore readily eroding.
Stream power	1	<10	Low	Low risk due to low energy.
	2	10-35	Medium	Medium risk due to moderate energy
	3	35-100	Medium	Medium risk due to moderate energy
	4	100-300	High	High risk due to high energy.
	5	>300	High	High risk due to high energy.
Sinuosity	1	<1.05	Low	Low risk as a straight channel (evidenced over time) indicates reluctance to change and therefore less potential erosion.
	2	1.05-1.3	Low	Low risk as a relatively straight channel (evidenced over time) indicates reluctance to change and therefore less potential erosion.
	3	1.3-1.6	Medium	Medium risk as the channel can have a highly sinuous channel that formed in last glacial period and is not currently active.
	4	1.6-2	High	High risk as high sinuosity possibly indicates an active channel with erosion.
	5	>2	High	High risk as high sinuosity possibly indicates an active channel with erosion.
Soil type	1	Bedrock at the surface	Low	Low risk due to high resistance to erosion.
	2	Made ground	Low	Low risk due to high resistance to erosion.
	3	Peat	Medium	Medium risk due to moderate resistance to erosion.
	4	Glacial till	High	High risk due to low resistance to erosion if unconsolidated tills or sand. However, possible consolidation increases resistance.
	5	Alluvium	High	High risk due to lowest resistance to erosion.
Land Use	1	Artificial land	Low	Low risk due to high resistance to erosion.
	2	Plantation/ arable	Low	Low risk due to high resistance to erosion.
	3	Woodland/ pasture	Medium	Medium risk due to moderate resistance to erosion.
	4	Open space	High	High risk due to low resistance to erosion.
	5	Wetland/ shrub/ herb	High	High risk due to low resistance to erosion, and could act as sediment sources.

Slope	1	<0.2	Low	Low risk due to decreased stream power (i.e. lower slope) and lower potential for geomorphological work, including erosion.
	2	0.2-10	Low	Low risk due to decreased stream power (i.e. lower slope) and lower potential for geomorphological work, including erosion.
	3	10-100	Medium	Medium risk due to moderate stream power and moderate potential for geomorphological work, including erosion.
	4	100-200	High	High risk due to increased stream power and higher potential for geomorphological work, including erosion. Lateral adjustment could also be apparent.
	5	>200	High	High risk due to increased stream power and higher potential for geomorphological work, including erosion. Lateral adjustment could also be apparent.

Table 2.2 Erosion ranking of variables

Parameter	Ranking	Categories	Risk of Deposition	Notes
Stream Power	1	>300	Low	Low risk due to fast flowing water reducing potential deposition.
	2	100-300	Low	Low risk due to fast flowing water reducing potential deposition.
	3	35-100	Medium	Medium risk due to moderate potential for geomorphological work, including deposition.
	4	10-35	High	High risk due to high potential for geomorphological work, including deposition.
	5	<10	High	High risk due to high potential for geomorphological work, including deposition.
Sinuosity	1	<1.05	Low	Low risk as a straight channel indicates reluctance to change, and therefore less potential for deposition.
	2	1.05-1.3	Low	Low risk as a relatively straight channel indicates reluctance to change, and therefore less potential for deposition.
	3	1.3-1.6	Medium	Medium risk as the channel can have a highly sinuous channel that formed in last glacial period and not currently active.
	4	1.6-2	High	High risk as high sinuosity indicates an active channel with deposition.
	5	>2	High	High risk as high sinuosity indicates an active channel with deposition.
Soil Type	1	Bedrock at the surface	Low	Low risk due to high resistance to erosion, leading to small sediment yield within channels.
	2	Made ground	Low	Low risk due to high resistance to erosion, leading to small sediment yield within channels.
	3	Peat	Medium	Medium risk due to moderate resistance to erosion, leading to moderate sediment yield within channels.
	4	Glacial till	High	High risk due to low resistance to erosion of tills or sand, increasing sediment yield within channels. However, possible consolidation increases resistance.
	5	Alluvium	High	High risk due to lowest resistance to erosion, increasing sediment yield within channels.
Land Use	1	Woodland/ wetland	Low	Low risk due to high resistance to erosion, leading to small sediment yield within channels.
	2	Shrub/ herb veg	Low	Low risk due to high resistance to erosion, leading to small sediment yield within channels.

	3	Open space/ artificial land	Medium	Medium risk due to moderate resistance to erosion, leading to moderate sediment yield within channels.
	4	Plantation/ pasture	High	High risk due to low resistance to erosion, leading to high sediment yield within channels.
	5	Arable	High	High risk due to low resistance to erosion and potential sediment sources, leading to high sediment yield within channels.
Slope	1	>200	Low	Low risk due to decreased stream power, and lower potential for geomorphological work, including deposition.
	2	100-200	Low	Low risk due to decreased stream power, and lower potential for geomorphological work, including deposition.
	3	10-100	Medium	Medium risk due to moderate stream power, and moderate potential for geomorphological work, including deposition.
	4	0.2-10	High	High risk due to increased stream power, and higher potential for geomorphological work, including deposition. Lateral adjustment could also be apparent.
	5	<0.2	High	High risk due to increased stream power, and higher potential for geomorphological work, including deposition. Lateral adjustment could also be apparent.

Table 2.3 Deposition ranking of variables

Parameter	Ranking	Categories	Risk of Change	Notes
Stream Power	1	<10	Low	Low risk due to low energy and low potential for geomorphological work.
	2	10-50	Medium	Medium risk due to moderate energy and moderate potential for geomorphological work.
	3	50-150	High	High risk due to high energy and high potential for geomorphological work.
	4	150-300	High	High risk due to high energy and high potential for geomorphological work.
	5	>300	High	High risk due to high energy and high potential for geomorphological work.
Soil Type	1	Bedrock at the surface	Low	Low risk due to high resistance to erosion, leading to small sediment yield within channels.
	2	Made ground	Low	Low risk due to high resistance to erosion, leading to small sediment yield within channels.
	3	Peat	Low	Low risk due to high resistance to erosion, leading to small sediment yield within channels.
	4	Glacial till	Medium	Medium risk due to moderate resistance to erosion of tills or sand, leading to moderate sediment yield within channels. However, possible consolidation increases resistance.
	5	Alluvium	High	High risk due to low resistance to erosion, leading to large sediment yield within channels.

Table 2.4 Stream power and soil type ranking

2.3 Limitations and Assumptions

The two approaches to assessment have been undertaken using a combination of desk based information and informed professional judgement obtained by working on British Rivers in general. The approach is therefore necessarily strategic/high level and no field visits have been made from a geomorphological perspective to verify the conclusions drawn. It should be noted that the results do not identify specific areas of deposition or erosion, but instead provide potential areas that could be at risk of erosion or deposition.

The following are specific assumptions and limitations of the two approaches:

- Approach One has assumed that all rivers above the 300m contour are likely to be predominantly bedrock channels. For the purposes of this assessment it is also assumed that there are no bedrock channels present below the 300m contour. The limitation is that an arbitrary contour might not be a suitable surrogate for channel slope measured between two contours and seen as a key variable used in stream power calculation (which can be related to channel type);
- Approach One assumes that all channels below the 40m contour and above the 300m contour are stable. The limitation is again that an arbitrary contour might not be a suitable surrogate for channel slope measured between two contours and seen as a key variable used in stream power calculation (which can be related to channel type);
- Approach Two has assumed that the sinuosity index is reflective of the entire catchment or sub-catchment (i.e. tributaries and drains), even though it has been calculated using the main stem of a reach of river only;
- For Approach Two the values for slope and stream power have been taken from available point data sources and are assumed to be reflective of adjacent reaches/areas. The stream powers have been calculated using a high level/strategic assessment of the bankfull width of a river at a specific data point;
- Approach Two has used informed professional judgement of the authors (based substantially on experience of British rivers) to develop variables used to define each category, with the scoring using a non-weighted approach to define the risks of erosion and deposition; and,
- For both approaches it has been assumed that all areas of historical channel change have been identified using available historical mapping.

3 Shannon Catchment Background Information

3.1 Catchment Overview

At 360.5km, the River Shannon is the longest river in Ireland, draining a relatively enormous area of over 18,000km2. The Shannon is flat, with the majority of the fall in altitude taking place on the 24km stretch between Killoe and Limerick. The Shannon flows southwards from Shannon Pot in County Cavan, before then flowing westwards to the 102.1km Shannon Estuary. Numerous tributaries contribute to the Shannon before discharging into Lough Allen. The river then flows through 11 Irish counties, incorporating the key tributaries of Boyle, Inny, Suck, Mulkear and Brosna, as well as several others, before reaching Limerick and the Shannon Estuary. Many artificial canals also connect to the River Shannon.

The Shannon is a traditional freshwater river for 45% of its total length, due to an extensive estuary. There are also 1,600 lakes in the Shannon catchment, with many located along the main channel.

Anthropogenic impacts are apparent throughout the catchment. Some of the watercourses have been heavily modified for uses such as navigation, water storage and public drinking water supply. These include Foynes Harbour, Limerick Dock, Doo Lough, Lough Derg and the River Fergus tidal barrage. A number of other watercourses are man-made, including the Grand Canal, Royal Canal and Shannon Erne waterway. These artificial channels provide important uses and benefits to society, with examples such as the Ardnacrusha hydroelectric power generation station which was built between Killaloe and Limerick, during the 1920s.

Limestone rocks dominate the geology of the Shannon District. The Burren in County Clare is well known for its seasonal lakes and disappearing rivers during prolonged dry spells. The most productive aquifers are located mainly in East Galway and Roscommon, contributing to approximately half of surface water.

There are a number of water dependent protected areas in the Shannon catchment, as summarised in Table 3.1.

Protected Areas	Legislation	Locations
Drinking Waters	The European Communities (Drinking Water (No. 2) Regulations 2007 (SI 278 of 2007)	Drumcliff, Ballinaguard
Shellfish Waters	European Communities (Quality of Shellfish Waters) Regulations 2006 (SI 268 of 2006) as amended in 2009	Inner Tralee Bay
Bathing Waters	Bathing Water Quality Regulations SI 79 of 2008	Kilkee, Lough Derg
Nutrient Sensitive Areas	Urban Waste Water Treatment Regulations 2001 (SI 254 of 2001) as amended in 2004 and 2010	The Brosna, the Upper Feale estuary
Special Areas of Conservation	European Communities (Natural Habitats) Regulations, SI 94 of 1997 as amended in 1998 and 2005. Environmental Objectives (Freshwater Pearl Mussel) Regulations (SI 296 of 2009)	River Shannon Callows, Lower Shannon Estuary, Clara Bog, Lough Ree
Special Protection Areas	European Communities (Natural Habitats) Regulations, SI 94 of 1997 as amended in 1998 and 2005	

Table 3.1 Water dependent protected areas within the Shannon Catchment (EPA, 2010)

3.2 Water Framework Directive

The Water Framework Directive (WFD) (Directive 2000/60/EC) is a significant piece of EU water legislation that came into force in 2000, with the overarching objective of enabling all water bodies in Europe to attain Good or High Ecological Status. In addition, any modification to a water body should not lead to deterioration in the status of a water body or any of the quality elements.

The surface water ecological status combines three factors: biological factors (including fish, aquatic invertebrates, diatoms, macrophytes, filamentous algae and phytoplankton), physico-chemical factors (including oxygen, nutrients, transparency, temperature, acidity, salinity and specific pollutants) and hydromorphological factors (including flow, lake level and tidal patterns). Reaches are classified into high, good, moderate, poor and bad status. Surface water ecological statuses for the Shannon Catchment are stated below in Table 3.2.

Waterbody	Satisfactory (high or good ecological status)	Unsatisfactory (moderate, poor or bad status)	Yet to be assigned
Rivers and Canals	42%	57%	1%
Lakes	43%	55%	2%
Estuaries	35%	35%	30%
Coastal Waters	27%	0%	73%

Table 3.2 Surface water ecological status (EPA, 2010)

There are 46 rivers, 16 lakes and one coastal water body classified by the Environmental Protection Agency (EPA) under the WFD as high status. These areas are affected negligibly by human activity, some at or near natural conditions and supporting naturally diverse aquatic wildlife. These areas are important for supporting species sensitive to enrichment or increased siltation, such as freshwater peal mussel and juvenile salmon. Presence of these areas increases overall species diversity and recolonization over the entire channel.

The Shannon River Basin Management Plan (RBMP) (Cycle 1) covers the period from 2009 and 2015, aiming to protect all waters within the Shannon catchment. This plan sets out to improve waters to reach at least good status by 2027. The four core objectives of the Shannon RBMP are to:

- Prevent deterioration;
- Restore good status;
- Reduce chemical pollution; and,
- Achieve water related protected areas objectives.

The EPA has highlighted a decline in high status waters over the past two decades. According to the 2009 EPA indicators report, the number of high quality river sites, nationally, has almost halved over the last 20 years and the Shannon catchment is one of the Districts with the greatest decline.

Some surface waters have been substantially changed in character or artificially constructed for uses such as navigation, water storage, public supply, flood defence, and land drainage. Twenty-one such waters have been designated as heavily modified waters or artificial waters in the Shannon International River Basin District. The objective for heavily modified waters and artificial waters is to achieve good ecological potential. This objective allows the important function of these waters to

be retained whilst ensuring that the ecology is protected or improved. The method used is based on a common approach, agreed between EU member states. The method requires a set of agreed mitigation measures to be implemented to improve the hydromorphological characteristics (water flow and physical conditions) as much as possible, without having significant adverse impacts on the function of these waters or the wider environment.

4 Approach One – Data Representation and Analysis

4.1 Overview

The analysis has been undertaken for the entire Shannon catchment. A channel typology has been developed using an existing British River typology, informed professional judgement, aerial photography and photographs taken from the over-arching hydrological site visit. The risk of erosion and deposition for each river type has also been determined, as well as potential river management techniques. Five river channel types have been defined in this Report:

- Type 1: Lower catchment channels;
- Type 2: Inactive alluvial channels;
- Type 3: Self-formed alluvial channels;
- Type 4: Self-formed alluvial channels – Piedmont; and
- Type 5: Bedrock channels.

The following provides the outputs from the GIS maps and shows general areas of high and low risk of erosion and deposition.

4.2 River Channel Typology Description and Risks

Type 1 river channels are taken to be low energy alluvial channels located below the 40m contour in the Shannon Catchment. These channels are predominantly sediment sinks due to the low stream power. Therefore river management should focus mainly on restricting fine sediments input, especially from point and diffuse sources upstream.

Type 2 river channels are determined as stable alluvial channels, between the 40m and 300m contours, with little scope for meander development. These channels are predominantly sediment transfer zones due to their confined nature. Localised issues of channel migration could occur if settlements are located in the valley bottom. Sedimentation (requiring periodic maintenance) could occur within artificially enlarged channels.

Type 3 river channels are taken as moderate energy, between the 40m and 60m contours. These channels are predominantly sediment exchange zones with active meandering present. Type 3 channels have lower erosion risks than type 4 river channels, but greater potential sedimentation issues. Generic issues are listed as follows:

- Moderate to high risk of bank and embankment erosion;
- Over-deep and over-wide channels could attempt to adjust to a more natural cross-section through deposition;
- Local modifications to channel morphology through flood works could cause or enhance an existing sediment sink; and,
- Previously straightened channels could have partially recovered their sinuosity by active meandering processes.

Type 4 channels are determined to be high energy located between the 60m and 300m contours. These channels are predominantly sediment exchange zones with active meandering present. Type 4 river channels have higher erosion risks than

type 3 river channels, but lower sedimentation potential. Generic issues are listed below:

- High risk of bank and embankment erosion – bank protection could need to be positioned on the outside of meander bends preventing lateral erosion (and this could prove to be unsustainable and environmentally unacceptable);
- Local modifications to channel morphology through flood works could cause a sediment sink; and,
- Previously straightened channels could have partially recovered by regaining some of their former sinuosity.

Type 5 river channels are high energy bedrock channels above the 300m contour. These channels are predominantly sediment sources due to their steep gradient. Erosion and deposition are unlikely to be a management issue in these channels.

4.3 Locations of River Channel Types

The location of each river channel type has been discussed below and shown in Figure 4.1.

Type 1

Type 1 river channels are located within the lower catchment, below the 40m contour. Much of the main stem of the River Shannon is also classed as a type 1 river channel. Multiple lakes are found associated with this type, including Lough Ree and Lough Derg. The lowland rivers within County Clare and northern County Kerry are also classed as type 1.

This river channel type has been stated as having a low risk of erosion and a high risk of deposition.

Type 2

Type 2 river channels are inactive between the 40m and 300m contours. This river channel type covers the vast majority of channels within the catchment. Main areas where there are not as many type 2 river channels are around Limerick in County Limerick, Tralee in County Kerry, and within County Clare.

This river channel type has been stated as having a low to moderate risk of erosion and deposition.

Type 3

Type 3 river channels are located between the 40m and 60m contours and are active. There are few type 3 river channels throughout the catchment. These are mainly located in County Rosscommon around Strokestown and Longford, in County Galway around Ballinasloe, in County Offally around Birr, and small areas in County Limerick, Clare and Kerry.

This river channel type has been stated as having a moderate to high risk of erosion and deposition.

Type 4

Type 4 river channels are located between the 60m and 300m contours and determined to be likely to be active. There are few type 4 river channels throughout the catchment. These are mainly located in northern County Kerry around Tralee and Listowel, in central County Roscommon around Castlerea, and in County Westmeath around Castlepollard and Kilbeggan.

This river channel type has been stated as having a high risk of erosion and a moderate risk of deposition.

Type 5

Type 5 river channels are located within the upper catchment, above the 300m contour. Apart from highlands to the east of Sligo, type 5 river channels are within the southern area of the catchment. Significant mountains where type 5 river channels are located include the Slieve Bloom Mountains, Slieve Felim Mountains, Silvermere Mountains, Mullaghreirk Mountains, Ballyhoura Mountains, Dartry Mountains, and Sieve Mish Mountians.

This river channel type has been determined in this study to have a very low risk of erosion and deposition.

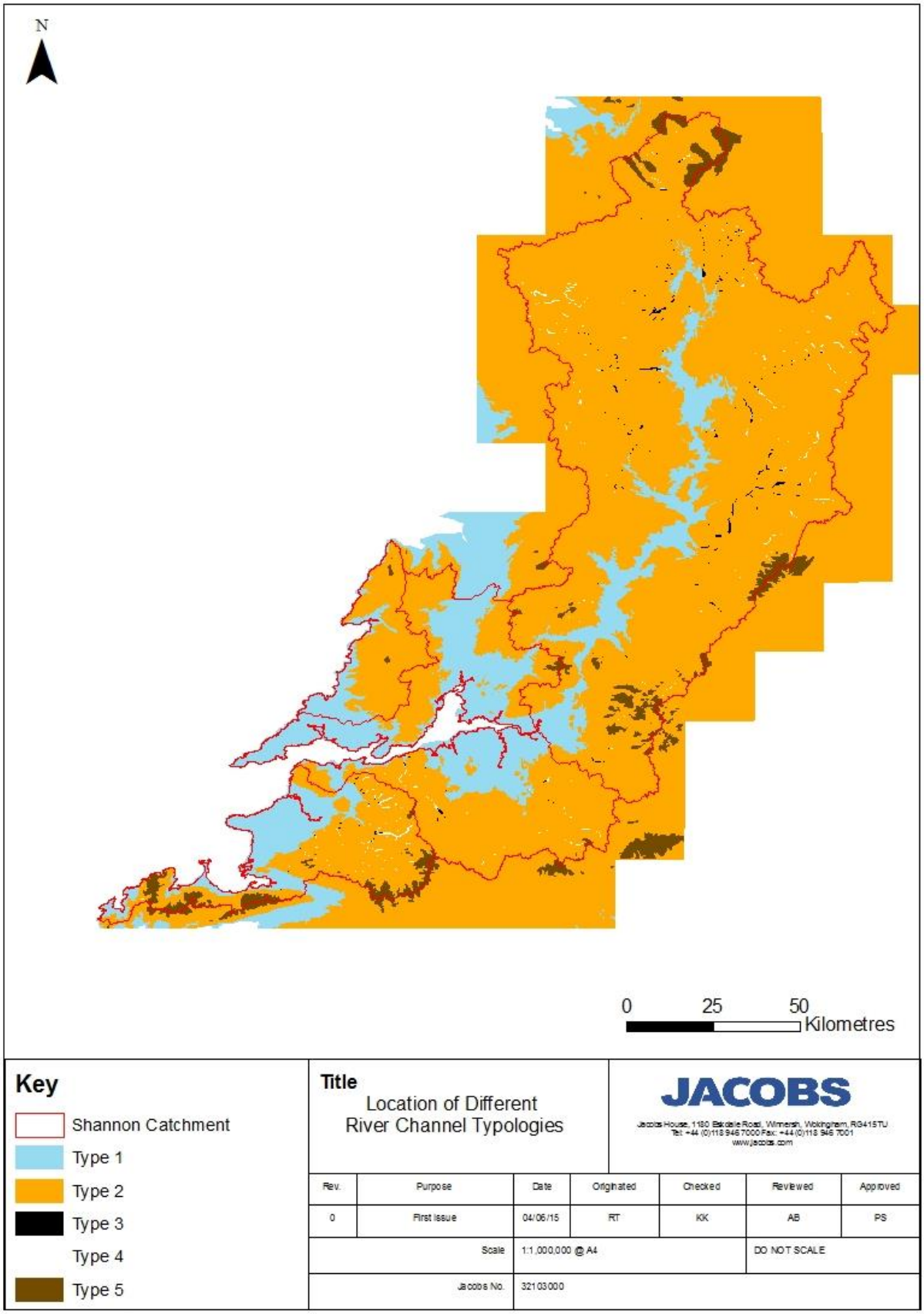

Figure 4.1 River channel types

Different river channel types vary in degree of risk of erosion and deposition. Table 4.1 below summarises the risks to each type as well as potential river management techniques to mitigate risk.

River Channel Type	Significant Locations	Risk of Erosion	Risk of Deposition	Potential River Management Solutions
Type 1	• Main stem of the River Shannon; • Lowland rivers in County Clare and County Kerry.	Low	High	• Land management to prevent poaching of existing eroding banks and control of diffuse runoff from agricultural sources; • Incorporate Sustainable Urban Drainage Systems (SuDS) and blue-green infrastructure into future developments, sustainably managing potential sources of sediment; • Riparian corridor planting along eroding banks to minimise access to channel, addition of a buffer and removing some sediment sources; and, • Dredging to remove fines directly from the channels (NB this could be unsustainable or environmentally undesirable).
Type 2	• Throughout the catchment.	Low to Moderate	Low to Moderate	• Incorporate Sustainable Urban Drainage Systems (SuDS) and blue-green infrastructure into future developments, sustainably managing potential sources of sediment; • Land management to prevent poaching of existing eroding banks and control of diffuse agricultural sources; and, • Riparian corridor planting along eroding banks to minimise access to channel, add a buffer and remove some sediment sources.
Type 3	• River Brosna around Ferbane in County Offally; • River Scramage around Strokestown in County Roscommon; • Hind river around Roscommon in County Roscommon; and, • The river network around Mohill in County Leitrim.	Moderate to High	Moderate to High	• Land management to prevent poaching of existing eroding banks and agricultural diffuse runoff; • Riparian corridor planting along eroding banks to minimise access to channel, add a buffer and remove some sediment sources; • Incorporate Sustainable Urban Drainage Systems (SuDS) and blue-green infrastructure into future developments, sustainably managing potential sources of sediment; • 'Soft' bank reinforcement such as

River Channel Type	Significant Locations	Risk of Erosion	Risk of Deposition	Potential River Management Solutions
				vegetative techniques reducing erosion and increasing resilience of eroding banks; • 'Hard' bank reinforcement such as gabions and concrete bed/banks reducing erosion and increasing resilience of eroding banks (NB this may be unsustainable and environmentally unacceptable); • Flow deflectors to protect eroding banks, encouraging flow diversity and remove fine sediment; and, • Dredging to remove fines directly from the channels (although this may be unsustainable and environmentally unacceptable).
Type 4	• The river network around Tralee and Listowel in County Kerry; • River Suck around Castlerea in County Roscommon; • River Brosna around Kilbeggan in County Westmeath; and, • The river network around Castlepollard in County Westmeath.	High	Moderate	• Land management to prevent poaching of existing eroding banks and control diffuse pollution from agricultural sources; • Riparian corridor planting along eroding banks to minimise access to channel, addition of a buffer and removal of some sediment sources from discharging into the channel; • Incorporate Sustainable Urban Drainage Systems (SuDS) and blue-green infrastructure into future developments, sustainably managing potential sources of sediment; • 'Soft' bank reinforcement such as vegetative techniques reducing erosion and increasing resilience of eroding banks; • 'Hard' bank reinforcement such as gabions and concrete bed/banks reducing erosion and increasing resilience of eroding banks; and, • Flow deflectors to protect eroding banks, encourage flow diversity and locally induce deposition of fine sediment.

River Channel Type	Significant Locations	Risk of Erosion	Risk of Deposition	Potential River Management Solutions
Type 5	• Slieve Bloom Mountains; • Slieve Felim Mountains; • Silvermere Mountains; • Mullaghreirk Mountains; • Ballyhoura Mountains; • Dartry Mountains; and, • Sieve Mish Mountains.	Very Low	Very Low	• Do nothing

Table 4.1 Risk of erosion and deposition to different river types

5 Approach Two – Data Representation and Analysis

5.1 Overview

Following the GIS analysis of the variables three outputs have been developed as follows:

- Sensitivity to erosion;
- Sensitivity to deposition; and,
- Comparison of stream power (including slope) and soil type.

Section 2 details the methodology for the assessment of each of the key variables. The following provides the outputs from the GIS models and details the areas potentially at risk.

5.2 Areas at Risk of Erosion

Figure 5.1 provides the output for erosion risk for the Shannon Catchment giving consideration to the following variables, further detailed in Section 2:

- Historical change;
- Stream power;
- Sinuosity;
- Soil type;
- Land use; and,
- Slope.

From initial analysis of the data, the key areas at risk of erosion are primarily located in the south west of the catchment and to the north of the catchment. This primarily includes the following rivers and locations:

- South West:
  - Along the Galey River;
  - River Feale (particularly by Abbeyfeale);
  - River Brick; and,
  - The river network by Tralee.
- North:
  - River Suck (particularly around Castlerea, Ballymoe and Athleague);
  - Arigna River;
  - Cloone River;
  - Eslin River (near Drumod);
  - River Eithne (near Ballinalack); and,
  - River Brosna (near Kilbeggan and Ballycumber).

The area of highest erosion risk in the south west of the catchment is located within an area of high slope where the river channels are sinuous or meandering. The stream powers have been calculated as ranging from 50-1000 Wm-2 and the soil type dominated by tills, alluvium and peat. Each of these factors is likely to have contributed to the higher risk of erosion. The alluvium and tills are more likely to be

relatively easily eroded, with the steeper slopes and higher stream powers indicating a greater stream power (i.e. energy for erosion). The area of high erosion risk in the north of the catchment is located in areas of low to mid slope except for the very northern reach feeding into Loch Aillionn, which has a steep catchment. Lower slopes would typically be associated with areas of less erosion risk. The stream powers are also typically low from less than 10Wm-2 to 50Wm-2, with only the very upper catchment areas having stream powers in excess of 50Wm-2. The substrate type is predominantly tills and alluvium with some areas of peat, which are more likely to be more susceptible to erosion, even with the lower stream powers. The River Suck channel to the west is classified as meandering, with the other rivers channels determined as sinuous (and some reaches with active meanders).

Some of the locations with embankments within the river corridor (particularly where some lengths of channel have been straightened) potentially have a greater risk of erosion than the upper sections where the river channel is more sinuous. This is particularly evident along the River Brick, Cashen River to the south west, the Clodiagh River to the west and the Ratty River to the east of the catchment. This is likely to be due to increased stream power as a result of direct channel modification and the embankment itself confining the higher flows from being dissipated on the floodplain.

The other areas within the catchment shown to have a decreased risk of erosion (Figure 5.1 – coloured yellow to pink) are typically located in the lowland areas around urban areas. The urban areas are typically assumed to be modified to some extent with altered geomorphological regimes. They are often sediment sinks due to traditional forms of flood control such as channel widening and channel deepening.

The confidence in flood estimation can be increased by having more high flow check gaugings at most gauging stations (in particular at stations 24008, 24011, 24012, 24015, 24029 and 24030). In addition, it is noted that stations 24003 (River Loobagh at Garroose) and 24006 (River Maigue at Creggane) are affected by backwater effects from the Maigue and Loobagh respectively, and both from the River Glen as well. It is therefore recommended that locations further upstream on the Loobagh and Garroose are considered for relocation of the gauges. The River Glen is currently not gauged, and a gauge on that watercourse would be beneficial for flood estimation along that watercourse, e.g. at Charleville.

It is recommended that the flood hydrology be reviewed every 5 to 10 years as more annual maxima and flood event data become available.

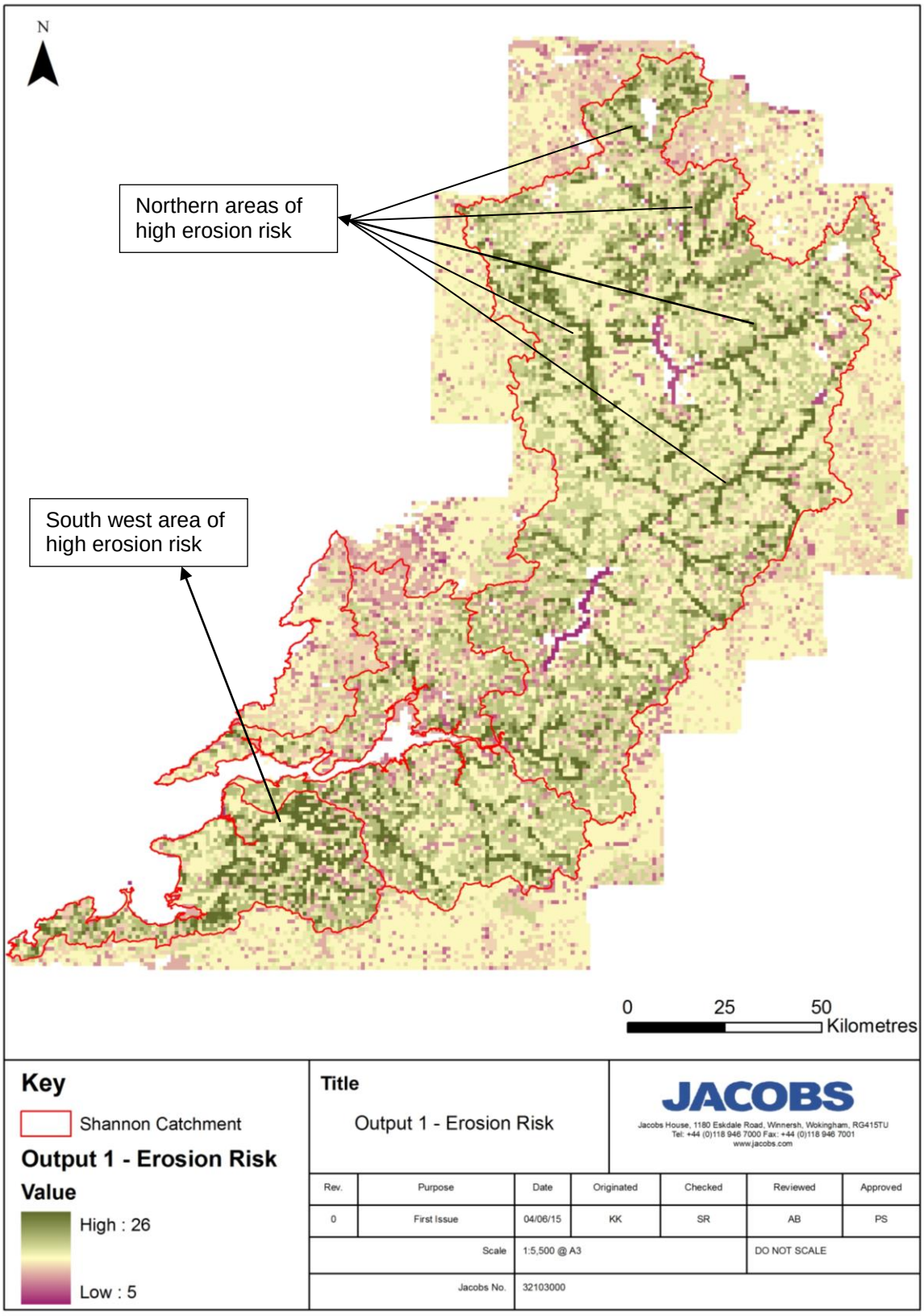

Figure 5.1 Potential risk of erosion (output 1)

5.3 Areas at Risk of Deposition

Figure 5.2 provides the output for the areas at risk of deposition. The study has given consideration to the following variables, further detailed in Section 2:

- Stream power;
- Sinuosity;
- Soil type;
- Land use; and,
- Slope.

From initial analysis of the data, the key areas at risk of erosion are primarily located to the south west, to the north and in the centre of the catchment. This primarily includes the following rivers and locations:

- South West:
  - River Brick (upstream of the Lixnew Canal confluence);
  - River Feale; and,
  - Galey River.

- North:
  - River Suck (particularly around Castlerea, Ballymoe and Athleague);
  - River Shannon (near Leitrim and Carrick-on-Shannon);
  - Camlin River;
  - Eslin River (near Drumod);
  - Rinn River (near Mohill);
  - River Eithne; and,
  - River Brosna

- Central:
  - River Shannon and tributaries near Limerick.

The area of high deposition risk in the south west of the catchment is primarily confined to the three rivers listed above. These typically have a mid to lower slope range and cut into alluvium and tills. The stream powers are typically within the range of 50-300Wm-2 and the rivers sinuous with the Galey River channel categorised as meandering. These factors all suggest that the rivers have sufficient energy to adjust their morphology and as a result are likely to have depositional processes and forms present, particularly on the inside of meander bends. Historical channel change analysis supports this with a number of the areas noted to have naturally migrated through time.

The area of high deposition risk in the north of the catchment typically is shown to have lower slope and lower stream power (ranging from less than 10Wm-2 to 50Wm-2) values. The river channels are all shown to have a sinuous planform. Although the slopes and stream powers are low, a sinuous planform suggests some form of channel adjustment could be occurring and likely to lead to deposition on the insides of meander bends. The lower stream powers suggest lower rates of energy within the river channel, likely to lead to deposition of sediments at specific locations. Following historical analysis a large portion of the northern catchment has been noted to have been realigned along a mix of short and long reaches, with some natural adjustment towards a more sinuous planform perhaps shown on the Rinn River and the River Eithne.

The River Suck channel to the north west is typed as meandering with a relatively low slope and lower range of stream powers. From aerial photographs this river channel can be seen to accommodate areas of erosion within a wide and deep channel. Deposition on the inside of meanders and in the form of shallower 'silty' areas can be observed at some locations.

The area of high deposition risk in the centre of the catchment is typically of a lower gradient (ranging from 0.2-10). The lower part of the catchment near the mouth of the Shannon exhibits lower predicted stream powers (less than 10Wm-2) with the upper section indicating some areas of higher stream powers (ranging from 50-300Wm-2). The section near to the mouth of the Shannon is also predominantly urban, but is still typed as sinuous or meandering. The lowest reach of channel near to the mouth is likely to be at risk of deposition due to the lower gradients and therefore lower stream powers. The upper reach of channel has a higher stream powers suggesting the river/tributary channels could have the energy to adjust their morphology. This is evidenced by some historic natural adjustment, which would include erosion and deposition particularly at meander bends.

Figure 5.2 highlights the risk of deposition throughout the Shannon Catchment (see medium risk colouring of light green). These reaches are typically the smaller channels with lower slopes and rivers with lower stream powers with the potential to deposit fine sediment.

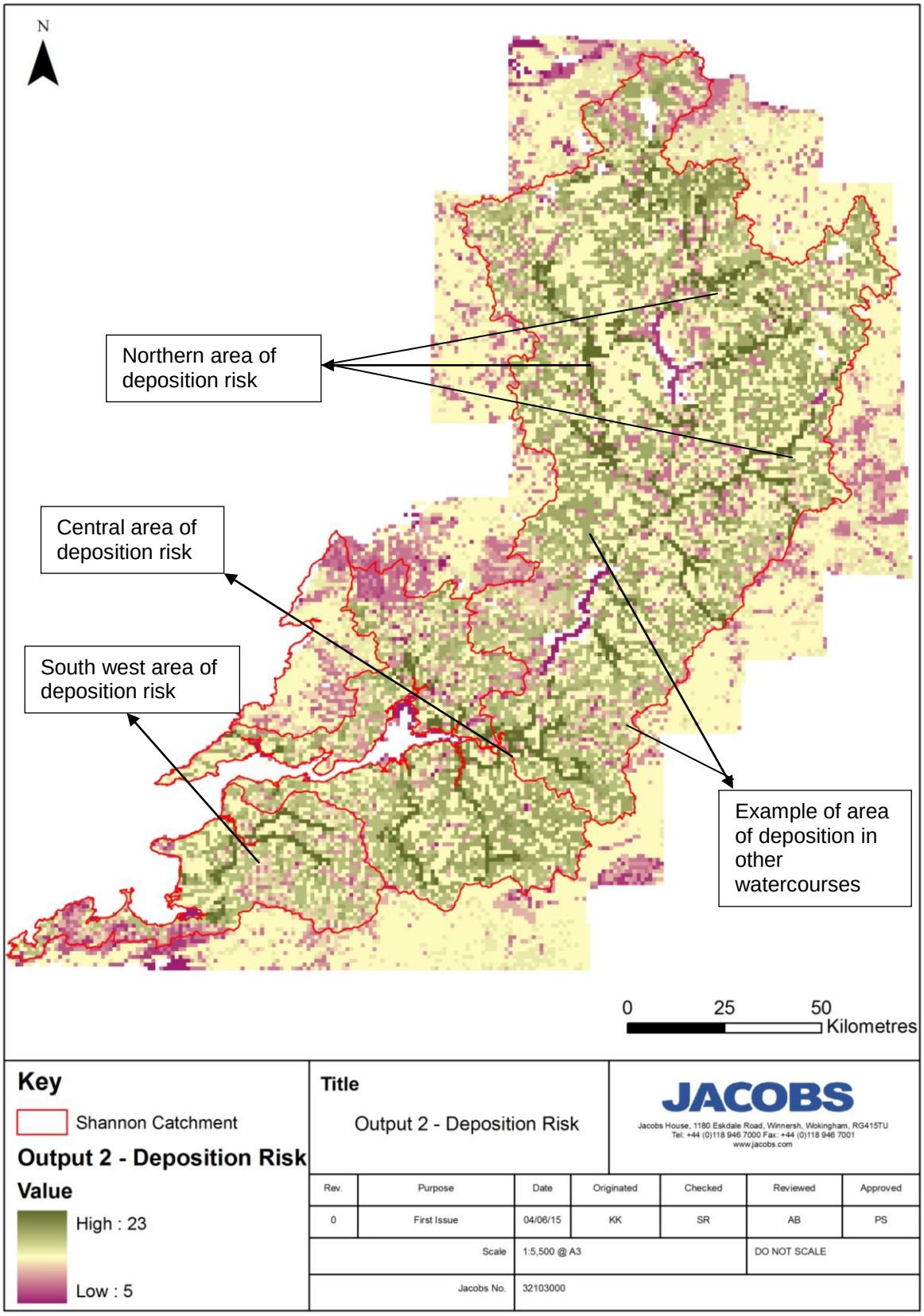

Figure 5.2 Potential risk of deposition (output 2)

5.4 Stream Power and Soil Type

Following analysis of the main erosion and deposition risk areas using the variables detailed in Section 5.2 and 5.3, a further assessment of stream power and soil type has been undertaken. The aim of this has been to identify key channels with higher stream powers, suggesting higher rates of energy with potential to erode the bed and banks, and reaches with a soil type particularly vulnerable to be eroded and undergo deposition.

Figure 5.3 shows the output of the analysis of stream power and soil type. Eight reaches of river channels have been highlighted in the figure as potentially having higher stream powers and soil types typically alluvium, tills or peat. The areas do coincide with those identified in Section 5.2 and 5.3 supporting the analysis made previously. These areas should be considered as at high risk for potential erosion and/or deposition.

Figure 5.3 also highlights channel reaches within the catchments at medium risk (light green). These are typically smaller channels within the main river catchments likely to either be steep with high stream powers and some erosion (and deposition risk) or channels with lower slopes more susceptible to deposition.

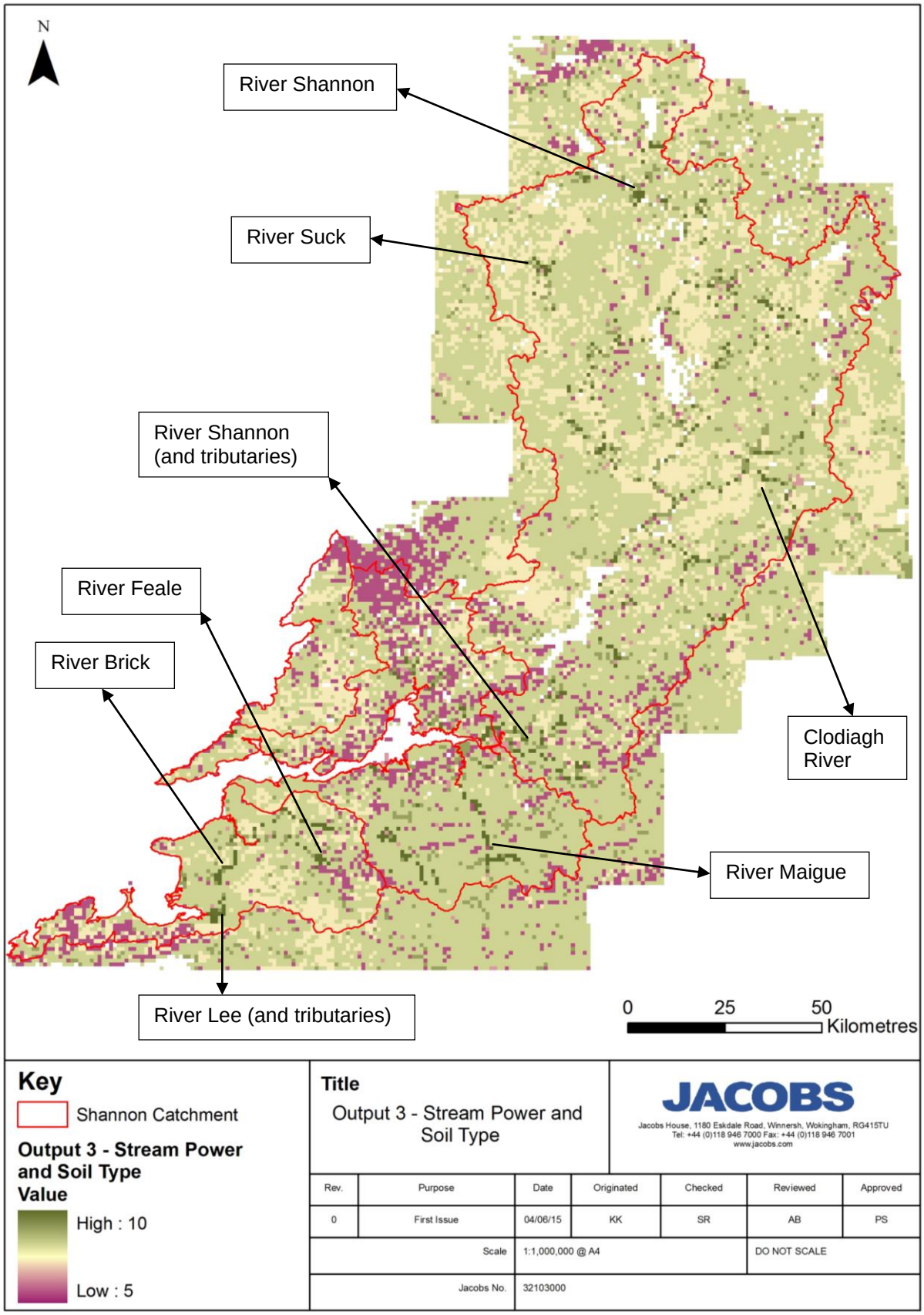

Figure 5.3 Stream power and soil type analysis (output 3)

6 Summary of Approach One and Approach Two

The first approach (Approach One) focused on river channel types. Analysis of these types has shown key areas of concern to be in the northern and south western areas of the Shannon Catchment. It should be noted that these river channel typologies are based on informed professional judgement and catchment information. Site visits have not been undertaken as part of this study.

The second (Approach Two) focused on multiple variables of hydrology, geology and adjacent land use. Analysis of the risk of erosion and deposition and the subsequent analysis of the key variables (stream power and soil type) have shown three key areas of risk in the northern, central and south western areas of the Shannon Catchment. It should be noted that these assessments are based on high level catchment information and a GIS analysis and further specific work could look to refine the outputs. Site visits have not been undertaken to ground truth the data collected as part of this initial study.

Various high risk areas were flagged up by both approaches, for both erosion and deposition. There has been most consistency in northern areas around the River Suck, Arigna River, Cloone River, Eslin River, River Eithne, Rinn River and River Brosna, as well as upper areas of the River Shannon itself. The River Feale and channels near the town of Tralee have been also flagged as at high risk areas using both approaches.

Active areas close to Limerick and within County Kerry have been identified only by Approach Two. This is probably because they are below the 40m contour and assumed to have been low energy river channels near to the mouth. However, these areas could be active due to development, structures and historic realignment, given the close proximity of the urban areas of Limerick and Listowel.

7 Analysis of Hydrological Sites

From the hydrological work that has been undertaken previously 66 priority sites have been defined for potential further work from the over-arching study. These priority sites are discussed in this section of the Report using the 'top-down approach' and 'bottom-up approach' assessments undertaken independently of each other. The sites have been grouped and discussed per catchment, and Table 7.1 provides a summary assessment for each proposed area.

7.1 Unit of Managemet 23

Seven sites have been identified in this catchment located to the south west of the catchment. The risk of erosion and deposition are primarily medium to high. One location has been identified as having a low risk, namely Moneycashen.

7.2 Unit of Management 24

Thirteen sites have been identified in this part of the catchment located to the south. The risk of erosion and deposition ranges from medium to high at most sites. Three sites have been identified with low risk including Tartbet (Power Station) with a low risk for erosion and deposition, Foynes with a low risk of deposition and Akeaton having a low risk of erosion.

7.3 Unit of Management 25 & 26

Thirty-seven sites have been identified in the north of this catchment. Typically the risk of potential erosion and deposition at these sites has been shown to range from medium to high. Some sites have been assessed as low risk of erosion (including Limerick, O'Brien Bridge and Portuma) but conversely all sites have been shown to have a medium to high risk of deposition.

7.4 Unit of Management 27

Eight sites have been identified to the west of this catchment. The Shannon Airport (IRR3) site has been shown to have a low risk of both deposition and erosion, with the site at Quin having a low risk of erosion. Otherwise all other sites in this management unit have been assessed to have a medium to high risk of erosion and deposition.

Site Name	Notes	Strategic Level Assessment			Overall Predicted Geomorphological Risk
		Provisional Typology	Risk of Erosion	Risk of Deposition	
Unit of Management 23					
Banna	Historically modified including realignment and channelisation. Scheme located in an area of made ground. Low slope and low stream power.	Type 1	High	High	High
Moneycashen	Sinuous planform cut into glacial till.	Type 1	Low	Low	Low
Listowel	Located immediately upstream of a reach that has naturally migrated. Situated in an area of made ground. Low stream power with some locally straightened reaches through a predominantly sinuous length of valley.	Type 1 and Type 2	Medium	High	Medium
Abbeydorney	Located in area that has been historically realigned or canalised. Typically straightened with upstream reach noted as sinuous. Medium stream powers. Channels underlain by made ground, tills and alluvium.	Type 1	High	High	High
Tralee	The south eastern extent of the area exhibits evidence of active lateral migration and the channels are predominantly sinuous. Stream powers are medium to high. The remainder of the area consists of artificially straightened channels.	Type 1 and Type 2	Medium	Medium	Medium
Athea	Located in a reach recorded to have naturally migrated (based on historical mapping). Bed and bank material potentially consists of alluvium and tills with the eastern extent composed mainly of bedrock at the surface. Meandering channel planform with medium slope. High stream power assessed for the river.	Type 2 and Type 4	High	High	High
Abbeyfeale	Southern extent located in a low risk zone. The remainder of the area is comprised of channels that have exhibited some historical channel change. Stream powers assessed as typically medium to high.	Type 2, Type 3 and Type 4	High	High	High
Unit of Management 24					
Ballylongford	Sinuous channel in an urban area.	Type 1	Medium	High	Medium
Tartbet (Power Station)	Some embankments recorded.	Type 1	Low	Low	Low
Foynes	Area predominantly consisting of sinuous channels with medium slope. River assessed to have medium stream power. Some reaches artificially straight.	Type 1	Medium	Low	Medium
Newcastle West	Sinuous channels with medium slopes and rivers with mid-ranging stream powers. Locally channelization/realignment in the defined area as well as some natural migration through time. A few locations to the north of the area have been identified as lower risk.	Type 2, Type 3 and Type 4	High	High	High
Dromcolliher	Typically sinuous channels with medium slopes. Rivers with mid-ranging stream powers,	Type 2	High	High	Medium-High

Site Name	Notes	Strategic Level Assessment			Overall Predicted Geomorphological Risk
		Provisional Typology	Risk of Erosion	Risk of Deposition	
Millford	Predominantly sinuous channels with medium slopes. Rivers with high stream powers. Some historic channel change recorded upstream and downstream of the defined area.	Type 2	High	High	High
Charleville	Sinuous channels with low slopes. Rivers with low predicted stream powers. Area underlain by tills and with a large reach located in an urban area.	Type 2	Medium	High	Medium
Rathkeale	Meandering and sinuous channels with medium slopes. Rivers assessed as having high stream powers. South western extent of the area is typically at a greater risk than the remainder of the area.	Type 1	Medium	Medium	Medium
Askeaton	Sinuous and straightened channels with a low slope. Rivers with low stream powers. Predominantly underlain by made ground or exposed bed rock.	Type 1	Low	Medium	Low-Medium
Clarina	On the outskirts of Limerick City, southern part of area is more at risk than northern part.	Type 1	Medium	Medium	Medium
Adare	Consists of meandering and sinuous channels with low slopes and rivers with low stream powers.	Type 1	Medium	High	Medium
Croom	Sinuous channels with low slopes and occupied by rivers with low stream powers, except for the river channel to the north of the area with a river with stream powers ranging from 10-50Wm^{-2}.	Type 1	High	High	High
Kilmallock	Typically sinuous channels, with one meandering tributary. Medium slopes and low-mid ranging stream powers.	Type 2 and Type 4	High	High	High
Unit of Management 25 and 26					
Limerick	The reaches to the north and far south of the area are those identified to be at greatest risk. Predominantly channels with a sinuous or meandering planform. Stream powers of the occupying rivers assessed to be low except for two steep channels to the north where the river is assessed to have locally higher energy.	Type 1	Low	Medium	Low
Springfield	Typically straightened channels with a low slope. Rivers assessed to have low stream power values.	Type 1	Medium	High	Medium
Cappamore	Medium slopes of channels, occupied by rivers with relatively high stream powers. Reaches both upstream and downstream of this area are embanked.	Type 2	High	High	High
Newport	Channels downstream of the area are embanked. The slope is typically medium with occupying rivers with high stream powers.	Type 2	High	High	High
Castleconnell	Primarily artificially straightened channels with a low slope and rivers with low stream power values. Some evidence of historic natural channel adjustment.	Type 1	Medium	High	Medium

Site Name	Notes	Strategic Level Assessment			Overall Predicted Geomorphological Risk
		Provisional Typology	Risk of Erosion	Risk of Deposition	
O'Briens Bridge	Primarily artificially straightened channels with a low slope and rivers with low stream power values. Predominantly canalised.	Type 1	Low	High	Medium
Killalow / Ballina	Primarily artificially straightened channels with low to medium slopes and occupying rivers with relatively low stream power values. Southern section of the area has been canalised.	Type 1 and Type 2	Medium	High	Low
Nenagh	Predominantly naturally sinuous channels with some evidence of artificial realignment to the east of the area. Medium slopes. Rivers with high stream powers to the east and low stream powers to the west.	Type 2 and Type 3	High	High	Medium
Roscrea	Sinuous planform with medium slopes. Rivers with low stream powers. Main area of risk is located to the north and east.	Type 2	Medium	Medium	Medium
Borrisokane	Sinuous channels with reaches channelized downstream of the defined area. Typically medium slopes with rivers of medium stream power (ranging from 10-50Wm^{-2}).	Type 2	Medium	Medium	Medium
Portuma	Channels with artificially straightened planform and medium slopes. Rivers with low stream powers. One reach with natural migration identified.	Type 1 and Type 2	Low	Medium	Low
Birr	Sinuous channels with medium slopes and rivers assessed as medium to high stream powers. Some channelization of channels to the east of the defined area and natural adjustment of channels within the northern extent of the area.	Type 2	High	High	Medium
Clonaslee	Sinuous channels with medium slopes and rivers with high stream powers. Embankments located along channels to the north of the defined area.	Type 2	High	High	High
Shannon Harbour	Artificially straightened channel with low slopes and rivers with low stream powesr.	Type 1	High	Medium	Medium
Shannonbridge (Power Station)	Bordered to the west by two naturally sinuous channels with one small reach of artificially straightened channel. Slope predominantly low with rivers of low stream powers (<10Wm^{-2}).	Type 1 and Type 2	High	High	Medium
Pollagh	Sinuous planforms with low gradients and rivers with relatively low stream powers.	Type 2 and Type 3	High	High	Medium
Rahan	Sinuous planform of channel with a medium slope. Occupied by rivers with high stream powers. Some areas with artificially realigned channel.	Type 2 and Type 3	High	High	High
Clara	Sinuous planforms with reaches of meandering channel. Low gradients and rivers of low stream powers. Some reaches with artificial realignment and channelization.	Type 2 and Type 3	High	High	High
Kilbeggan	Sinuous planforms with low gradients and rivers with low stream powers. Some historic natural adjustment evident; however, some reaches of the channel embanked.	Type 2 and Type 4	High	High	Medium

Site Name	Notes	Strategic Level Assessment			Overall Predicted Geomorphological Risk
		Provisional Typology	Risk of Erosion	Risk of Deposition	
Ballinasloe	Meandering channels with low slopes and rivers with typically low stream powers. Some historic natural adjustment upstream and some artificial realignment to the west of the defined area.	Type 1 and Type 2	Medium	High	Medium
Ahascargh	Meandering channels with low slopes and occupied by rivers with typically low stream powers.	Type 2	High	High	High
Athlone	A combination of naturally sinuous and artificially straightened channel planforms. Low slope and rivers with low stream powers. Some reaches with of historic channel adjustment identified.	Type 1 and Type 2	Medium	Medium	Low
Mullingar	Sinuous planforms with low channel slope and rivers of low to medium stream power. Some artificial realignment within the defined area.	Type 2 and Type 3	Medium	High	Low
Abbeyshrule	Sinuous channel planforms with low slopes and occupied by rivers with low stream powers.	Type 2	High	High	Medium
Ballymahon	Sinuous channel planforms with low slopes and occupied by rivers with low stream powers. Some historic channel adjustment recorded and slightly higher stream powers present for the rivers upstream of the defined area.	Type 1 and Type 2	High	High	Medium
Athleague	Meandering channel planform with low slopes and occupied by rivers with low stream powers. Some historic channel adjustment noted in the defined area.	Type 2	High	High	Medium
Roscommon	Meandering channel planform with low slopes and rivers with low stream powers. The northern extent exhibits rivers with some higher stream powers. Some artificial channel realignment noted downstream of the defined area.	Type 2	Medium	High	Medium
Lanesboro (Power Station)	Artificially straightened planforms with low slopes and rivers with low stream powers.	Type 1	High	High	High
Edgeworthstown	Sinuous channel planforms with medium slopes. Rivers of medium stream powers. Predominantly underlain by tills, with made ground present in the central areas.	Type 2	Medium	High	Medium
Longford	Sinuous channel planforms with low slopes and occupied by rivers of low stream power. Marginal areas exhibit rivers with higher stream power values from 10-50Wm^{-2}.	Type 2	Medium	High	Medium
Cloondara	Sinuous channel planforms with low slopes and occupied by rivers with low stream powers.	Type 1 and Type 2	Medium	Medium	Low
Castlerea	Meandering channel planforms with some historic natural channel adjustment noted. Channel slopes typically low and rivers with low stream powers. Southern extent of defined area exhibits rivers with slightly higher stream powers. Channels to the east have been historically realigned.	Type 2 and Type 4	High	High	High

Site Name	Notes	Strategic Level Assessment			Overall Predicted Geomorphological Risk
		Provisional Typology	Risk of Erosion	Risk of Deposition	
Dramod	Sinuous channel planforms with low slopes but rivers with medium stream powers (ranging from 10-50Wm^{-2}). Reach has been historically realigned.	Type 2 and Type 3	High	High	High
Mohill	Sinuous channel planform with low slopes but rivers with medium stream powers (ranging from 10-50Wm^{-2}).	Type 2 and Type 3	High	High	High
Carrick on Shannon	Low channel slopes with rivers of medium stream powers. Some channelization to the south of the defined area.	Type 2	Medium	High	High
Boyle	Eastern extent consists of low channel slopes with rivers of low stream power; some historic natural adjustment noted. Reach to the west has a medium channel slope and rivers with medium stream powers.	Type 2 and Type 3	High	High	Medium
Leitrim Village	Low channel slopes and rivers with low stream powers. Historic modification recorded in the form of channelization, with other reaches canalised.	Type 2	High	High	Medium
Drumshanbo	Medium channel slopes and rivers with high stream powers.	Type 2	Medium	High	High
Unit of Management 27					
Kilkee	Sinuous and meandering channels, with some straighter reaches. Predominantly medium slope with rivers of high stream powers.	Type 1	High	High	High
Kilrush	Sinuous channels in upstream section, which then become more artificially straight at the coastal area. Medium channel slopes with rivers of high stream powers.	Type 1	Medium	High	Medium
Shannon Airport (IRR3)	Located in an area bordered to the east by sinuous channels and rivers with medium stream powers. Typically underlain by made ground – i.e. urban area.	Type 1	Low	Low	Low
Shannon	Typically underlain by made ground and some marine deposits and exposed bedrock. Sinuous channels with low slopes and rivers with low stream powers. Embankments present along coastal area.	Type 1	Medium	High	Medium
Bunratty	Low channel slope and rivers with low stream powers with a predominantly embanked, artificially straightened channel.	Type 1 and Type 2	High	High	Low
Sixmilebridge	Sinuous channel planform with medium slopes and rivers with high stream powers.	Type 1	High	High	High
Quin	Area with medium channel slopes and rivers of high stream powers.	Type 1	Low	Medium	Medium

Site Name	Notes	Strategic Level Assessment			Overall Predicted Geomorphological Risk
		Provisional Typology	Risk of Erosion	Risk of Deposition	
Ennis	Large area covering predominantly sinuous channels with some artificially straighter reaches. The channel slope is typically low to medium with rivers of medium to high stream powers. Downstream of the defined area the channels are embanked.	Type 1	High	High	Medium

Table 7.1 High level geomorphology risk for each of the 66 catchment areas (based on outputs from Approach One and Approach Two. NB: this is a high level strategic assessment)

8 Summary, Recommendations and Next Steps

This report summarises a high level strategic assessment of the potential for geomorphological change (and specifically erosion and deposition processes) within the Shannon Catchment. Due to the uncertainties inherent at such a strategic level of study, two independent approaches were followed in an attempt to provide more certainty in the findings. Promisingly the two approaches have arrived at similar conclusions of geographical areas potentially at risk. The northern and south western extents of the catchment have been identified by both approaches as being at particular risk. Using the channel typology (developed in the first approach) these channels have been classed predominantly as Type 2, Type 3 and Type 4. The risk of erosion and deposition for these types ranges from Low to High. There are necessarily a series of limitations and assumptions made at this strategic level, not least that ground truthing through a site visit has not been possible.

This geomorphological assessment is intended to inform the CFRAMS hydrological study for the Shannon Catchment carried out in parallel. This hydrological study had previously identified a number of potential units of management (or areas) and most of the specific sites identified have been identified in this report as a Medium to High risk of either erosion or deposition. Before specific flood risk management solutions can be identified for individual rivers, tributaries or reaches then further geomorphological assessment would be required to more accurately inform options/decisions. Such work would need to involve desk based and field based elements and would allow a handle on the scale and extent of geomorphological change.

A detailed walkover survey (fluvial audit) might reveal that in a natural reach there could be a mix of sediment sources, transfers/exchanges and sinks operating. The fluvial audit approach (now a British industry-wide standard) was first developed by Sear, Newson and Brookes (1995). So the locating of a structure or channel works at a specific point along a river's long section could be variously influenced by these processes (and in turn influence them). This would potentially affect the need for and frequency of channel maintenance. Capital works and maintenance records were not available from OPW (or other readily available sources) for this study. In practice it is highly likely that previous channel works in the Shannon Catchment will have been extensive, particularly extensive arterial drainage schemes. These will have been implemented in the past hundred or so years to facilitate free fall drainage of adjacent fields primarily by lowering the channel bed. In effect these will have become sediment traps extended over a considerable distance of the main stem or tributaries. Again the consequence locally could have been to artificially trap and store the entire bed load of a river. In turn this could have had downstream consequences, locally initiating erosion (due to sediment starvation) or reducing the need for sediment management in a downstream flood scheme (for example).

9 References

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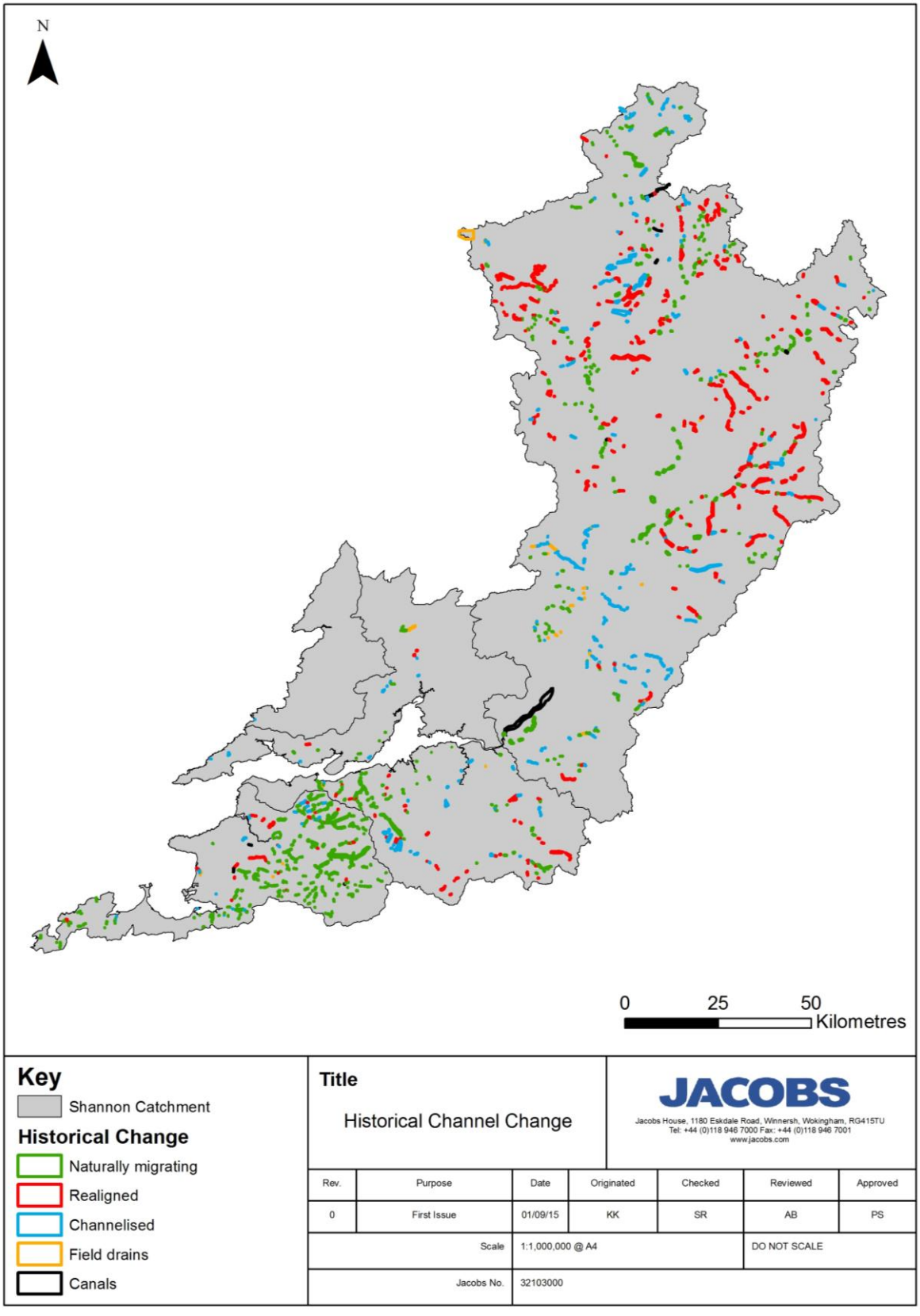
Appendix A Gauging Station Information Sheets



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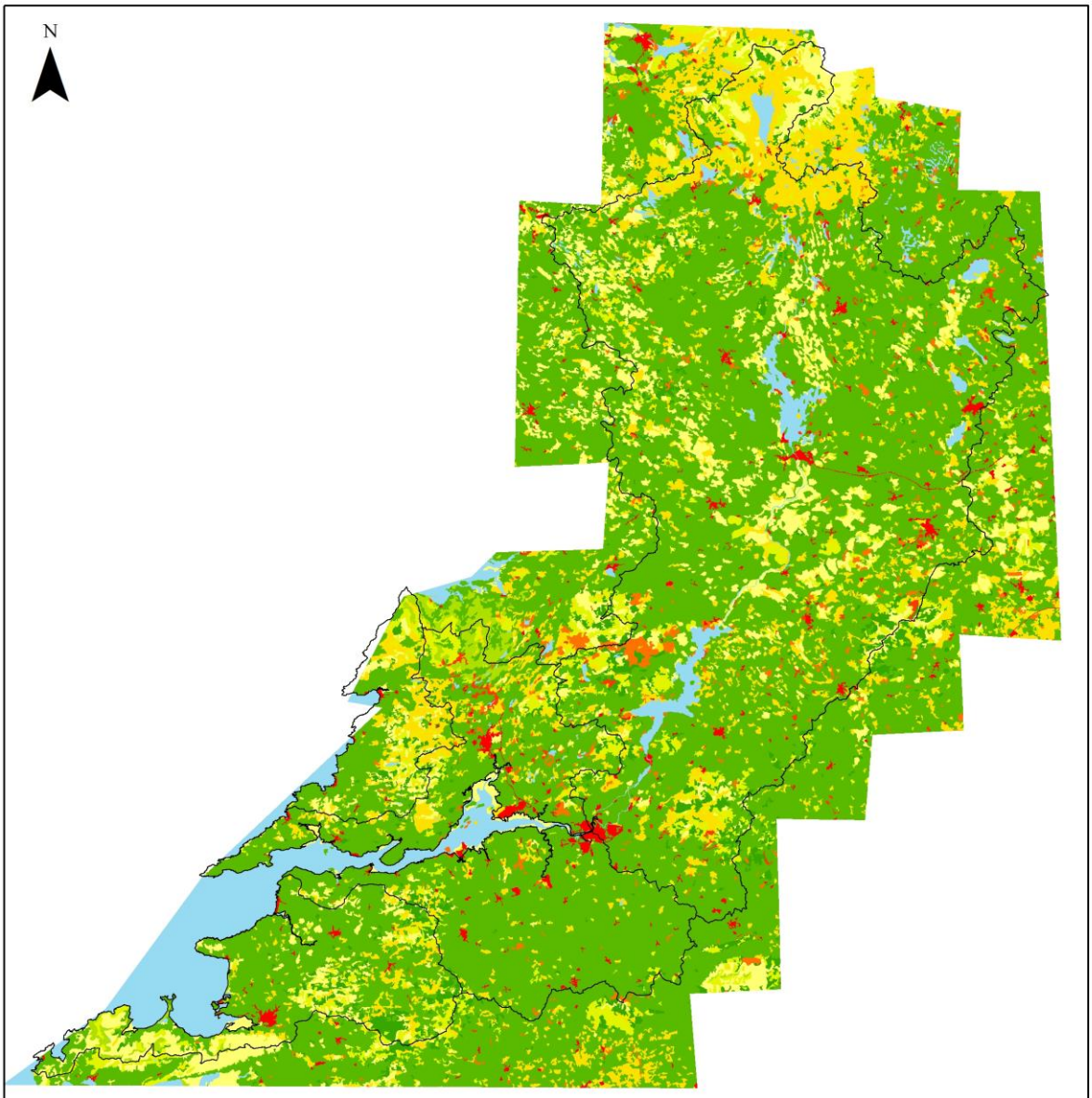

Title

Land Use

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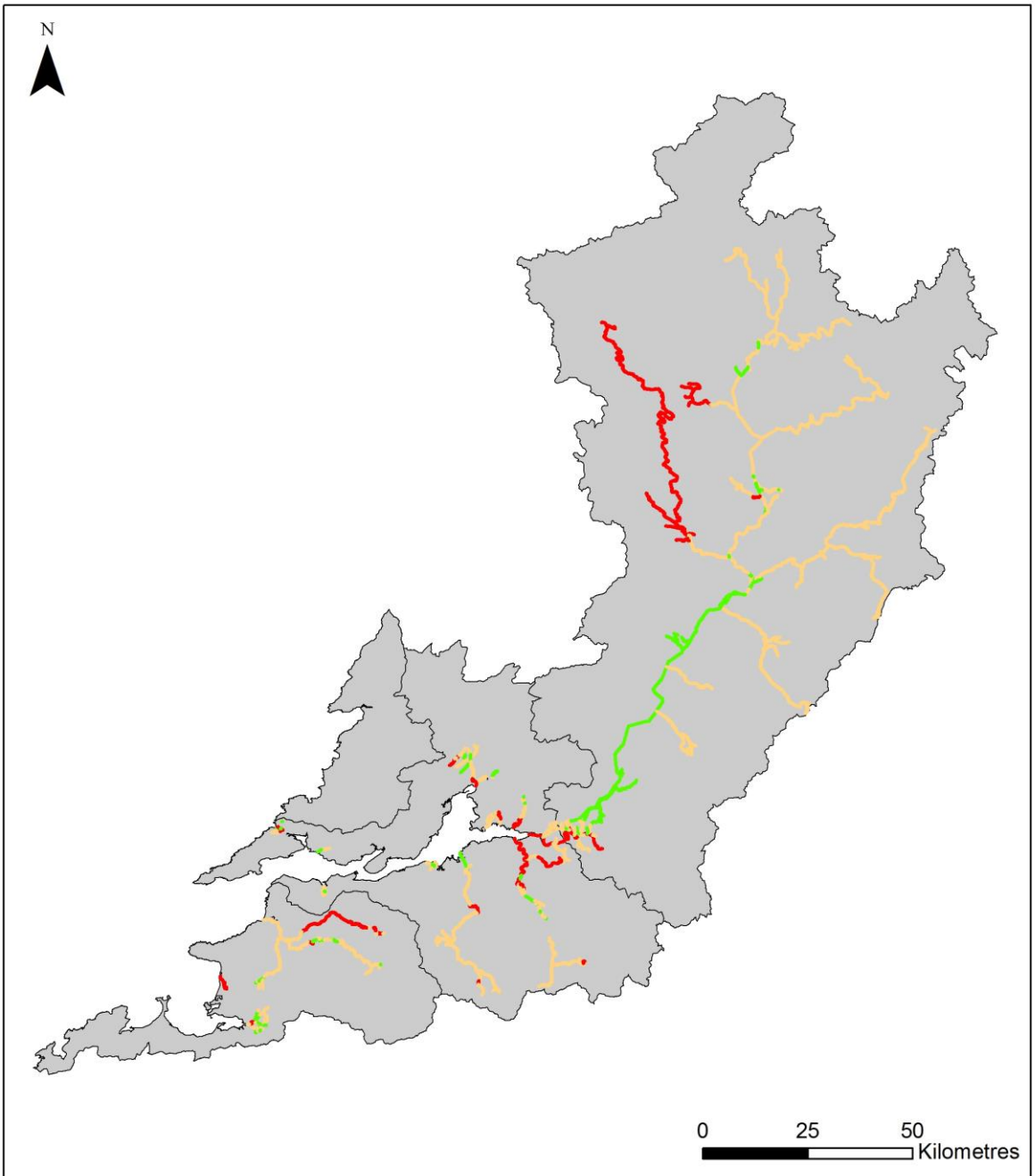

Key

Shannon Catchment

Sinuosity

Straight

Sinuous

Meandering

Title

Sinuousity Index

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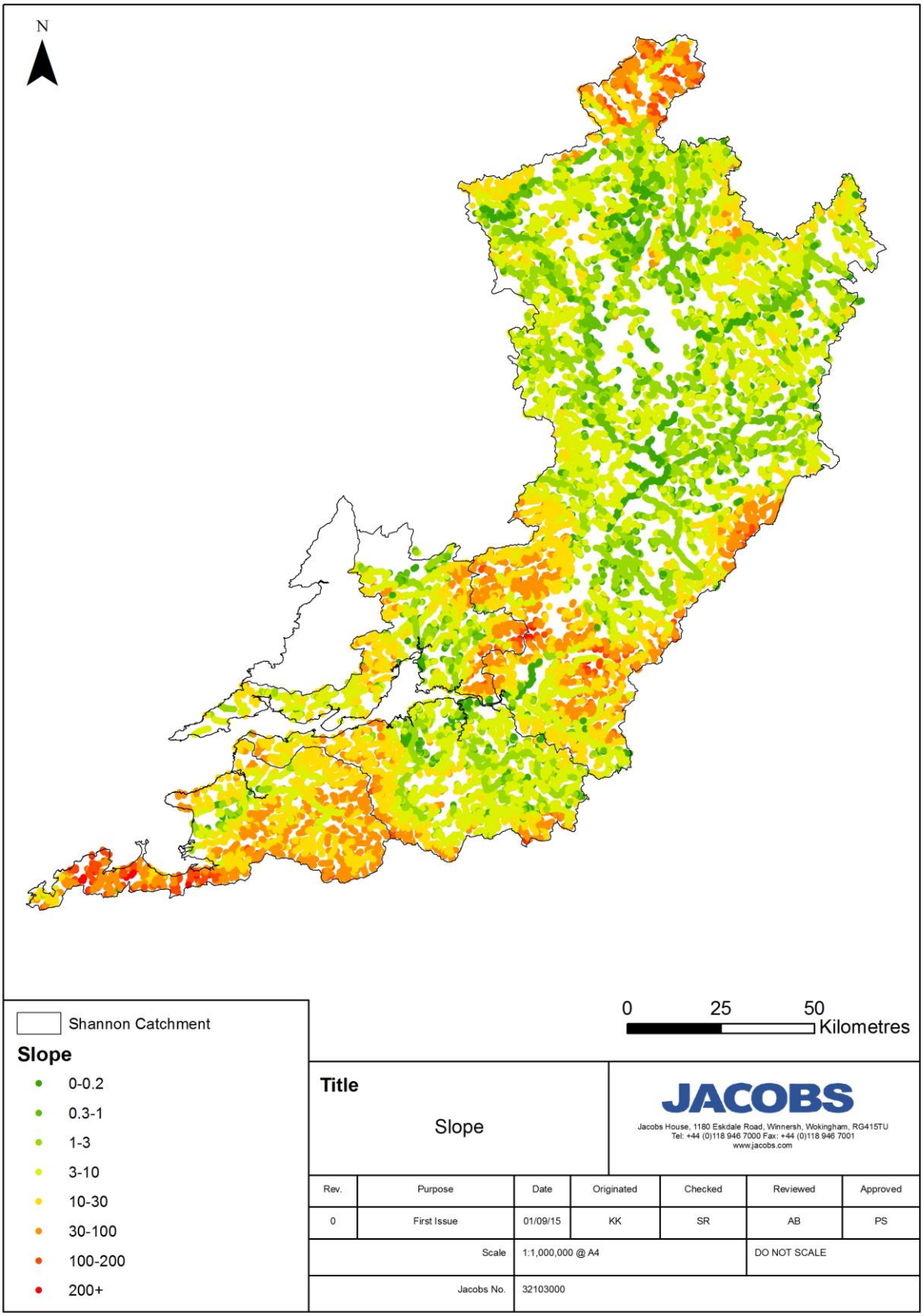

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Slope

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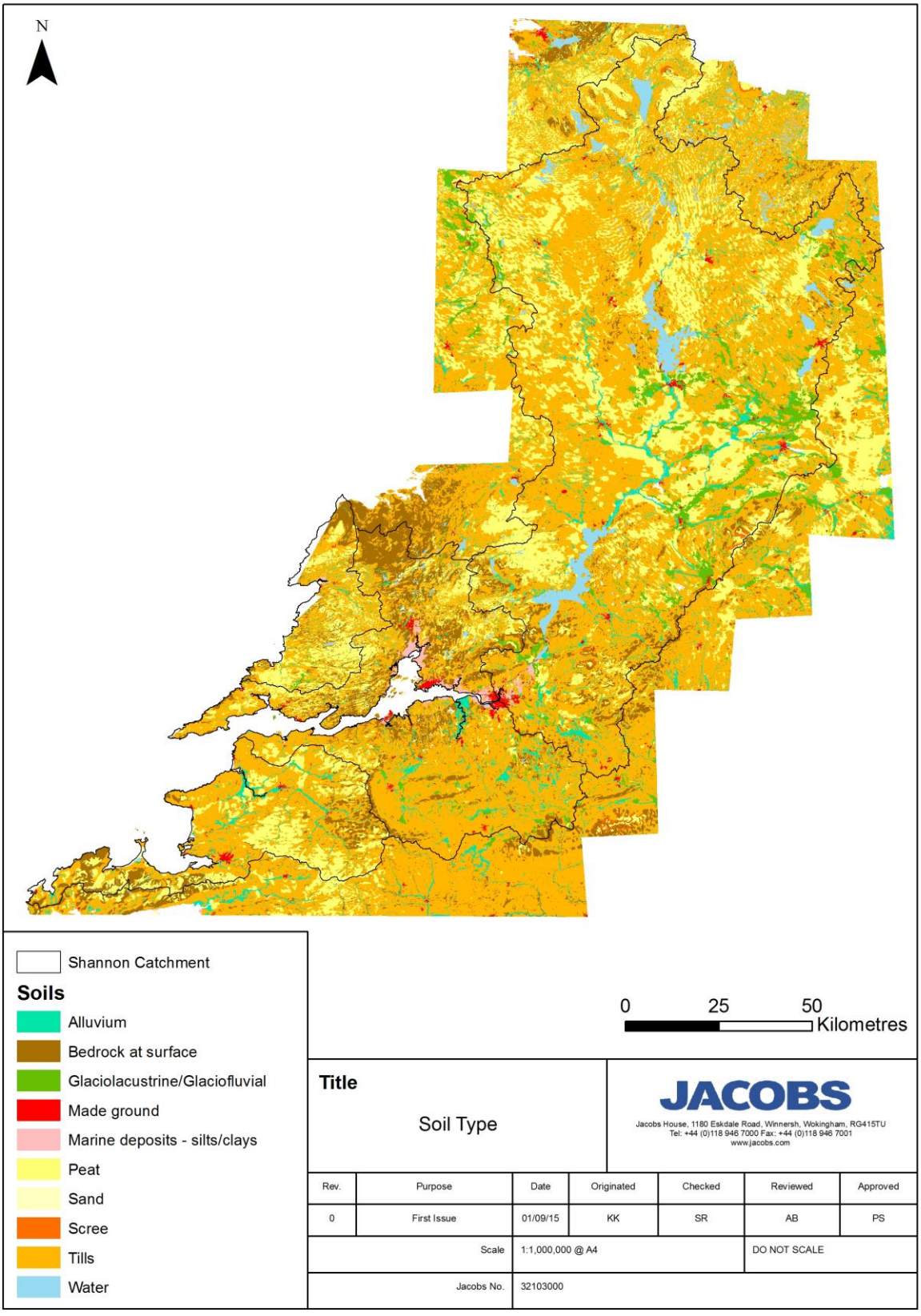

Title

Soil Type

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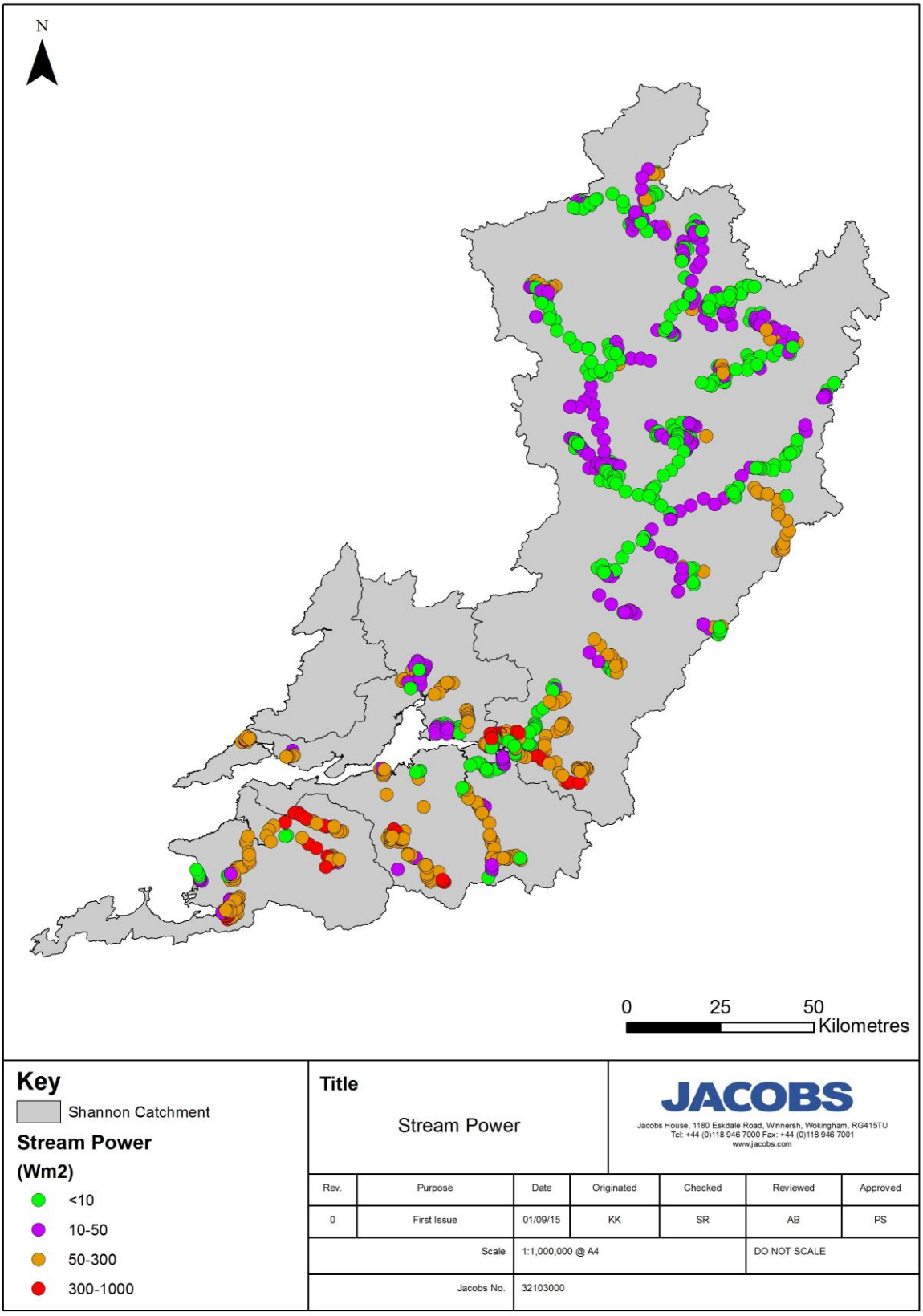
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50
Kilometres
Key
Shannon Catchment
Stream Power
(Wm2)
<10
10-50
50-300
300-1000
Title
Stream Power
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