06 – NATIONAL INDICATIVE FLUVIAL MAPPING: APPLYING AND UPDATING FSU DATA TO SUPPORT REVISED FLOOD RISK MAPPING FOR IRELAND

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Abstract

A first cycle National Preliminary Flood Risk Assessment (PFRA) for the Republic of Ireland, completed in 2012, identified areas at significant flood risk, and included the production of national indicative fluvial flood maps. The recent National Indicative Fluvial Mapping (NIFM) project has produced second generation indicative fluvial flood spatial data that are of a higher quality and accuracy to those produced for the first cycle PFRA. This project has covered 27,000 km of river reaches, separated into 37 drainage areas, consisting of 509 sub-catchments. The main project goals were to produce higher quality flood maps, improving upon the outputs of the first cycle PFRA, to take account of potential climate change impacts on flooding, and to produce mapping to improve risk assessments for areas not covered by the National Catchment Flood Risk Assessment and Management (CFRAM) Programme. The NIFM approach to this national-scale modelling project has combined intelligent automation of the repetitive processes, such as hydrological calculations and the burning of watercourses into the 2D model mesh, with rigorous quality assurance techniques.

The hydrological inputs to the 2D hydraulic models, notably the index flood (Q_{MED}) values and hydrograph shape, were derived from Flood Studies Update (FSU) node data. The FSU Physical Catchment Descriptors (PCDs) and methods were developed using a dataset that extended to 2012. Since then, additional recent years of observed data had become available, during which period some significant flood events had occurred (notably in December 2015 – the largest event of the observed record at several locations across Ireland). Furthermore, flood growth factors, which convert the index flood to floods of higher return periods, had also been developed on the dataset to 2012, under the National CFRAM studies. It was therefore necessary and timely to reflect the impact of the additional recent years of data on the index flood and growth curve calculations.

Annual maxima data were used to calculate adjustment factors to the Q_{MED} values, and these were applied using the pivotal site approach. A pivotal site is the gauging station that is considered most relevant to a particular flood estimation problem at the subject site, ideally, lying a short distance upstream or downstream from the subject site at which the flood estimation is required. In this project, pivotal sites were selected as the nearest downstream gauge on the same river; in the circumstances where no downstream gauge existed, the nearest gauge was used. Traditional alternative approaches to this method, such as the use of analogue catchments, can be potential sources of error; furthermore, the selection of analogue catchments is subjective and therefore difficult to implement on a widespread, automated basis such as the approach being used in this project.

CFRAM growth factors had been derived on a range of different bases for different Units of Management (UoM). Growth curves for each UoM were recalculated for the extended data series. The change in the growth factors as a result of the additional years of flow data was calculated for each OPW gauge. The growth curves

for each UoM based on CFRAM growth curves were then scaled to account for the additional years of flow data.

1. INTRODUCTION

A first cycle National Preliminary Flood Risk Assessment (PFRA) for the Republic of Ireland, completed in 2012, identified areas at significant flood risk, and included the production of national indicative fluvial flood maps. Article 14.1 of the Floods Directive (Council of the European Communities, 2007) indicates that the PFRA, and the flood hazard and risk maps, should be reviewed, and if necessary updated, at regular intervals. The recent National Indicative Fluvial Mapping (NIFM) project has produced second generation indicative fluvial flood spatial data that are of a higher quality and accuracy to those produced for the first cycle PFRA. This project has covered 27,000 km of river reaches, separated into 37 drainage areas, consisting of 509 sub-catchments.

The NIFM approach to this national-scale modelling project has combined intelligent automation of the repetitive processes, such as for the hydrological calculations. Data and methods from the Flood Studies Update (FSU) have been used as far as possible to provide the hydrology to underpin the hydraulic modelling and flood mapping.

The FSU methodologies were developed using a dataset that extended to 2012. Since then, additional recent years of observed data have become available, during which period some significant flood events have occurred (notably in December 2015 – the largest event of the observed record at several locations across Ireland). Furthermore, flood growth factors, which convert the index flood to floods of higher return periods, had also been developed on the dataset to 2012, under the National Catchment Flood Risk Assessment and Management (CFRAM) Programme studies. CFRAM growth factors had been derived on a range of different bases for different Units of Management (UoM). Ireland was divided in to 29 UoMs, hydrological divisions, for the purpose of the National CFRAM Programme. It was therefore necessary and timely to reflect the impact of the additional recent years of data on the index flood and growth curve calculations. This paper describes the development of the modified approach used in the NIFM project.

2. ASSESSMENT OF AVAILABLE DATA

The most up-to-date dataset of annual maxima flow data was required for the hydrological assessment, in order to capture the greatest possible number of representative flood events. Due to the timing of earlier relevant hydrological assessments (the Flood Studies Update (FSU) and CFRAM studies), they were based upon a gauged dataset that ended in 2012. More recent annual maxima (AMAX) data were required in order to calculate adjustment factors to apply to Q_{MED} values and growth curves wherever necessary.

Significant flood events occurred in the winter of 2015, when a series of storms (Desmond, Eva, Frank) affected large parts of Ireland. The AMAX series extension data included hydrometric year 2015 (December 2015 to January 2016), and the AMAX flow of that year was in the top five events for the whole record at 85 out of 123 gauges with data (i.e. approximately two-thirds of the gauged series indicated that the 2015 flood events had an important status in the historical record) (Figure 1).

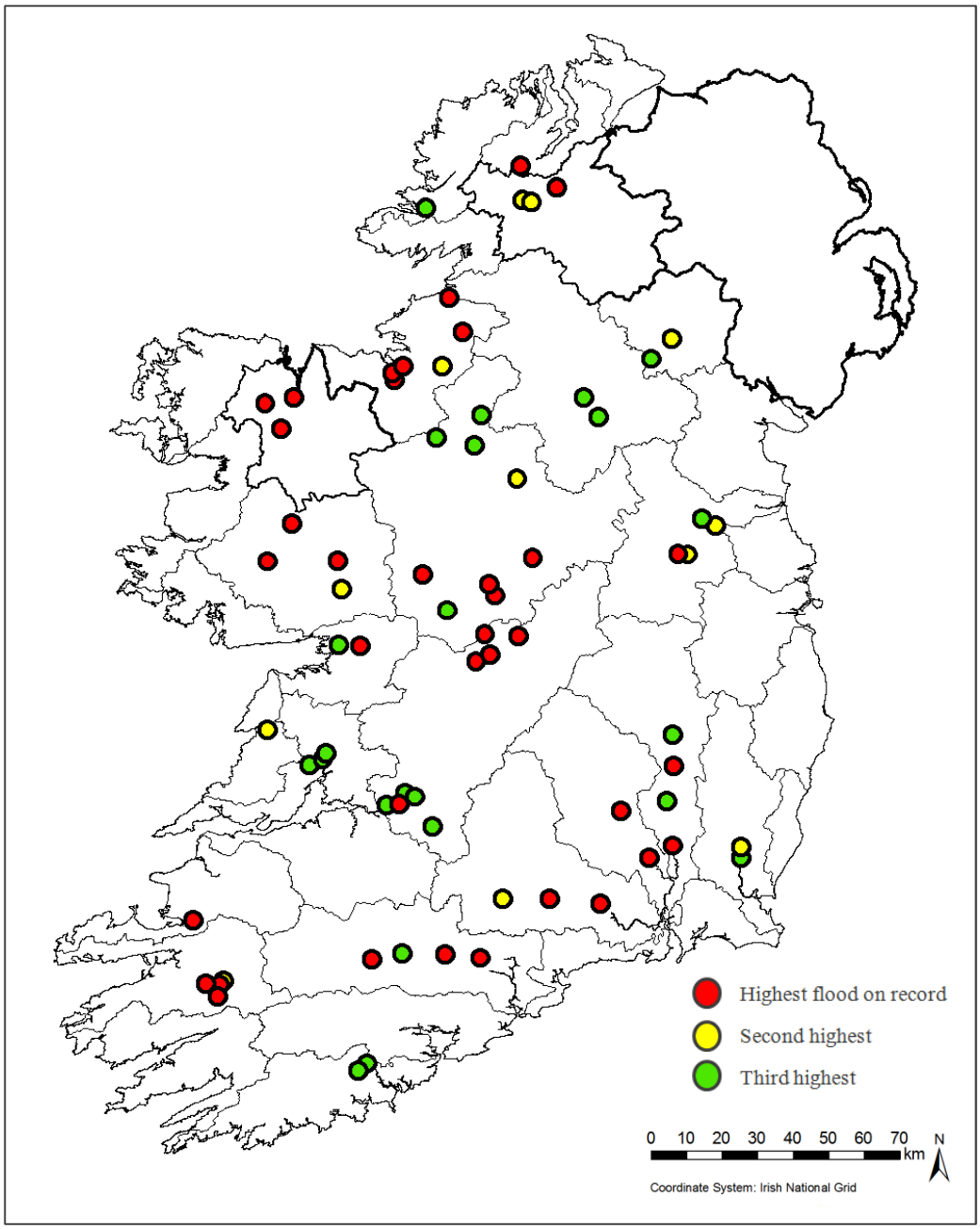

Figure 1: *Spatial distribution of the winter 2015/2016 flood events*
Source: Reproduced from Figure 7, NDFEM (2016)

More recent data were obtained for the 149 OPW gauges up to the 2016 hydrometric year (inclusive). The data represented water level gauge readings, level gauge readings, and derived flow data (estimated via rating equations), along with the dates of the maximum values.

Of the 149 gauges, 128 had suitable data for the hydrological analysis, with 21 having been noted to indicate problems relating to the calculation of flows in the associated gauge listing (such as problems with the rating equation).

3. ADJUSTMENT OF INDEX FLOOD FLOWS

The median annual flood, Q_{MED}, was used as the index flood in the Flood Studies Update; it has an Annual Exceedance Probability (AEP) of approximately 50%. In the NIFM project, Q_{MED} was used as the index flood for derivation of the current scenario for the modelled rivers, it was uplifted to provide predicted flows under climate change, and it was used as the starting point for generating the river channel capacity (the starting assumption was that all watercourses are "bank-full" for peak flows in the Q_{MED} event and that any flows above

Q_{MED} are floodplain flows). It was therefore important to capture the impact of the extended data series on the Q_{MED} values calculated from the FSU PCD data. The extended, gauged AMAX dataset, described above, was used to perform an adjustment to the Q_{MED} values calculated from the PCDs.

The Q_{MED} adjustment factor is the ratio between the AMAX Q_{MED} value and the PCD-derived Q_{MED} value; these are mapped for each gauge in Figure 2. The map shows that the adjustment factors vary within hydrometric areas; there is no discernible pattern to the increases and decreases across the region.

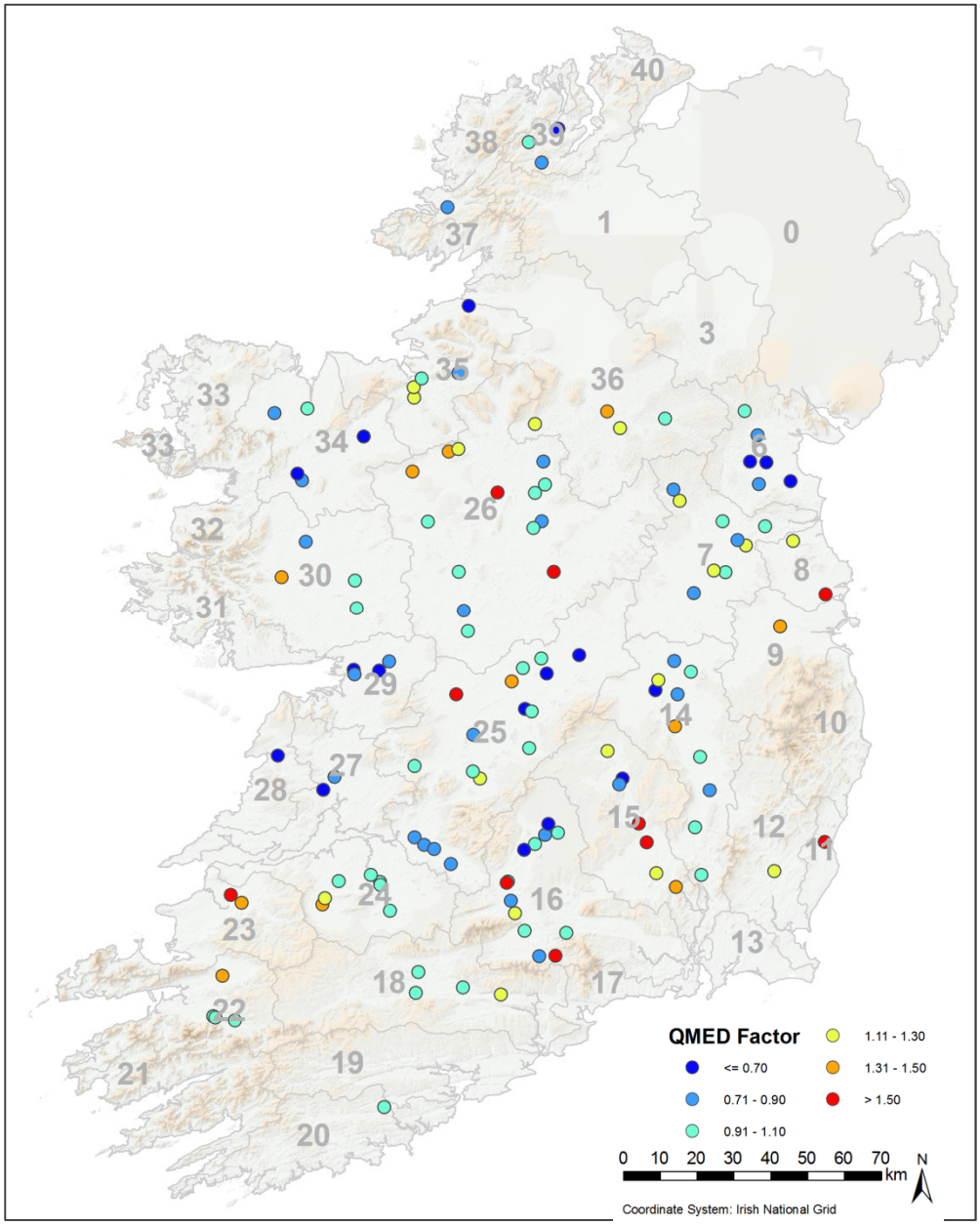

Figure 2: *Map showing Q_{MED} adjustment factors calculated from AMAX versus PCD-derived values*

The adjustment factors from these gauged locations were applied to the FSU-derived Q_{MED} values using the pivotal site approach. A pivotal site is the gauging station that is considered most relevant to a particular flood estimation problem at the subject site, ideally lying a short distance upstream or downstream from the subject site at which the flood estimation is required. Pivotal sites were selected as the nearest downstream gauge on the same river. In the circumstances where no downstream gauge exists, the nearest gauge was used. Traditional alternative approaches to this method, such as the use of analogue catchments, can be potential sources of error (Morris, 2003); furthermore, the selection of analogue catchments is subjective and therefore

difficult to implement on a widespread, automated basis such as the approach being used in this project. Kjeldsen *et al*., (2008), following research based upon the newer, longer HiFlows-UK flood database, and feedback from FEH users, suggest that preference should be given to sites with geographical proximity rather than similarity of catchment characteristics, and this approach was used here.

Since the equation for calculating Q_{MED} was based upon essentially rural catchments, an adjustment for urbanisation was required. Therefore, the recommended adjustment for urbanisation (the Urban Adjustment Factor, UAF) was calculated, and applied to the rural Q_{MED} value estimated after application of the gauge adjustment factor.

4. ESTIMATION OF ADJUSTED GROWTH CURVES

The FSU approach to flood frequency estimation is based on the index flood method in which the peak magnitude of the T-year flood at any location is estimated as the product of the index flood (Q_{MED}) and a flood growth factor at that location.

Flood growth curves in the Republic of Ireland tend to be relatively mild, with the 100-year flow typically no more than about double the mean annual flow (Reed and Martin, 2005). Figure 3 shows the regional growth curves from the Flood Studies Report, in which Regions 1 to 10 cover England, Scotland and Wales, for comparison with Ireland. This mildness is largely due to attenuation in lakes and on flood plains, such as that demonstrated widely in UoM 26 (the Upper Shannon). As a consequence of this, the proportion of in-channel flow is high; estimation of channel capacity was important in this project, since the flooding is sensitive to channel size.

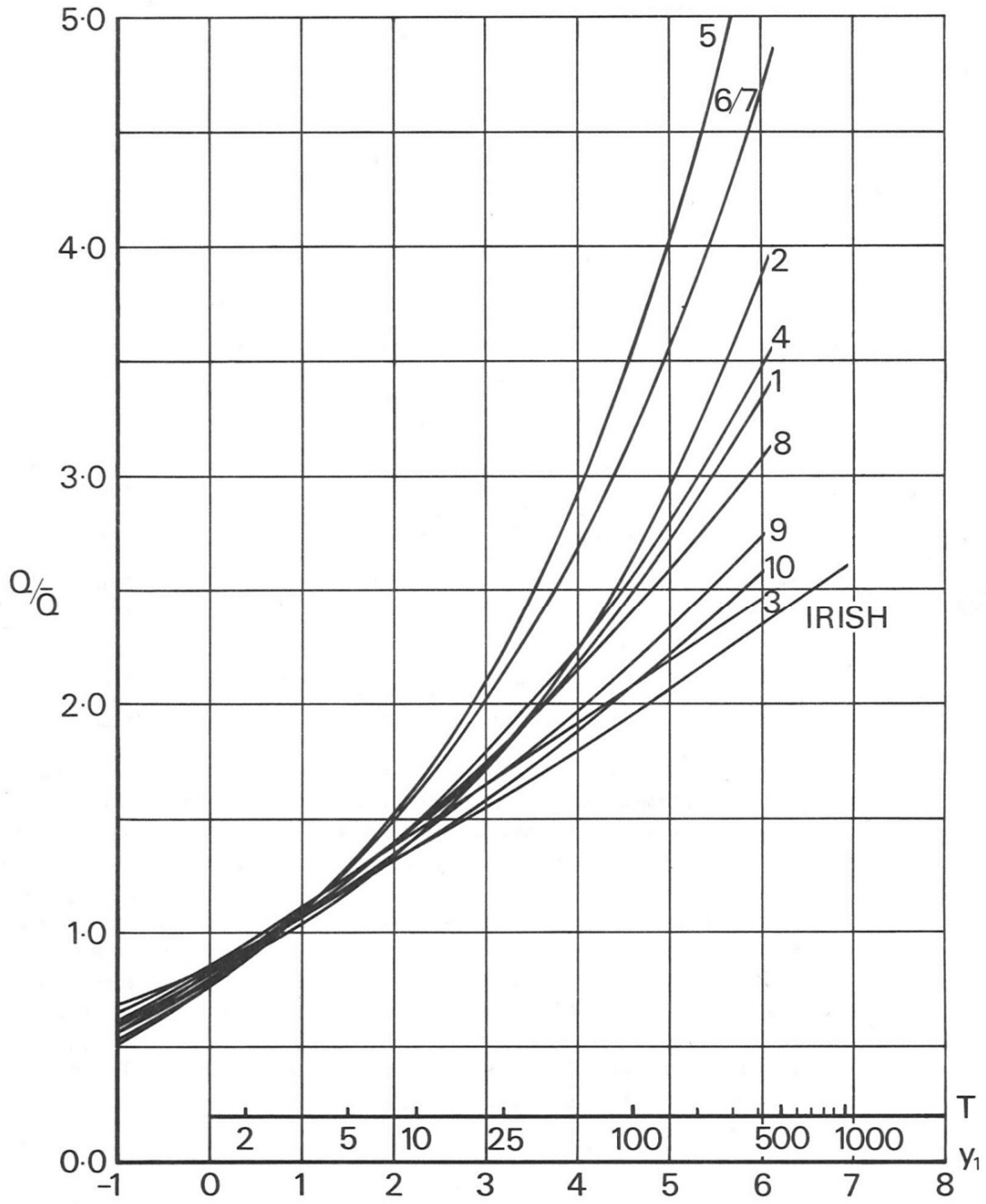

Figure 3: *Regional Growth Curves for Britain and Ireland*
Source: Reproduced from Fig. 2.14, Volume I, NERC (1975)

Flood growth factors and growth curves had already been derived under the CFRAM studies, and the approach for this project was designed to use this information as far as possible. A nationwide review of CFRAM growth factors and curve fitting was carried out in order to develop a pragmatic approach for the national roll out, to be tested in the Pilot Studies.

In some cases, the CFRAM studies had resulted in numerous growth factors within a single river system; for some UoMs, the factors were grouped into bands of relevant catchment size; at others, the factors were grouped by reaches; while in others, the factors were developed at local gauge locations. Such differing approaches and baseline information offer challenges for transition from growth curve to growth curve, as well as for consistency not only within a river system but across a wider area. In order to address these challenges for this national mapping project, growth curves were developed using a procedure that was considered to be a sensible

compromise between the high levels of detail in some UoMs, and earlier approaches that had been based upon a single growth curve for the whole country.

4.1 Extraction of CFRAM growth curves

Baseline growth curve information was extracted from the CFRAM studies. The required information included CFRAM growth factors and curve fitting information from the relevant hydrology reports. Under the CFRAM studies, growth curves were fitted using a number of different distributions, with the Generalised Extreme Value (GEV) and Generalised Logistic (GLO) tending to give the best fit. Research has shown that these distributions, and particularly the GEV, are widely applicable, and are suitable for use in Ireland (OPW, 2009; Ahilan et al., 2012).

4.2 Adjustment of CFRAM growth curves

The impact of recent flow data (2012 to 2016) on CFRAM growth curves was assessed, by generating growth curves for the two periods (the historical period to 2012 as used in the CFRAM analyses; and the historical period to 2016). The growth curves were fitted using the GEV distribution; a sample is shown in Figure 4.

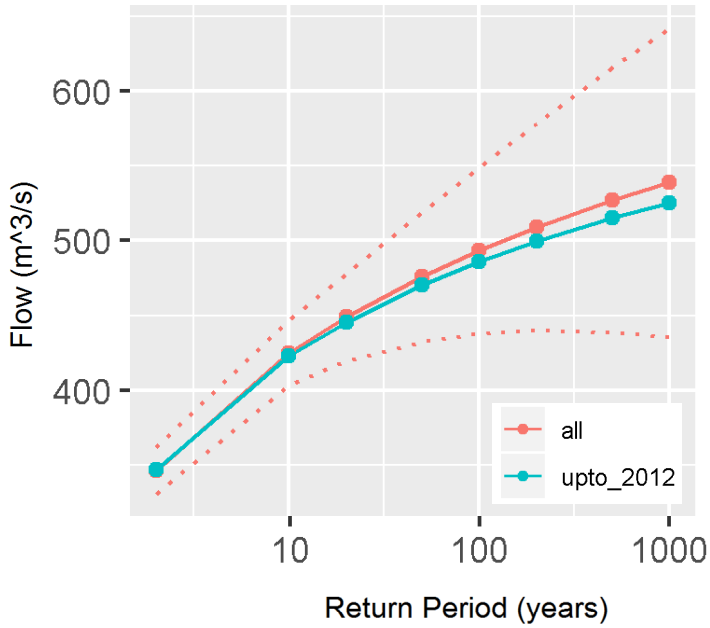

Figure 4: *Sample gauge growth curves. The 95% confidence intervals are shown as dotted lines.*

The change in the GEV growth curve as a result of the additional four years of flow data was calculated for each OPW gauge. The growth curves for each UoM based on CFRAM growth curves were then scaled to account for the additional recent years of flow data.

A single adjustment factor was developed for each UoM based on an average of the gauges (Figure 5). The adjustment factor was then applied to the growth factors.

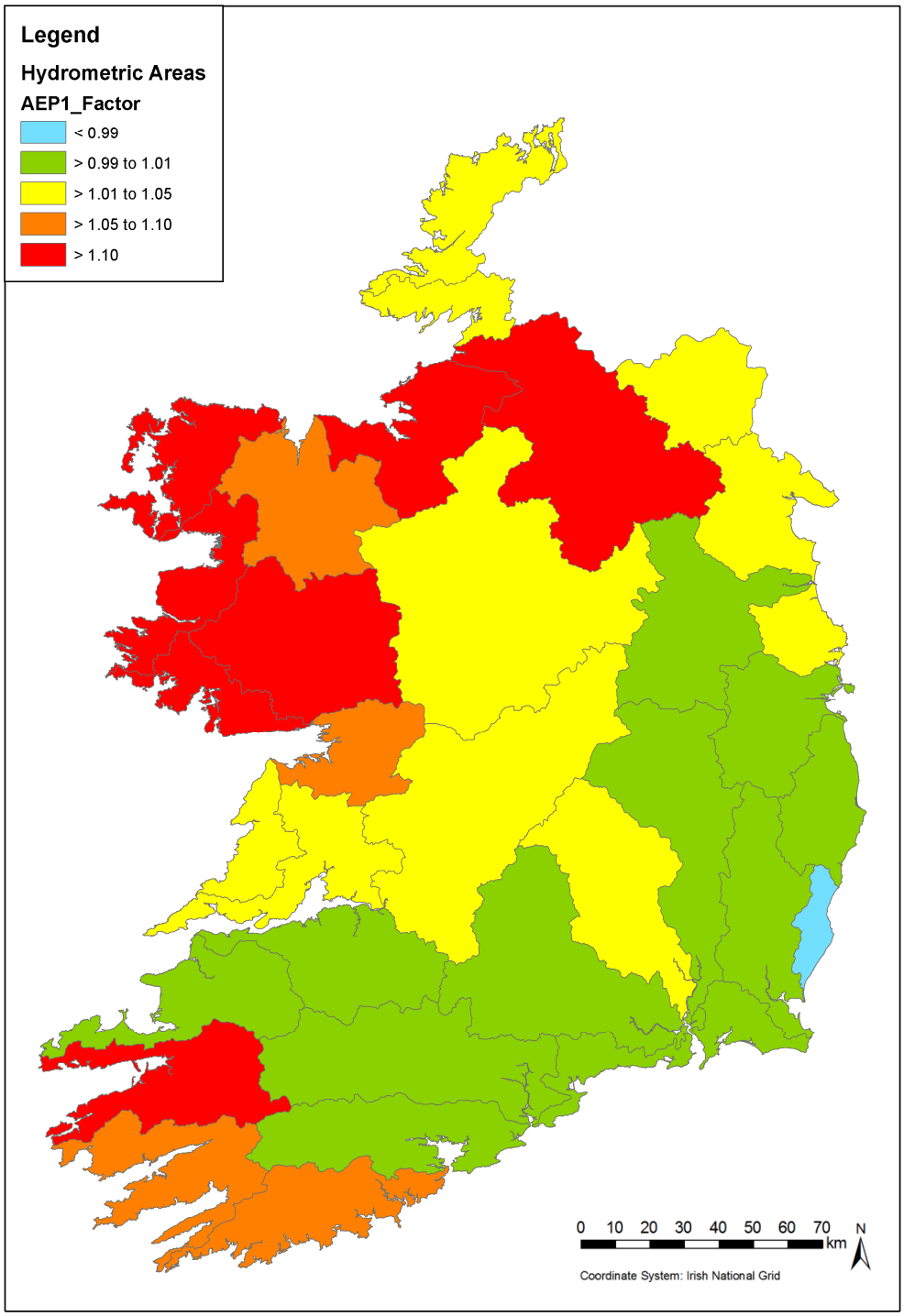

Figure 5: *Map showing growth factor adjustments per Unit Of Management for AEP 1%*

5. CONCLUSIONS

This paper has described the development of the modified hydrological approach used in the NIFM project. The approach has been developed to provide a balance between the need for a nationwide method that could be efficiently applied, and the need to adjust the fundamental datasets and hydrological techniques upon which the method is based.

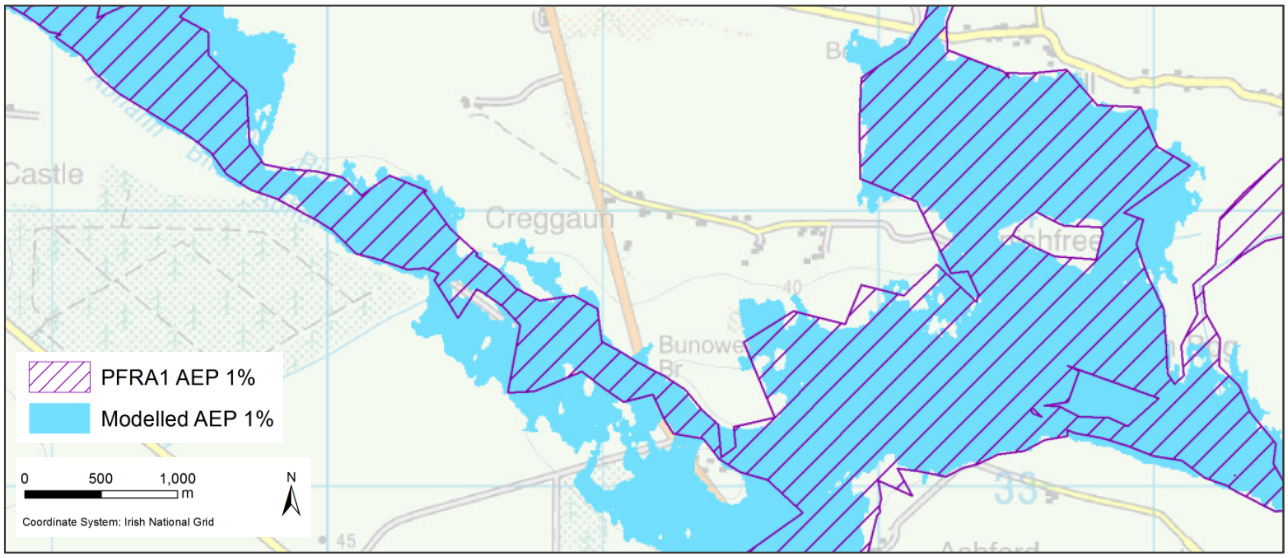

Figure 6: *NIFM modelled results versus PRFA1 results for 1% AEP at a sample location*

The approach was tested through two pilot study applications, where detailed CFRAM results were available, and has been proven to support improved inundation mapping over that of the first cycle PFRA (Figure 6). Furthermore, these techniques are straightforward to reproduce for subsequent cycles of inundation mapping required by the Floods Directive.

6. REFERENCES

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