OPW

Review of Flood Flow Ratings for Flood Studies Update.

Final Report
J2194

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Prepared by

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FINAL REPORT

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1. INTRODUCTION

1.1 Preamble

This report is submitted by Hydro-Logic Ltd. (HL) to summarise the work undertaken between 25th July 2005 and the 4th February 2006 for the Office of Public Works (OPW) to review, and where appropriate amend high flow ratings for gauging stations in the Republic of Ireland. In addition, annual maxima (Amax) series and median annual flood estimates were produced for all the gauging stations that had ratings considered to be capable of producing high flow data of a sufficient level of quality for subsequent flood studies and analysis. In order to achieve the project objectives two flood hydrologists/Hydrometrists were seconded to OPW for the duration of the project to undertake the work. In addition, a third hydrologist spent several weeks on the project to assist with the extraction of Amax series for several Environment Protection Agency (EPA) sites and to undertake some of the uncertainty analysis. The main objective of the project was to assist with the implementation of the update of the Flood Studies Report in Ireland.

1.2 Background

OPW is leading a major research and development programme to update the Flood Studies Report (NERC, 1975) and develop new ratings and methodologies for flood estimation in Ireland. The programme has a number of phases or work packages. One of the first steps to be undertaken was to ensure the data being used was the best and most appropriate available. The Office of Public Works (OPW) did not have the resources available to undertake this work and as such contracted Hydro-Logic Ltd (HL) to provide two appropriately experienced hydrologists to implement the work. This part of the project has been referred to as FSU Work Package 2-1 – HL work. The two key team members who were seconded to the OPW offices in Headford were Julian Parkin (Team Leader/Principal Hydrometric Engineer) and Eleanor Foster (Hydrologist). In addition, several other staff from Hydro-Logic contributed to the project. In particular Stewart Child (HL - Project Director) provided guidance and support to the two key members and Karen Weekes (Hydrologist) provided assistance with the extraction of Amax data for some of the EPA sites and assisted with the uncertainty analysis.

OPW was responsible for leading and managing the Project but the Environment Protection Agency (EPA) and the Electricity Supply Board International (ESBI) who also have responsibilities for the collection, analysis and dissemination of hydrometric data are also participating in the project.

OPW's project management team consisted of Mark Adamson and John Martin from the Dublin office and Alex McAllister in Headford. Peter Newport provided additional support and assistance. The main point of contact at the EPA was Michael MacCarthaigh and at ESBI it was Tommy Bree and Tom Garry.

Even though the Project Team was based in Headford, the Team Leader spent a significant amount of time in Dublin at the offices of OPW, EPA and ESBI to access data and information held at these locations.

The principal duties associated with the positions as specified in the original Project Brief were as follows:

1. Review and, if necessary, amend or develop flood-rating curves (stage-discharge relationships).

2. For appropriate stations, identification of actions to improve the flood rating within the timescale of the Flood Studies Update (FSU) programme.
3. Other analyses or duties necessary to achieve the required objectives and the successful progression of the programme.
4. Identification and classification of gauging stations, the data from which would be suitable for use in the subsequent FSU analysis and studies.

In addition to the above it was agreed at the Project Inception stage that the Project Team would undertake the preparation of Amax flow series, which would be one of the main outputs of the project.

1.3 Principal duties and tasks

1.3.1 Introduction

The main tasks undertaken are referred to in Sections 1.3.2.

The objective of the work was to provide, to the overall FSU group, a set of gauging station sites that have usable Amax level series and stage discharge relationships from which accurate high and flood flows can be obtained. The target was to produce about 200+ sites providing a total number of years record of 5000 (approx.) in the A category list.

Only sites that have a record length of over 10 years were to be considered. However, new sites that have less than the required 10 years were to be assessed to see if they exhibit the properties to become a suitable site in a few years time. Also if they already fall into one of the categories A1, A2 or B then they may be included. These sites were to be highlighted to say that they fall below the requisite number of years in the database.

1.3.2 Review of stage-discharge relationships

- Assembly and review of all relevant data and information including stage-discharge data, dimensions of flow measurement structures, cross-sectional data[1] (where it exists), gauging station histories (including rating changes), most recent flow data and statistics for the stations, photographs particularly any under flood conditions and other relevant metadata.
- Comparison of existing ratings and theoretical ratings for structures[2] with stage-discharge (current meter gauging) data, deviations between rating and current meter gauged flows with respect to time and stage;
- Evaluation of revised or new ratings;
- Comparison of current meter gaugings with archived flows for the same time period;
- Identification of potential instability and sensitivity problems, including establishment of modular limit for structures.
- Estimation of ratio between the highest gauged flow and the median annual flood. This is often used as an initial indicator of how well the high flow rating has been determined/confirmed.
- Uncertainty analysis – to assist with rating evaluation classification.
- Recommendations for changes to existing ratings[3].
- No reconnaissance visits were undertaken[4].

Notes:

1. Very little cross-sectional data was available at the time of commencing work. However, OPW staff established bank full levels at a number of key sites identified by the project team to assist with the rating analysis.

2. OPW operate of the order of 12 - 14 flat-v weir gauging stations.
3. It was agreed, even though the rating review team might feel that there were better ratings available for determining flood flows than the OPW ratings, the latter would be used whenever the team felt it were possible to do so. If the differences between the OPW derived ratings and the ratings preferred by the team were not considered to be significant then the OPW ratings would be adopted. This was to avoid a situation whereby two different data sets exist for the same station i.e. the normal time series data currently held on OPW's web site and the new flood analysis data set. Amax flow series derived using both OPW and the project preferred ratings as part of this analysis to assess the significance of the differences between the two ratings.
4. It was hoped to undertake reconnaissance site visits to key gauging stations but this was not possible during the timescales of the project. Therefore, the project team had to base most of their conclusions on the interpretation of photographs, other available metadata and discussions with key members of staff.

1.3.3 Classification of gauging stations

OPW have produced an earlier classification of gauging stations. The Project Team were requested to review the classification of each gauging station for which the data from was considered to be suitable for use in the subsequent phases of the project. The original review had been mainly based on a subjective review of the ratings, knowledge of each site and the magnitude of the highest gaugings. In order to make the review slightly more objective uncertainty/statistical analysis was undertaken based on the methodology for computing uncertainties contained in “BS ISO 1100-2:1998 Measurement of flow in open channels - Part 2: Determination of the stage-discharge relation”. The final classification of gauging stations has been used to determine which data sets can be used for the different analyses to be undertaken in the subsequent FSU work programmes.

1.3.4 Amax flow series

OPW, EPA and ESBI provided the project team with Amax level series. From these the recommended ratings were used to derive annual maxima flow series. Estimates of Q_{med} were also determined.

1.3.5 Recommendations for further work

It was not possible in the timescales available to undertake a comprehensive analysis of each rating, particularly the extension of rating curves using appropriate extrapolation techniques e.g. stage-velocity-area. When there was sufficient information available e.g. bank full levels then some cautious logarithmic extension of some rating curves has been considered provided the stages were still within bank. Nevertheless the project team felt that there was scope to greatly improve a number of ratings by means of cross-sectional surveys and other follow up-actions. The most appropriate method of rating curve extension will be site specific, and may also be dependent on the time available and the availability of cross-sectional and other data. However, at certain key sites it is felt that some ratings could be greatly improved by use of one or more of the following techniques resulting in an upgrading of the rating classification:

- Further gaugings in specific stage and flow ranges. A gauging programme would need to be produced. This would necessitate a prioritisation of sites and flow ranges.
- The undertaking of additional gaugings using Acoustic Doppler Velocity Profilers (ADVPS) where conventional gauging is not possible or problematic.
- Use of alternate methods of continuous flow measurement at key locations e.g. use of horizontal ADVPs.
- The need for cross-sectional surveys for rating extension.

- Rating curve extension, using techniques such as stage-velocity-area method, Steven's method, Manning, slope-area and 1-D models (HEC-RAS).

1.3.6 Project deliverables

The project deliverables can be described as follows:

1. Spreadsheet containing metadata for each site including site descriptions when these could be obtained, comments on the rating and the recommended rating, gauging station classification, the ratio between highest gauged flow and Q_{med} and the uncertainty in Q_{med} and where appropriate twice Q_{med}.
2. Annual maxima flow series for each gauging station considered suitable for inclusion in subsequent phases of the project, appropriately annotated with supporting information and comments.
3. A final report describing the work that was undertaken, the methodologies used to review ratings, problems and issues encountered and recommendations for follow up-actions.

2. GAUGING STATION CLASSIFICATION

2.1 Original Site Classification

Prior to the project commencing OPW had produced an initial classification of gauging stations. This can be summarised as follows:

A sites – sites that had stage discharge ratings that were considered good for determining high and flood flows.
B sites – sites that had good high flow ratings, but where there were some concerns over the flood flow ratings.
C sites – sites that had reasonable medium to high flow ratings, where it was not possible to determine flood flows with any confidence due to the fact that at high flows the site was either not rateable or there were insufficient gaugings to produce a rating.
P sites – these were classified as poor and were not considered suitable for high and flood flow determinations. It is possible that some of these sites could be used in future if sufficient gaugings and other information were available.
U sites – these are sites where the data would be totally unusable for determining high flows. These could for example be level only sites where it is not possible to measure discharges and thus develop stage-discharge relationships.

P and U sites were not considered in any detail during the project.

For site archives held by EPA specific visits to their office in Dublin were undertaken. A list was provided with a classification of the ratings for the sites. This classification was not complete for all sites and was produced about three years prior to this project. Q_{maf} values were obtained from the EPA's archiving database WISKI for all sites that were to be considered for inclusion in the FSU.

The ESB also have an archive for their network of hydrometric gauging stations. Even though their network is small the sites they operate have extensive records going back for many years, in some cases up to 60 years of records may be available.

From the list of sites that was produced a simple ranking index was created, based on the ratio between the Q_{maf} value and the highest gauged flow.

2.2 FSU site classification

The basis for the first level of site categorisation for the FSU was

A sites – suitable for flood frequency analysis. These were sites where the highest gauged flow was significantly higher than the mean annual flood (Q_{med}^*) [at least 1.3 x Q_{med}] and it was felt by the OPW staff concerned that the rating(s) provided a reasonable representation of extreme flood events.
B sites – suitable for flows up to Q_{med}^*. These were sites where the flows where the rating was well defined up to Q_{med} i.e. the highest gauged flow was at least equal to or very close to Q_{med}, say at least 0.95 Q_{med} and no significant change in channel geometry was known to occur at or about the corresponding stage.
C sites – possible for extrapolation up to Q_{med}. These are sites where there was a well-defined rating up to say at least 0.8 x Q_{med}.

Note: During the initial stages of the work Mean Annual Flood (Q_{maf}) values were used instead of Q_{med} since these had been previously determined and for most sites the values should not be significantly different. For all subsequent analysis the Q_{med} value was used.

Q_{maf} values for OPW sites were obtained from the station records file and if not available then from Amax series spreadsheets available from the OPW archives.

The categorisation was then further refined to allow for a split in the A classified sites. This allows for sites that have very good confidence in their ratings and data for flood frequency analysis and those that, whilst still good, don't achieve the highest classification.

The **A** sites were then sub-divided in to

A1 sites – Confirmed ratings good for flood flows well above Q_{med} with the highest gauged flow greater than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 times Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
A2 sites – Ratings confirmed to measure Q_{med} and up to around 1.3 times the flow above Q_{med}. Would have at least one gauging to confirm and have a good confidence in the extrapolation.

The B and C categories were defined as

B sites – Flows can be determined up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value.

C sites – 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}.

2.3 Statistical and uncertainty analysis

The criteria for the classification referred to in Section 2.2 above was mainly the ratio of the highest gauged flow (HGF) to the estimated Q_{med}, thus:

$$Ratio = \frac{HGF}{Q_{med}}$$

Therefore, if the highest gauge flow was 85 m^3/s and Q_{med} was 53 m^3/s the ratio would be 1.6 and as such if there was no special issues e.g. doubts about the quality of high flow gaugings, the station would have been given an A1 classification. This is believed to be a very important indicator of the quality of the high flow rating. Nevertheless the classification system has a certain amount of subjectivity. Therefore, following discussions with OPW it was decided to also consider the uncertainties in the high flow ratings which would take account of the amount of scatter at high flows and also the limited amount of high flow gauging data. Therefore, it was decided to estimate the uncertainties for Q_{med} values at the 95% confidence level. These estimates were made using Hydro-Logic's Gauger Analysis software. Using this it is possible to enter the stage value corresponding to Q_{med}, or any other stage value, and obtain the 95% confidence limits ($2s_{mr}$ values). For the A1 sites the uncertainties have also been determined for flows equivalent to 2 x Q_{med}.

The methodology used to estimate the uncertainties is referred to in Appendix 2.

The uncertainty analysis has been used to further classify the station ratings as follows:

Uncertainty	Uncertainty classification
< ± 10%	Very good
± 10 – 30 %	Good
> ± 30%	Fair

For example, based on the forgoing if a station was classified as A1 (very good) this would mean that:

1. Confirmed ratings good for flood flows well above Q_{med} with the highest gauge flow greater than 1.3 x Q_{med} and/or with a good confidence of extrapolation up to 2 times Q_{med}, bankfull or, using suitable survey data, including flows across the flood plain.
2. The estimated uncertainty in the estimated value of Q_{med} should be within ± 10% of the true value at the 95% confidence level.

3. RECORDS DATABASE

OPW intend to make gauging station flood data and supporting metadata readily available to assist users of the new Flood Studies methodology. In order to produce station reports containing metadata including comments on the gauging station and its rating a simple database is required. As a forerunner to this and due to the size of the list of gauging stations a relatively simple Excel database was established during the project containing details of the sites. This was also used by the Project Team as a management, tracking and working tool during the duration of the project. Consideration was given to the development of other types of database such as Access, but it was decided that the Excel spreadsheet was the best way forward in this instance.

An example portion of the spreadsheet is contained in Appendix 3. Information stored on the spreadsheet/database can be summarised as follows:

Category of information	Information details
General site information:	Station number, name, river name, catchment, grid reference, operating body, technician, catchment area (km^2), SAAR (mm), station/site remarks
Flow & level information:	Q_{med}, MAF, MAF stage, HGF, bankfull stage
Management information:	Simple bank survey requested, priority of station for full bank level survey, priority for detailed rating review, rating reviewed, preliminary rating classification
Rating review	Rating versions approved, final station rating quality classification, ratio HGF/Q_{med}, ratio HGF/MAF, $2S_{mr}$ @ Q_{med}, $2S_{mr}$ @ MAF, rating recommendation, mean % diff. between FSU Q_{med} & OPW Q_{med}, rating remarks, comments
Amax series	Length of record (years), drainage years, no. of drainage years, Amax level missing data (dates), Amax level missing data (no. of years), remarks
Other	Comments specific to OPW & EPA data availability. These additional columns are used due to the different databases and processing procedures used

4. REVIEW OF STAGE-DISCHARGE RELATIONSHIPS

4.1 Introduction

OPW and the EPA have undertaken a considerable amount of work on the development of stage-discharge relationships. ESBI have previously employed Consultants to produce ratings for their sites. These historic and existing ratings were used as the basis of the review.

OPW in particular have undertaken a considerable amount of rating development and review work during the last 5 – 10 years. The amount of effort and the resulting outputs are to be highly commended.

OPW ratings normally take the following form:

$$Q = C(D + DG)^p$$

Where

Q = discharge
D = gauge height or stage
DG = datum shift constant (corresponds to a in the international convention)
p & C are constants corresponding to β and c in the international convention.

Many of the OPW ratings have been derived by plotting D+DG (stage plus datum shift) against discharge instead of stage as per international convention. For many of the OPW ratings if a rating change takes place the C and p values are kept constant and the DG value is altered i.e. rating changes are reflected solely by changes in datum change. The Consultants can fully understand this philosophy which is valid if there has been a datum shift due to a change in stage zero e.g. due to the stage monitoring device (staff gauge) being shifted. However, on occasions it is felt that by only varying one constant and keeping the other two fixed the optimum stage-discharge relationship is not being realised. For a number of the ratings analysed it is felt that changes were initiated to improve the fit to the data points at low flows to allow for the affects of variable backwater caused by factors such as changes in channel roughness (weed growth). At a number of sites we feel that this has resulted in changes that do not improve the high flow determinations and has arguably resulted in an unnecessary number of rating curves. Even though on occasions we feel that high flow ratings could be improved we have not recommended changes to the OPW rating unless this creates a significance difference in the derived flows (see Section 1.3.2).

EPA ratings tended to be based on the conventions laid down in ISO 1100-2:1988.

4.2 Analysis tools used

All ratings and gaugings were plotted using the Sked function in WISKI or using Hydro-Logic's Gauger Analysis. The analysis and evaluation tools available in both these packages were used to review existing and proposed ratings. In addition deviation plots between current meter gauged and rating flows were produced both against stage and date to assist with the identification of any discontinuities in the ratings. Continuous reference was made to the station history files to obtain metadata on datum shifts, changes in control etc. and where appropriate contact was made with appropriate personnel and in particular hydrometric file staff. This allowed the Consultants to evaluate the validity of ratings to assess whether there needed to be any further work undertaken on them to define a better flood flow rating.

4.3 Review procedure adopted

The following steps were undertaken in the review of ratings:

1. At the outset of the project, estimates of Q_{maf} were available. These were compiled along with the highest gauged flow (HGF) for each gauging station and the ratio of HGF/Q_{maf} estimated. This ratio was used to review the original OPW classifications and come up with an initial A, B and C classification for the gauging stations under consideration.

2. Undertook an initial trawl through all the A, B and C ratings to obtain an initial feel for their quality and characteristics. During this initial trawl sites were identified where some basic survey information could assist with the rating classification. In addition, rating periods were identified and in particular pre-drainage and post-drainage scheme splits were established. Simple surveys were arranged for a number of key sites to establish the top of bank level relative to gauge zero.

3. The initial records database was established at an early stage in the project and was initially populated with readily available information. This was refined and updated as the project progressed.

4. On completion of the initial trawl of the ratings a more detailed assessment of the ratings was undertaken. During these more detailed investigations the Consultant ascertained whether the existing ratings could be used or whether a refined, or totally revised rating(s) was required. This aspect of the work was undertaken using the analysis tools in Sked and Gauger Analysis and the Station History files (see Section 4.2). On the basis of this analysis ratings were selected for use in the uncertainty analysis (see Section 2.3) since as in many cases, as noted in Section 4.1, many of the historic rating changes are not justified in terms of high/flood flow determinations e.g. only the current rating may have been used in the post-drainage uncertainty analysis. The Consultant's recommend ratings were indicated on the spreadsheet database.

5. Amax levels were provided to the Consultant by OPW in Excel spreadsheets. For the EPA sites this work was undertaken by the Consultant by extracting data from Wiski and filling in gaps by examination of some of the chart data. Amax flows were determined using the OPW and EPA ratings. For sites where the Consultant felt that the there was a better rating or it could be improved on, Amax flow series were also produced for the proposed new or revised rating. If there was an insignificant difference between the OPW and Consultant's recommended ratings the OPW/EPA ratings were used. Normally if the estimated Q_{med} values determined from both series were within 10%, this was considered to be satisfactory. If there was considered to be a significant difference between the two sets of Amax flow series a further review of the ratings and station history files was undertaken to explain the differences further.

6. Those ratings the Consultant felt needed to be changed were discussed with OPW. If the proposed changes were agreed to, these were then used to produce the Amax flow series.

4.4 Gauging Station Surveys

By looking at the rating periods, their respective gaugings and the bankfull level it was possible in some cases to extrapolate the flood ratings above the highest gauged flow (HGF). Initially the limit of extrapolation would be to the bankfull level at the measuring point, if the channel has a relatively regular cross section i.e. the bankfull levels if known could be used as the limits of extrapolation.

For sites that have a more complex stage discharge relationship a more detailed and thorough topographic survey would be required. However it was not possible for the OPW or EPA to undertake detailed surveys within the timescales of this project.

During the initial review of ratings stage (see Section 4.2, point 2) a list of priority sites that required bankfull level surveys was forwarded to the relevant OPW technicians. This survey work was incorporated the routine rounds of their sites.

A list of EPA sites needing surveys was also established. However, due to the EPA's workload and lack of resources this information had not been undertaken by the end of the project period. This information could still be useful for further improvement and refinement of the ratings.

For the seven sites identified by ESBI for inclusion in the FSU the bankfull levels were available from the previous reports undertaken for these sites.

5. DELIVERABLES AND RELATED ISSUES

5.1 Identification of missing data for key sites and dates

Whilst Hydro-Logic were working on the Amax flow series gaps were identified in the existing data series. The majority of these gaps have been rectified by OPW but some sites still require attention. Hydro-Logic personnel in filled gaps in the EPA data. Any further gaps will be due to missing data so no further work is required. ESBI had not produced the Amax level series by the end of the project and will pass the data to OPW when this becomes available.

5.2 Provide suitable high flow ratings for all sites

For all sites that are to be included in the FSU a set of high flow ratings for each site that will allow for the determination of high and flood flow events have been confirmed or recommended and agreed.

5.3 Produce Q_{med} values for all sites

As an addition to the original project brief a Q_{med} value for each site in categories A1, A2 and B was determined. These have been entered onto the Excel database. In addition these are available on the Amax flow series spreadsheets.

5.4 FSU site classification

Each gauging station has been classified to give the user of the data an indication of both the quality of the data available and the rating itself. This classification will allow like for like comparisons between stations within the pooling groups.

The classification is based mainly on two criteria.

1. The ratio between the highest gauge flow (HGF) and Q_{med}.
2. Width of the 95% confidence limits at the Q_{med} value for each rating.

5.5 Final Numbers of sites per classification

The number of gauging stations and years of record that are considered suitable in the subsequent FSU analysis are summarised in Table 1.

Table 1: Summary of station records considered suitable for flood analysis

Site Classification	No. Of Sites	Station Years
A1	75	2326
A2	119	3197
Total	***196***	***5523***
B	103	1748

From the above it can be seen that the original FSU target of at least 200 stations and 5000 station years in Classification A has effectively been achieved.

6. ISSUES IDENTIFIED DURING THE PROJECT

As the project progressed several problems were identified. Some of these were overcome with dialogue with the relevant gauging authority. Others may require further investigation and possible coverage in future updates.

Problems that were encountered during this project: -

- Incomplete Amax level series
  Gaps were filled during the course of the project.
  Some gaps still remain due to non-digitised chart data, we recommend that this is done as soon as is possible, and unfortunately some gaps are due to unrecoverable data loss. These gaps can lead to non-representative Q_{med} values, especially if the gaps are proportionally large in comparison the length of record.
- At some sites there was insufficient gauging data to undertake stage discharge rating review and analysis.
- Data gaps due to non digitised chart information and unrecoverable data loss
- Lack of site information to allow extrapolation of flow series to a usable range.
- Concern that at this time it is possible that there will not be a sufficient range of catchment sizes incorporated into the FSU.

7. CONCLUSIONS AND RECOMMENDATIONS

Now the rating review project has been completed it is believed that the Republic of Ireland can confidently use the majority of A and B category station data in the further phases of the FSU. However, in the longer term it is believed that there is considerable potential to improve on the quality and quantity of data available. This is important since in view of the pooling groups approach, the new FSU will make use of all relevant, high flow data i.e. the FSU is not a one off exercise in terms of data use therefore there will be the possibility of using improved data in the future. We believe that there is good potential to improve the ratings for many sites. This could result in an upgrading of some C sites to B, Bs to A2 and A2 to A1.

It is realised that it is not possible to actively tackle all the sites at once. Therefore, we would suggest that sites requiring upgrading are prioritised. The prioritisation could be based on a number of criteria that may include the following:

- Catchment area and other catchment characteristics – for example there could be insufficient data available for small catchments. Also, there could be other types of catchments that have insufficient coverage. It is believed that catchment types that do not have good coverage e.g. Specific soil types will probably be identified during the analysis stages of the FSU project.
- Sites of strategic importance e.g. upstream of a town prone to flooding or where a flood improvement scheme is planned.
- Sites which just failed to qualify for a higher classification.

The work required to improve the ratings would consist of a combination of additional gauging (see Section 1.3.5), cross-sectional surveys and the use of rating extension techniques. It is believed that if cross-sections can be established at a number of the gauging stations reviewed it would be possible to significantly improve the confidence in the ratings.

In Section 4.1 we have commented on the OPW procedure that has been used for rating development in the past. We understand fully the reasons for adopting this methodology. However, we would strongly recommend that when reviewing and evaluating ratings in future use is made of the tools available on Sked as part of the recently installed Wiski data management system. If these tools are used to good effect along with OPW's own in-house knowledge of the sites we believe that this could result in improved ratings.

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'Go raibh mile maith agaibh'

APPENDIX 1

GLOSSARY

Term	Definition
ASGZ (Above staff gauge zero).	Refers to a water level (stage) related to the zero point on a staff gauge
Category/classification	Used interchangeably when referring to FSU site classification
DG	DG is a value applied to the stage reading by OPW. This is to account for actual or perceived datum shifts in the gauge zero during the period of record.
Drainage Years	A period in a station's history when the river catchment was subject to channel works to improve drainage. The dates often refer to the catchment as a whole and not necessarily to the reach containing the gauging station. Normally it is not possible to make use of data obtained during major drainage works since the stage-discharge relationships would have been continually varying with time and/or the characteristics of the catchment could change.
FSU	Abbreviation for Flood Studies Update.
FSU Site classification	FSU site classification is a method used to classify the quality of rating curves in terms of determining flood flows. It has been based mainly on the ratio between highest gauged flow and Q_{med} and is further refined and based on the 95% confidence limits at Q_{med}.
Gauging Station/Site	A river section at which there is a continuous stage recorder and where flow determinations are made using stage-discharge relationships. These terms can be used interchangeably. Site is perhaps more general.
HGF	Abbreviation for Highest gauged flow
POR (Period of Record)	The length of time for which there is continuous level and/or flow data for a particular station.
Q_{med}	Median annual flood
Q_{maf}	Mean annual flood
RC	Abbreviation for rating curve
SAAR	Standard Average Annual Rainfall.
SOR (Start of Record)	The date when the station was installed and started producing data.

APPENDIX 2

UNCERTAINTY ANALYSIS

Uncertainty in stage discharge relationships

The stage-discharge relationship is a line of best fit obtained by linear regression techniques. The relationship takes the form:

$$Q = c(h - a)^{\beta} \qquad \text{Equation 1}$$

Where

Q = discharge
h = gauge height or stage
a, β & c are constants

The above equation can be represented in its logarithmic form

$$\log Q = \log c + \beta \times \log(h - a) \qquad \text{Equation 2}$$

The goodness fit of a relationship can sometimes be ascertained using the coefficient of determination (r^2), which for a straight line relationship is the same as the correlation coefficient squared. However, this can sometimes be misleading and does not look at uncertainties or confidence levels at specific points in the stage-discharge relation. A high coefficient of determination may not necessarily mean that the rating curve will determine high flows to a low level of uncertainty. In order to estimate confidence limits, uncertainties for different stages or flows for a specific rate two parameters are estimated:

1. The standard error of estimate (s_e); and
2. The standard error of the mean relationship (s_{mr}).

If the rating consists of a number of segments (different equations) then these parameters are estimated for each segment of the rating.

The standard error of estimate is determined from the following:

$$s_e = \left[\frac{\sum (\ln Q_g - \ln Q_c)^2}{n-2} \right]^{0.5}$$

where Q_g is the gauged discharge
Q_c is the discharge determined from the rating equation
n is the number of pairs of stage and discharge observations used to derive the rating equation
ln is the natural logarithm

The random percentage uncertainty ($2s_{mr}$) in the calculated value of $\ln Q_c$ at the point $\ln(h\text{-}a)$ is given by:

$$2s_{mr} = \pm t_{\alpha} s_e \left\{ \frac{1}{n} + \frac{\left[\ln(h-a) - \overline{\ln(h-a)}\right]^2}{\sum\left[\ln(h-a) - \overline{\ln(h-a)}\right]^2} \right\}^{0.5} \times 100 \qquad \text{Equation 4}$$

t_{α} is the critical value of the Students t value corresponding to a total probability of α under both tails of the uncertainty distribution for n – 2 degrees of freedom. The $100(1 - \alpha)$% confidence limits for any given stage h can be estimated using equation 4. In hydrometry we normally estimate $2s_{mr}$ to 2 x standard deviations or the 95% confidence level. The students t value can be obtained from tables knowing the degrees of freedom and by taking an α value of 0.05. If there are more than 20 pairs of data points the Students t value can be assumed to be 2.

Hydro-Logic's Gauger Analysis software has a routine that allows the uncertainty (95% confidence limits) to be estimated for a given value of stage that can be entered manually into the software during each stations rating analysis. During the review and analysis of the ratings the stage values corresponding to Q_{med} for all Category A and B stations were entered and the software produced estimates of the upper and lower confidence limits and thus the percentage uncertainties were obtained.

The above analysis is described in BS ISO 1100-2:1998, Measurement of Liquid Flow in Open Channels – Part 2: Determination of the stage-discharge relationship. This is currently under review as a slightly different approach to estimating uncertainties in hydrometric data is being implemented by ISO. However, the methodology for stage-discharge relationships will not alter significantly and will not effect the conclusions concerning the quality of the ratings.

APPENDIX 3

EXAMPLE OF ACCOMPANYING SPREADSHEET

ROI - HYDROMETRIC STATIONS

FLOOD FLOW RATING ASSESSMENTS

Key

A1	A2	B	Use of Amax series from diff period to calculate Qmed	ESB Sites	Unusable for FSU

Station Number	Station Name	River Name	Catchment	Grid Reference	Gauging Authority	BDS	Technician	Catchment Area (km2)	SAAR	Qmed (cumecs)	MAF (cumecs)
10022	CARRICKMINES (Post 10/07/84)	CABINTEELY	Coastal	O220241	EPA	DLR		10.4	990	3.85	3.27
7007	Boyne Aqueduct (01/10/1962 to 12/10/73)	Boyne	Boyne	N 692452	OPW		Frank Quinn	432	898	**31.00**	34.9
27002	Ballycorey (pre 01/11/1972)	Fergus	Clare	R 344803	OPW		?	562	1252	**32.00**	33.1

Bankfull Stage (m)	Simple Bank Survey Requested	Rating Reviewed (Y/N)	Rating Versions Approved (FSU rating)	Final Station Rating Quality Classification	Station/Site Remarks (type of control, bypassing, bank level above S G zero etc)	Rating Remarks (limit of reliable extrapolation, stability, concerns over particular gaugings, assumptions made etc)	Amax Series Remarks quality, dubious data, reasons for gaps etc)	Sta
								A
?	Y	Y	RC2	A1		RC2 to be applied to the later period from 10/07/84 to Date after the datum shift was applied. Upper limit of extrapolation is be determined by HGF from the period. Rating is classed as A1		
N/A	N	Y	RC2	A1	Velocity-area station installed in 1939 and automated in 1953. Drainage works 12/10/73 to 05/04/79. Natural channel control at all flows. Rock bed. Weed growth all year.	Reasonably stable rating. Maximum extent of extrapolation 3.73m (HGF).	OK	O
N/A	N	Y	RC1	A1	Velocity-area station installed in 1940 and automated in 1954. Flat V crump weir acts as control. Stable bed, negligible weed growth.	Stable, reliable rating, maximum extrapolation 2.47m (HGF).	OK	Ap

Drainage	No of Drainage Years	Amax Level Missing Data (dates)	Amax Level Missing Data (no. Of years)	2Smr at Qmed	2smr at 2 Qmed	2smr at Qmed (revised)	2smr at 2 Qmed (revised)	Uncertainty Classification (at Qmed)	Mean % difference in FSU Amax flow series compared to OPW Amax flow series	Rating Recommendation	Comments	OPW Comments
		98-02	5	0.00	0.00	***0.00***	***0.00***	***Very Good***		EPA Ratings		
No	0	None	0	0.00	0.00	***0.00***	***0.00***	***Very Good***	-5.2	FSU rating	Rating curve 3 wrongly applied to water year 72.	
No	0	None	0	3.79	62.16	3.78	17.80	Very Good	0	OPW ratings		