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

# Inception Report – Unit of Management 27

# Draft Final Report

## Appendix B: Preliminary Hydrological Assessment and Method Statement

JACOBS

**18 September 2012**

JACOBS

# Document control sheet  BPP 04 F8

Client: The Office of Public Works
Project: Shannon CFRAM Study  Job No: 32103000
Document Title: Preliminary Hydrological Assessment and Method Statement – UoM 27

| | Originator | Checked by | Reviewed by | Approved by |
|---|---|---|---|---|
| **DRAFT V0_0** | NAME **Helen Harfoot** | NAME **Steve Dunthorne** | NAME **Iain Blackwell** | NAME **Mike Hind** |
| DATE **15 Aug 2011** | SIGNATURE | SIGNATURE | SIGNATURE | SIGNATURE |
| **Document Status** Issued as part of Draft Inception Report | | | | |

| | | | | |
|---|---|---|---|---|
| **REVISION V0_A** | NAME **Helen Harfoot** | NAME **Iain Blackwell** | NAME **Iain Blackwell** | NAME **Peter Smyth** |
| DATE **12 Jan 2012** | SIGNATURE | SIGNATURE | SIGNATURE | SIGNATURE |
| **Document Status** Issued as part of Draft Final Inception Report | | | | |

| | | | | |
|---|---|---|---|---|
| **REVISION V1_0** | NAME **Elmar Torenga** | NAME **Iain Blackwell** | NAME **Iain Blackwell** | NAME **Peter Smyth** |
| DATE **18 Sep 2012** | SIGNATURE | SIGNATURE | SIGNATURE | SIGNATURE |
| **Document Status** | | | | |



**Legal Disclaimer**
This report is subject to the limitations and warranties contained in the contract between the commissioning party (Office of Public Works) and Jacobs Engineering Ireland Limited.

## Contents

JACOBS

Appendix A - All Hydrometric Stations listed in EPA Register
Appendix B - Double Mass Rainfall Plots
Appendix C - 1-day and 4-day Rainfall Probability Plots
Appendix D - FSU Depth Duration Frequency Plots
Appendix E - Daily Mean Flow Review
Appendix F - Flood Frequency Probability Plots
Appendix G - Catchment Boundary Discrepancies
Appendix H - Gauging Station Summary Sheets
Appendix I - Historical Flood Risk Review Details

## List of Tables

**List of Figures**

## Glossary

| | |
|---|---|
| AEP | Annual Exceedance Probability (expressed as a percentage) |
| APMR | Areas of Potential Moderate Risk |
| APSR | Areas of Potential Significant Risk |
| CFRAM | Catchment Flood Risk Assessment and Management |
| DAD | Defence Asset Database |
| DAS | Defence Asset Survey |
| DoEHLG | Department of Environment, Heritage and Local Government |
| DEM | Digital Elevation Model (Includes surfaces of structures, vegetation, etc.) |
| DTM | Digital Terrain Model (often referred to as 'Bare Earth Model') |
| EPA | Environmental Protection Agency |
| FRMP | Flood Risk Management Plan |
| HEFS | High-End Future Scenario |
| HPW | High Priority Watercourses |
| IRR | Individual Risk Receptors |
| MPW | Medium Priority Watercourses |
| MRFS | Mid-Range Future Scenario |
| NTCG | National Technical Coordination Group |
| PFRA | Preliminary Flood Risk Assessment |
| RBD | River Basin District |
| UoM | Unit of Management |
| WFD | Water Framework Directive |

# 1 Background

## 1.1 Background

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 Inception Reports, one covering each Unit of Management within the Shannon River Basin District (RBD).

A major requirement of the Inception Report is to report on the hydrological aspects of the study. The work undertaken for the hydrological analysis to date will form the basis of a significant part of the Hydrological Report, scheduled for delivery in 2012. The hydrological aspects of the Inception Report are reported in this **Preliminary Hydrological Assessment and Method Statement.**

## 1.2 Preliminary Hydrological Assessment and Method Statement

This report fulfils the requirements of the preliminary hydrological assessment and method statement within the Inception Report, as set out under Section 2.4.2, Item (4) in the Stage I Project Brief:

*a) A preliminary hydrological assessment, including a review of historical floods, catchment boundaries and hydrometric and meteorological data as defined in Sections 6.2, 6.3 and 6.4 (but not including Section 6.4.3).*

*b) Discussion of historical flood events, including the dates they occurred, their duration, mechanisms, depths, impacts (e.g., number of properties flooded, infrastructure affected, etc.), severity (e.g., flows, levels, estimated annual exceedance probability), etc.*

*c) A preliminary assessment of past floods and flooding mechanisms.*

*d) A detailed method statement, setting out the datasets to be used and the approaches to be followed for the hydrometric review as defined in Section 6.4.3, and statistical analysis of data for the estimation of design flows (Section 6.5) for all hydrometric stations (Final reporting of all aspects of the hydrological analysis shall be reported upon in the Hydrology and Hydraulics Report).*

The requirements set out in sections 6.2, 6.3 and 6.4 (excluding 6.4.3) as referred to in a) above, are outlined below:

***6.2. REVIEW AND ANALYSIS OF HISTORIC FLOODS***
*The Consultant shall analyse all available previous studies and reports and the historic flood data collected (see Sections 3 and 4) in terms of peak levels, flood extents, damage caused, flows, etc. Such data shall be utilised in the analysis described below. The Consultant shall also rank the historic flood events in the APSRs and, for fluvial flood events, within each catchment within the Study Area, in terms of magnitude, including those for which only outline information is available, and estimate annual exceedance probabilities for all such events using*

*appropriate statistical methodologies. The Consultant shall use the peak levels and flood extents, including anecdotal information from informed individuals, recorded or observed during historical flood events, as references for comparison with design flood levels (developed as per Section 6.5, 7.2 and 7.2) and flood extents (developed as per Section 7.5) to ensure consistency between observed events and design events, particularly with reference to the estimated annual exceedance probabilities of those events.*

### *6.3. CATCHMENT BOUNDARIES*

*The Consultant shall, following necessary hydrological analysis, establish the catchment boundaries and sub-catchment boundaries for each of the Hydrological Estimation Points (see Section 6.5.3), and provide details of same to the OPW in compliance with GIS and hard copy format requirements for this project. The catchment boundaries defined for the purposes of the implementation of the Water Framework Directive will be provided to the Consultant to facilitate, and form the basis of this process, but the Consultant shall review and confirm these boundaries and, with the assistance of the OPW and, where relevant, through cooperation with consultants undertaking other CFRAM Studies, resolve any discrepancies arising.*

### *6.4. ANALYSIS OF HYDROMETRIC AND METEOROLOGICAL DATA*

#### *6.4.1. Rainfall Data*

*The Consultant shall, promptly upon receipt, analyse historic and recorded rainfall data throughout the catchment in terms of severe rainfall event depths, intensities, durations, etc., and shall estimate probabilities for significant and / or recent events, with reference and comparison made to the Flood Studies Update data and other relevant research.*

*The OPW shall provide the Consultant upon appointment with the rainfall depth-duration frequency data as generated by Met. Éireann for the Flood Studies Update. This data, available in GIS format, provide national coverage of depth-duration-frequency data for 2km grid squares.*

#### *6.4.2. Hydrometric Data Review*

*The Consultant shall promptly upon receipt analyse the historic and recorded water levels, including tidal and surge levels and estimated flows (with due reference given to the rating reviews – Section 6.4.3), in terms of peak flood levels and flows, hydrograph shape, flood volumes, etc. and shall estimate probabilities for major or recent events, with reference and comparison made to the Flood Studies Report and / or other relevant research.*

The hydrological work for the Inception report has focused on the Communities at Risk (CARs) and Individual Risk Receptors (IRRs) identified in Technical Note 007 ($17^{th}$ March). The CARs and IRRs form the basic Areas of Potential Significant Risk (APSR) to which will be added the additional areas identified in the Flood Risk Review to form the final list of APSRs. The Flood Risk Review has been undertaken in parallel with this hydrological work.

# 2 Study Area

## 2.1 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. The Shannon RBD is designated an international RBD as a consequence of a small portion of the Shannon headwaters lying within County Fermanagh, Northern Ireland. This study will focus on the Shannon RBD within the Republic of Ireland.

## 2.2 Shannon River Basin District

The Shannon River Basin District is the largest River Basin District (RBD) in Ireland, covering approximately 17,800km$^2$ and more then 20% of the island of Ireland. The Shannon RBD is an International RBD. 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 1).

The Shannon River rises in the Cuilcagh Mountains, at a location known as the Shannon Pot in the counties of Cavan and Fermanagh (in Northern Ireland). The river flows in a southerly direction before turning west and discharging through the Shannon Estuary to the Atlantic Ocean between counties Clare and Limerick. While the River Shannon is 260km long from its source to the Shannon Estuary in Limerick City, over its course the river falls less then 200m. Significant tributaries of the Shannon include the Inny, Suck and Brosna. There are several lakes in the RBD, including Lough Ree, Lough Derg and Lough Allen. Several of these lakes are on the River Shannon.

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.

## 2.3 Units of Management

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

There are five units of management within the Shannon River Basin District (ref. Figure 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 the Shannon Estuary North Unit of Management (UoM 27) only.  Analysis and discussion for the remaining units of management are presented in separate reports.

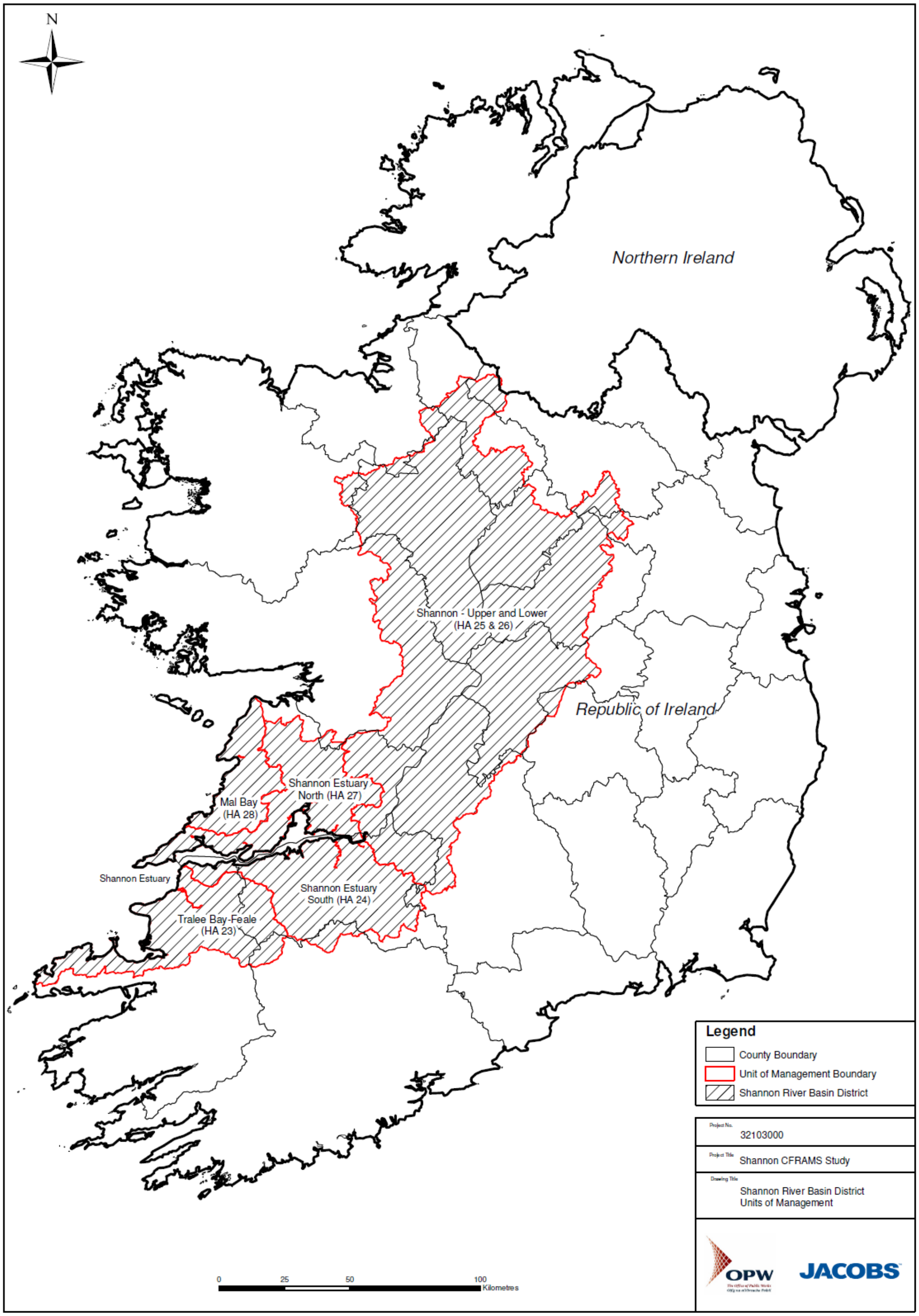



***Figure 1 Shannon River Basin District and the five Units of Management***

## 2.4 Shannon Estuary North (UoM 27)

The Shannon Estuary North Unit of Management (or UoM 27) is shown in its wider context within the Shannon RBD in Figure 1, and in more detail in Figure 3. It is located almost entirely within County Clare, with only a very small part of the unit of management within Limerick and Galway (Figure 1).

In addition to the Shannon Estuary forming the southern boundary of UoM 27, this unit of management is dominated by three main river catchments, which are, from east to west, the Owenogarney (or Ratty) River, the Rine River, and the River Fergus, all of which discharge into the Shannon Estuary (see Figure 3). The largest of these is the River Fergus. Further to the west, the rivers are much smaller, with several rivers draining generally southwards into the Shannon Estuary, such as the Crompaun and the Cloon. The total area of UoM 27 is approximately 1650 $km^2$.

The coastline extends along the Shannon Estuary from Limerick City in the east to where it meets the Atlantic Ocean at Loop Head in the far west of County Clare. From Loop Head the coastline extends northeast to Kilkee, along which, the coastline is fully exposed to the Atlantic Ocean. UoM 27 is bounded to the east by the Lower Shannon Hydrometric Area (part of UoM 25/26), to the north by the Western RBD, and to the west by UoM 28 separated from it by the upland area which creates the catchment divide.

The far north of UoM 27 includes the southern part of The Burren, with its characteristic karst limestone features, and the virtual absence of any surface water features. This is seen in Figure 3 in which The Burren is indicated by the upland area in the far north of UoM 27. Figure 2 shows a simple geological map of County Clare, demonstrating the influence of the limestone geology on the northern and central part of UoM 27, in the area north of Ennis.

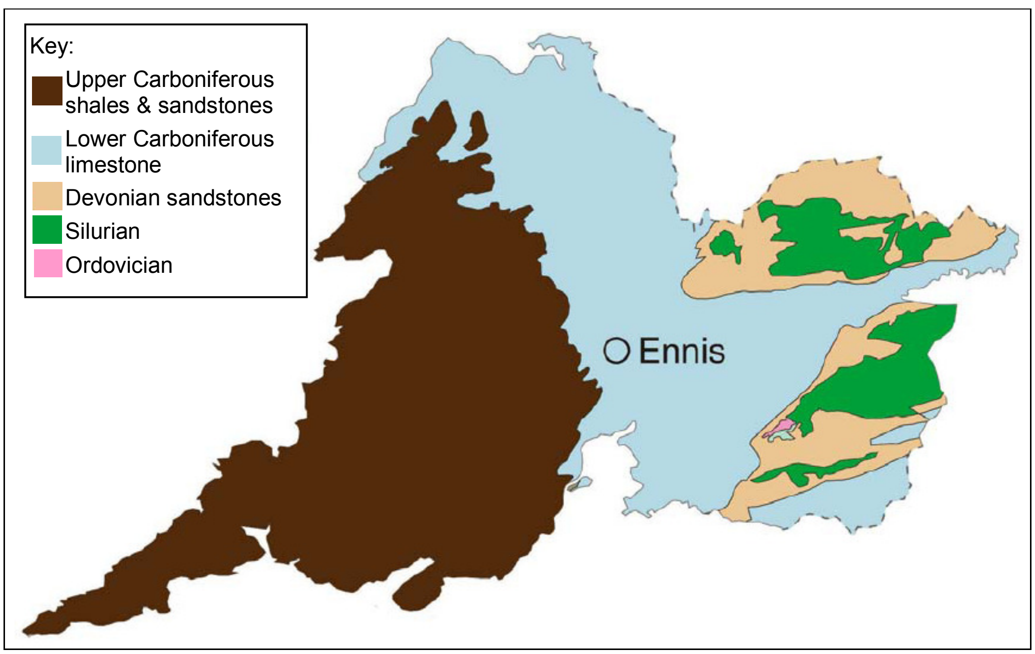



***Figure 2 Geological Map of County Clare(incorporating UoM 27, 28 and a part of 25/26)***

The southern part of UoM 27 is dominated by the tidal influence of the Shannon Estuary, which is reflected in the extensive flood defence assets (typically tidal embankments) located along the low-lying shoreline for much of its length in the eastern part of UoM 27.

In the central part of UoM 27, the River Fergus dominates, rising northwest of Corrofin near Killinaboy, flowing through Corrofin and then heading east towards the low lying central part of UoM 27. It then turns to the south where it is joined by the Castle River which (with its tributaries) drains the northern part of the catchment. The Fergus continues in a broadly southerly direction through the central part of UoM 27, where it is dominated by numerous groundwater-fed lakes, heavily influenced by the limestone geology. Just north of Ennis it flows through Ballyallia Lough before splitting into two channels in the northern part of Ennis. The main channel flows through the northwestern part of the town and the town centre (where the Claureen (or Inch) River joins the Fergus from the west) while the smaller channel flows southeast through the northern part of the town. The two parts of the Fergus rejoin on the eastern side of Ennis.

South of Ennis, the river widens and there is a tidal barrage located at Clarecastle approximately 4km south of the centre of Ennis. 3km south of Clarecastle, the River Rine (or Ardsollus River in its lower reaches) flows into the Fergus before entering the Shannon Estuary.

Towards the eastern boundary of UoM 27, the Ratty (or Owenogarney) River flows into the Shannon Estuary, draining the eastern part of the catchment, and separated from the Lower Shannon catchment (part of UoM 25/26) by the Slieve Bearnagh Mountains.

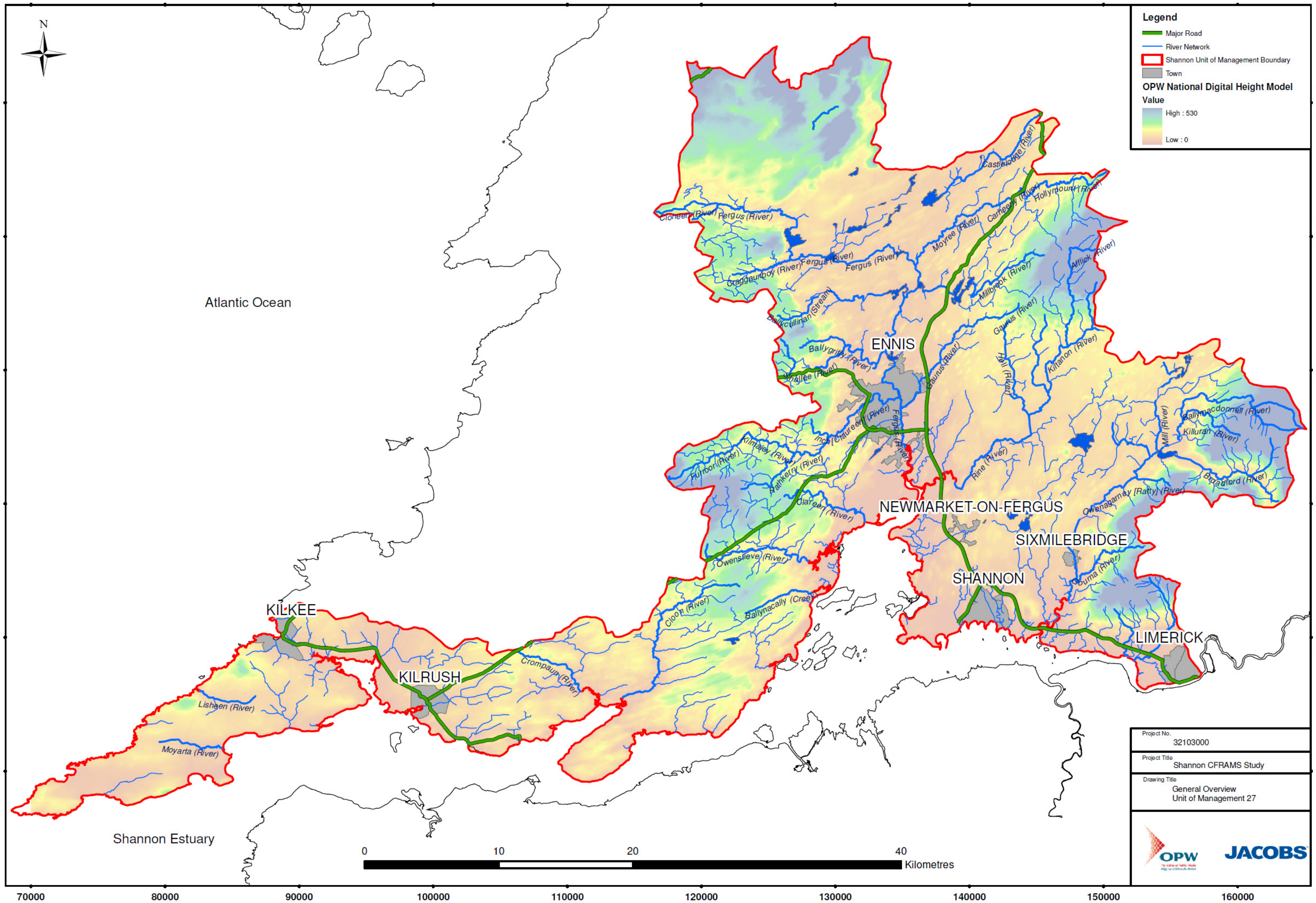



*Figure 3 Shannon Estuary North Unit of Management (UoM 27)*

JACOBS

### 2.4.1 Communities at Risk

Communities within UoM 27 are at risk from tidal and/or fluvial flooding. Table 2-A outlines the communities identified by OPW as at risk of fluvial or tidal flooding. The locations of the Communities at Risk (CARs) are shown in Figure 4.

| No. | Location | Easting | Northing | Fluvial Catchment | At risk of fluvial flooding? | At risk of tidal flooding? |
|---|---|---|---|---|---|---|
| CAR14 | Bunratty | 145308 | 160869 | | No | Yes |
| CAR28 | Ennis | 134500 | 177000 | Fergus | Yes | Yes |
| CAR33 | Kilkee | 88731 | 160073 | Victoria Stream | Yes | Yes |
| CAR36 | Kilrush | 99458 | 155376 | River Wood | Yes | Yes |
| CAR38 | Lissan West | 134500 | 172500 | | No | Yes |
| CAR53 | Shannon | 139750 | 162000 | Various | Yes | Yes |
| CAR55 | Sixmilebridge | 147400 | 165935 | Owenagarney (Ratty) | Yes | No |

***Table 2-A Communities at Risk in* Shannon Estuary North *(or UoM 27)***

### 2.4.2 Individual Risk Receptors

A number of assets within the Shannon RBD have been identified as Individual Risk Receptors (IRRs). These assets located outside of an Area of Potential Significant Risk (APSR) and if flooded, would give rise to significant detrimental impact or damage.

Three Individual Risk Receptors (IRRs) are located within the Shannon Estuary North as shown in Table 2-B and Figure 4.

| No. | Location | Easting | Northing | Fluvial Catchment | At risk of fluvial flooding? | At risk of tidal flooding? |
|---|---|---|---|---|---|---|
| IRR 5 | Shannon International Airport. | 137674 | 161045 | | No | Yes |
| IRR 6 | Radar Station for Shannon Airport | 137684 | 160636 | | No | Yes |
| IRR 7 | Moneypoint Power Station | 103700 | 151500 | | No | Yes |

***Table 2-B Individual Risk Receptors in* Shannon Estuary North *(or UoM 27)***

# 3 Hydro-Meteorological Data and Availability

## 3.1 Introduction

Within the Shannon River Basin District the hydro-meteorological network is owned and operated by various government and private organisations. These include:

- The Office of Public Works (OPW);
- Environmental Protection Agency (EPA);
- Waterways Ireland;
- Electricity Supply Board (ESB);
- Met Éireann;
- Local Councils;
- Bord Na Mona;

Hydro-meteorological data is collated, quality assured and distributed primarily by the following organisations:

- Flow and lake levels and flows by the OPW, the EPA (on behalf of Local Councils), Waterways Ireland and ESB;
- Rainfall data by Met Éireann;
- Tidal data by the OPW.

Historically, organisations have collected data in accordance with their own requirements. This historical requirement is important to bear in mind when considering the appropriateness of flow data, for example if low flows were the target of monitoring, the location may be inappropriate for high flow assessment.

Since the introduction of the Arterial Drainage Act 1945, the OPW has collected flow and level data, with an emphasis on high flows, to monitor the impact of drainage schemes .

A national programme of hydrological data collection is coordinated by the EPA in accordance with the Environmental Protection Act 1992. However, there is not currently any single organisation responsible for collecting flood peak data, although in a recent strategic review the recommendation was made that this responsibility should be given to the OPW (JBA, 2008). The following organisations each has a role with regard to collection of flood peak data:

- Office of Public Works;
- Environmental Protection Agency;
- Waterways Ireland;
- Electricity Supply Board.

Organisations listed above were all approached for data during the data collection phase of the Shannon CFRAM study.

## 3.2 Data Requirements

The following hydro-meteorological data sets were identified as essential for the Shannon CFRAM hydrological assessment:

- Instantaneous (15 minute or digitised chart logger) river and lake level, flow and tidal data;
- Daily mean river and lake level, flow and tidal data;
- Rating equations and reviews for hydrometric sites;
- Spot flow gaugings;
- Annual Maximum (AMAX) flow and level series;
- Daily and sub-daily rainfall;
- Soil Moisture Deficit;
- All Flood Studies Update (FSU) reports and worksheets.

The EPA hydrometric register (dated January 2011) lists 31 river and lake level, flow and tidal level gauging stations within UoM 27 (Appendix A), of which only 19 locations are currently active.

Within this preliminary data collection phase, all efforts were made to obtain a full record of all available hydrometric data within UoM 27. Various hydrometric data sets were provided by the OPW at the start of the Shannon CFRAM Study. When incomplete data sets were identified and it was not possible to obtain all records, 'key' hydrometric stations were identified to ensure that sufficient data was obtained to fulfil our requirements for the study (ref. Table 3-A). Key stations were identified based on the following criteria:

- Proximity to Communities at Risk or Individual Risk Receptors;
- Whether a rating review was required;
- Whether a hydrometric station improved the spatial distribution of data throughout the unit of management and sub-catchments.

Where appropriate, short records, inactive stations, staff gauge or flow measurement only sites were included in the list on the basis that even minimal data may provide some information on peak flows or flow characteristics in the absence of any other information.

At this stage all gauges within the UoM have been considered, and the key stations of Table 3-A were selected on the basis that they are likely to be of greatest value based on the criteria listed above. However, it is conceivable that in subsequent stages of the study, data from other gauging stations may prove to be useful. Exclusion of a gauge at this stage does not imply that it would not be considered further.

| Station No. | Station Name | Watercourse | Status | Station type | Proximity to CAR/IRR? | Rating Review required? | Improve Spatial Coverage? |
|---|---|---|---|---|---|---|---|
| 27001 | Inch Br. | Claureen | Active | Recorder | | Yes | |
| 27002 | Ballycorey | Fergus | Active | Recorder | Ennis | | |
| 27003 | Corrofin | Fergus | Active | Recorder | | | Yes |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | Active | Recorder | Sixmilebridge | Yes | |
| 27013 | Kilrush | Wood | Inactive | Staff Gauge Only | Kilrush | | |
| 27023 | Victoria Bridge | Fergus | Active | Recorder | Ennis | | |
| 27024 | Mill Bridge | Fergus | Active | Recorder | Ennis | | |
| 27025 | Knoxs Bridge | Fergus | Active | Recorder | Ennis | | |
| 27026 | Tulla Road Bridge | Fergus | Active | Recorder | Ennis | | |
| 27028 | Gaurus Bridge | Gaurus | Active | Recorder | Ennis | | |
| 27060 | Doora Br | Fergus | Active | Recorder | Ennis | | |
| 27066 | Ennis Br. | Fergus Esty | Active | Recorder | Ennis | | |
| 27092 | Gaurus Landfill | Drain | Active | Recorder | Ennis | | |

***Table 3-A Key hydrometric stations identified for Shannon Estuary North (grey boxes indicate N/A)***

## 3.3 Hydrometric Network in relation to CARs and IRRs

Of the seven Communities at Risk (CAR) and three Individual Risk Receptors (IRRs), only five have been identified at risk of fluvial flooding (ref. Figure 4 and Table 2-A). Of these five only three (Ennis, Kilrush and Sixmilebridge) have flow or level gauges located either at the site or in the vicinity. Three CARs; Kilkee, Lissan West and Shannon do not have any flow or level gauges located within their catchment. There are plenty of flow gauges located on the fluvial Fergus upstream of Lissan West but none on the watercourse draining through the settlement. Consideration should be given to improving the gauging network in these locations for the benefit of future flood studies.

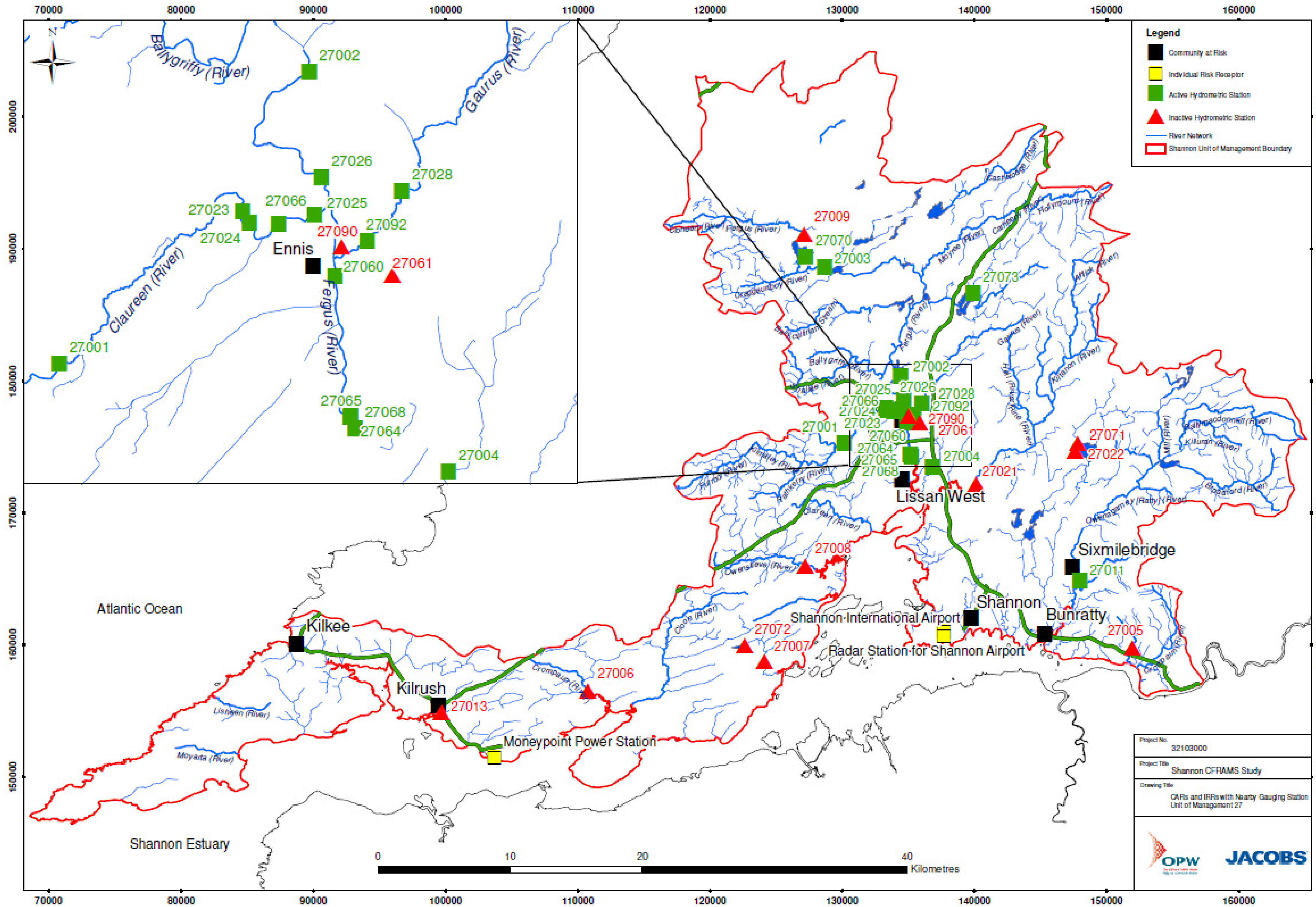



*Figure 4 Location of hydrometric gauging stations in relation to Communities at Risk and Individual Risk Receptors within Shannon Estuary North*

## 3.4 Rainfall Data

### 3.4.1 Background

Rainfall measurement in Ireland is coordinated by Met Éireann with data collected from their own raingauges and those operated by individual volunteers and organisations. Rainfall data is collected hourly, daily or monthly.

The majority of the approximately 750 raingauges located throughout Ireland are read daily, the remainder being monthly read gauges located in remote areas. Monthly readings are of little value to this study and will not be considered any further. Across Ireland, Met Éireann run 15 sub-daily gauges, where rainfall is measured on an hourly basis, these provide valuable information on rainfall intensity. No details on the Met Éireann quality assurance procedures applied to rainfall data were available.

Met Éireann also operate two radars for rainfall detection, one at Dublin Airport and the other at Shannon Airport. These provide almost complete coverage of Ireland. Data from the radars are processed to produce a number of different products including intensity and periodic totals. This data will be used as part of this study where appropriate, but is unlikely to be sufficiently accurate to be used in calibration of models. However, it may be feasible to use the data in some form if suitable ground truthing is possible near to the location of interest. The radar data can provide useful information on the extent of rainfall for particular events, when there are issues about how widespread the event may have been.

The National Roads Authority (NRA) may be another potential source of sub-daily rainfall information. The NRA has recently established a network of sensors along major roads to measure and record the type and intensity of precipitation at 10 minute intervals. This information is used to help warn the NRA of extreme weather and warn drivers of road conditions. There is one NRA rainfall sensor located within the Shannon Estuary North Unit of Management. Insufficient data was available at the time of writing of this report to determine the precision of the NRA rainfall sensors or to correlate the rainfall depths estimated from the sensors with Met Éireann daily rain gauges. The accuracy of the data compared to traditional measuring devices therefore remains untested. With such uncertainty it was not deemed appropriate for use in this study.

### 3.4.2 Daily Rainfall Data

Daily rainfall data is recorded at seven locations within the Shannon Estuary North Unit of Management. Storage raingauges are used to collect rainfall and are read and emptied daily at 09:00 hours. This daily threshold can result in a storm event being recorded over two consecutive days, potentially leading to an underestimation of daily rainfall depth versus a 24 hour rainfall depth obtained over no fixed time period.

Table 3-B summarises the raingauges located within Shannon Estuary North and the availability of data. Figure 5 shows the distribution of the raingauge network.

| Raingauge no. | Raingauge name | Data available? |
|---|---|---|
| 418 | Dromoland Castle | Yes |
| 517 | Kilkee G.S. | Yes |
| 718 | Corofin | Yes |
| 1218 | Tulla | Yes |
| 2018 | Carheeny Beg | Yes |
| 2118 | Crusheen (Caherphuca) | Yes |
| 5311 | Moneypoint E.S.B. | Yes |

***Table 3-B Daily rainfall data available within Shannon Estuary North***

### 3.4.3 Sub-Daily Rainfall Data

Sub-daily or hourly rainfall is recorded at Airports and TUCSON (The Unified Climate and Synoptic Observations Network) stations. At these locations rainfall is automatically measured by tipping bucket raingauges with 0.1 or 0.2 mm buckets.

There is one hourly rainfall station located within UoM 27. This is the synoptic station at Shannon Airport (Figure 5).

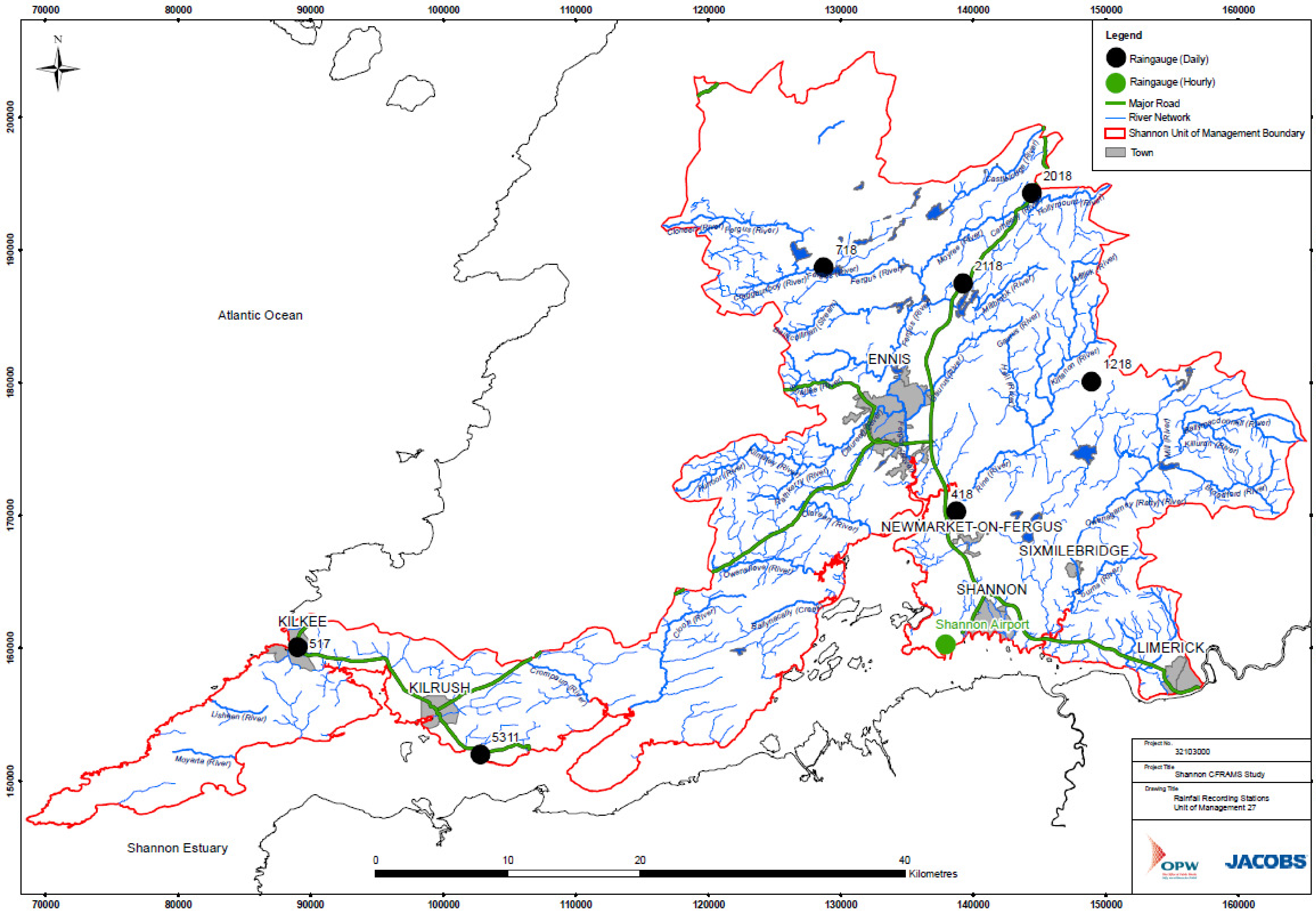



***Figure 5 Location of raingauges within Shannon Estuary North***

## 3.5 Hydrometric Data

### 3.5.1 Background

The location of hydrometric stations in the Shannon Estuary North is shown in Figure 6. The majority of flow and level gauging stations within UoM 27 are located on the River Fergus and its tributaries, with a significant cluster of gauges in and around Ennis. Six gauges are located on watercourses draining into the Shannon Estuary and a further three gauges on the Owenogarney (or Ratty) River and its tributaries.

Gauging stations within the Shannon RBD are generally located within natural sections and therefore generally do not have any purpose-built control structures to ensure critical flow e.g. a flume or weir. However, the majority of gauging station sites are located downstream of man-made structures, such as bridges. These structures will provide some stability to the rated section, but without critical flow there is unlikely to be a consistent relationship between flow and level. In addition, any geomorphological changes to the channel cross-section will result in further changes to the flow-level relationship.

Water levels are recorded at the majority of stations. However, ratings have only been developed at selected locations. Both flows and levels will be useful in this study.

Depending on the station configuration, flow and level measurements can either be discrete or continuous measurements in time. The EPA hydrometric register specifies three broad station types within the Shannon RBD, viz. staff gauge, flow measurement site and recorder:

**Staff gauge** – this is a fixed plate with levels marked on, which is used to read off the water level during visits. This will provide a record of discrete water levels with limited use for flood estimation purposes. However, where no other flow or level data is available, staff gauge readings may be used to obtain some indication as to the behaviour of water levels at a given location. Staff gauge stations for which check gaugings (spot flow gaugings) are available are also referred to as **flow measurement sites**. Flow measurement sites are also of limited use for flood risk purposes, except where check gaugings have been taken at high flows.

**Recorder** – Indicates a station fitted with a staff gauge and an automatic water level recorder. The automatic level recorder can either be an autographic recorder or a digital datalogger. An autographic recorder is a simple float-operated device that records the water level by activating a pen marking the water level on a chart. These charts are then digitised to convert the data to a digital format. A datalogger is a device that records water levels in digital format in 15-minute intervals. Both types of recorder can be considered instantaneous for fluvial and tidal flooding purposes.

Autographic recorders are gradually being replaced by digital data loggers within the Shannon RBD. This removes the requirement to digitise the records and also allows the transmission of the water level data via telemetry.

Check gaugings may also be available at recorder sites and are used to develop or confirm the rating relationship between the level and flow.

### 3.5.2 Instantaneous Flow and Level Data

Level data measured either via autographic recorder or at regular intervals by a data logger will be collectively treated as instantaneous and continuous data. Water levels recorded by an autographic recorder are digitised at inflection (or change) points and should therefore reliably capture any significant changes to the water levels at a site.

Instantaneous data for varying periods of record is available at 19 stations within UoM 27 (Table 3-C). These stations are located on Figure 6 along with their current status (active or inactive). Jacobs have been advised that not all data from autographic recorders has been digitised and uploaded onto the archives and will therefore not be readily available for this study. However, for specific events, such data may be of benefit (which will require digitising by OPW) and will be requested as the need for such data arises. Data listed in Table 3-C outlines all the instantaneous digital data available and provided to Jacobs.

Instantaneous flow and level data are useful for event analysis as it provides a greater temporal resolution than the daily mean flow and level series. This is especially important for analysing events in fast-responding flashy catchments.

### 3.5.3 Daily Mean Flow or Level Data

Daily mean flow and level data is derived from a 15 minute flow or level series. Daily mean flow data is useful when seeking a long-term view of the flow or level record to help identify any trends or sudden shifts in the dataset and to obtain an understanding of the behaviour of flows at a given location.

Initially, all daily mean flow and level data was obtained via the OPW hydrodata website (http://www.opw.ie/hydro/). The OPW later provided daily mean flows for the OPW stations listed as requiring a rating review (ref. Table 3-D). In some instances the two data series for a given station were not consistent; where this was the case the data provided directly by the OPW was used.

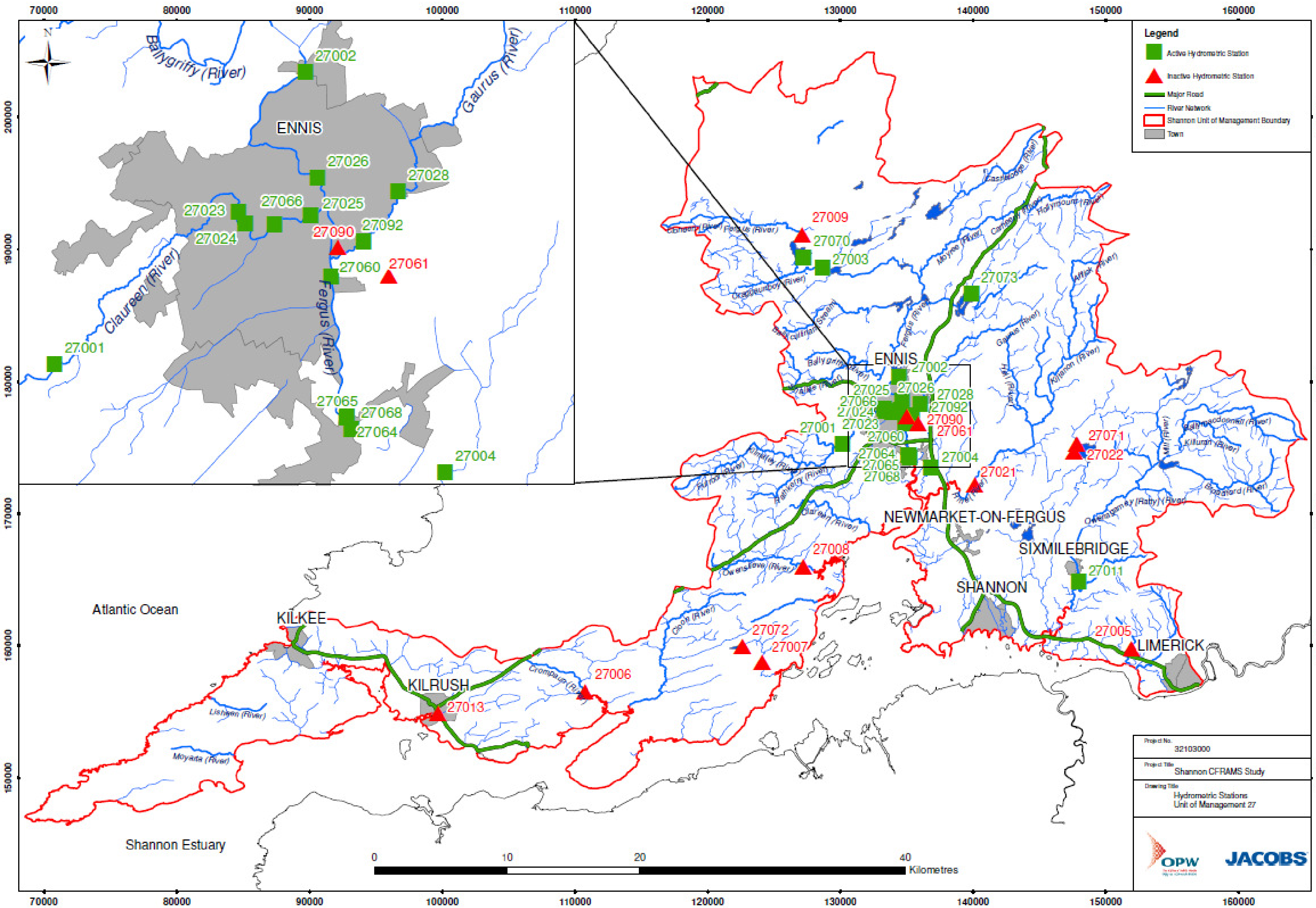



***Figure 6 Location of hydrometric gauging stations within Shannon Estuary North Unit of Management***

| Station number | Station name | Watercourse | Station status | 15 min flow start | 15 min flow end | 15 min level start | 15 min level end |
|---|---|---|---|---|---|---|---|
| 27001 | Inch Br. | Claureen | Active | 09/10/1972 | 09/09/2010 | 01/10/1972 | 09/09/2010 |
| 27002 | Ballycorey | Fergus | Active | 03/05/1954 | 09/09/2010 | 03/05/1954 | 09/09/2010 |
| 27003 | Corrofin | Fergus | Active | 01/10/1972 | 05/01/2010 | 01/10/1972 | 05/01/2010 |
| 27004 | Carnelly | Manus | Active | | | 04/12/2007 | 10/09/2010 |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | Active | 03/02/1997 | 11/01/2003 | 03/02/1997 | 11/01/2003 |
| 27023 | Victoria Bridge | Fergus | Active | | | 01/08/2003 | 30/04/2010 |
| 27024 | Mill Bridge | Fergus | Active | | | 20/06/2002 | 09/05/2008 |
| 27025 | Knoxs Bridge | Fergus | Active | | | 19/06/2002 | 30/04/2010 |
| 27026 | Tulla Road Bridge | Fergus | Active | | | 18/06/2002 | 30/04/2010 |
| 27028 | Gaurus Bridge | Gaurus | Active | | | 19/06/2002 | 30/04/2010 |
| 27060* | Doora Br | Fergus | Active | | | 18/06/2002 | 30/04/2010 |
| 27064* | Clarecastle u/s | Fergus Esty | Active | | | 21/02/2003 | 09/09/2010 |
| 27065* | Clarecastle d/s | Fergus Esty | Active | | | 19/06/2002 | 30/04/2010 |
| 27066 | Ennis Br. | Fergus Esty | Active | | | 02/08/2007 | 10/09/2010 |
| 27068* | Clarecastle Bridge | Fergus | Active | | | 19/06/2002 | 30/04/2010 |
| 27070** | Baunkyle | L. Inchiquin | Active | | | 11/11/1976 | 16/12/2010 |
| 27071** | Cullaun | Cullaun L. | Inactive | | | 04/11/1981 | 22/12/1986 |
| 27073 | Inchicronan Lough | Inchicronan Lough | Active | | | 17/02/2010 | 09/11/2010 |
| 27092 | Gaurus Landfill | Drain | Active | | | 19/06/2002 | 30/04/2010 |

***Tidal stations***

**** Instantaneous data from the EPA is a combination of regular 15 minute data (from data loggers) and irregular data based on digitised chart data (from autographic recorders).***

***Table 3-C Instantaneous flow and level data available within UoM 27 and their period of record (Grey boxes indicate no data available)***

| Station no. | Station name | River | Daily mean flow data | | Daily mean level data | |
|---|---|---|---|---|---|---|
| | | | Record start | Record end | Record start | Record end |
| 27001 | Inch Br. | Claureen | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 27002 | Ballycorey | Fergus | 01/01/1956 | 12/01/2010 | 01/06/1954 | 12/01/2010 |
| 27003 | Corrofin | Fergus | 01/10/1972 | 31/12/1999 | 01/10/1972 | 27/02/2005 |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | 03/02/1997 | 11/01/2003 | 03/02/1997 | 09/09/2010 |

***Table 3-D Daily mean flow and level data available within UoM 27 and their period of record***

.

### 3.5.4 OPW Quality Codes

To assist users of daily mean and instantaneous flow and level data, the OPW have assigned quality codes to each flow or level value. The quality codes indicate whether the data has been checked and if so, what confidence the OPW have in the data. Quality codes assigned by the OPW have been grouped into broader classifications for this study as outlined in Table 3-E. Where quality codes did not match an OPW code, they were classed as ‘unknown’. These quality codes will be referred to as necessary when considering how the data is to be used.

| OPW Code | OPW Description | Jacobs classification |
|---|---|---|
| **WATER LEVEL DATA** | | |
| 1 | Unchecked digitised water level data – Data is provisional only and must be used with caution | Unchecked |
| 31 | Inspected water level data – Data may contain some error, but has been approved for general use | Good |
| 32 | As per Code 31, but where the digitised water level data has been corrected | Good |
| 99 | Unchecked imported water level data – Data is provisional only and must be used with caution | Unchecked |
| 145 | Data is below prescribed data range and must only be used with caution | Beyond Limits |
| 146 | Data is above prescribed data range and must only be used with caution | Beyond Limits |
| 150 | Partial statistic – Data has been derived from records that are incomplete and do not necessarily represent the true value | Caution |
| 101 | Unreliable water level data – Data is suspected of being erroneous or is artificially affected (e.g., during drainage works) and must only be used with caution | Caution |
| >150 | Data is not available as it is missing, erroneous or of unacceptable quality | Missing |
| **ESTIMATED FLOW DATA** | | |
| 31 | Flow data estimated using a rating curve that it is considered to be of **good** quality and inspected water level data – Data may contain some error, but is considered to be of acceptable quality for general use | Good |
| 32 | As per Code 31, but using water level data of Code 32 | Good |
| 36 | Flow data estimated using a rating curve that it is considered to be of **fair** quality and inspected or corrected water level data – Data may contain a fair degree of error and should therefore be treated with some caution | Fair |
| 46 | Flow data estimated using a rating curve that it is considered to be of **poor** quality and inspected or corrected water level data – Data may contain a significant degree of error and should therefore be used for indicative purposes only | Poor |
| 56 | Flow data estimated using an extrapolated rating curve (see Section 3.2) and inspected or corrected water level data – Reliability of data is unknown and it should therefore be treated with caution | Caution |
| 99 | Flow data that has been estimated using unchecked water level data – Data is provisional only and must be used with caution | Caution |
| 101 | Flow data that has been estimated using unreliable water level data – Data is suspected of being erroneous and must only be used with caution | Caution |
| 145 | Data is below prescribed data range and must only be used with caution | Beyond Limits |

| OPW Code | OPW Description | Jacobs classification |
|---|---|---|
| 146 | Data is above prescribed data range and must only be used with caution | Beyond Limits |
| 150 | Partial statistic – Data has been derived from records that are incomplete and do not necessarily represent the true value | Caution |
| >150 | Data is not available as it is missing, erroneous or of unacceptable quality | Missing |

***Table 3-E OPW quality codes and corresponding Jacobs classification***

### 3.5.5 Annual Maximum Flow and Level Data

The annual maximum flow or level is usually derived from the highest recorded value in a continuously measured data series for the hydrometric year (1 October to 30 September).

Annual maxima data was provided from two sources, the OPW and the FSU (via the OPW). Where both sets of data were available for a given location, the OPW advised that the former series be used in preference, due to the additional work undertaken to extract the peak flows. The FSU series was developed for the Flood Studies Update in 2005/6 and accordingly the series ends in 2004. AMAX data was available at 10 hydrometric stations, including 2 tidal gauges (27066 and 27068) located within UoM 27 (Table 3-F). The annual maxima flow series at 27025 , 27026 and 27068 are currently too short (8 years, 6 years and 4 years respectively) to be of any use in subsequent statistical analysis, but has been included for completeness.

| Station number | Station name | Waterbody | AMAX (Flows) (from OPW) | AMAX (Levels) (from OPW) | AMAX (Flow) (from FSU)* |
|---|---|---|---|---|---|
| 27001 | Inch Br. | Claureen | 1972 - 2009 | | |
| 27002 | Ballycorey | Fergus | 1954 - 2009 | | |
| 27003 | Corrofin | Fergus | | 1957 - 2009 | |
| 27004 | Carnelly | Manus | | 1978 - 2009 | |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | 1996 - 2009 | | |
| 27025 | Knoxs Bridge | Fergus | | 2002 - 2009 | |
| 27026 | Tulla Road Bridge | Fergus | | 2004 - 2009 | |
| 27066 | Ennis Br. | Fergus Esty | | 1980 - 2009 | |
| 27068** | Clarecastle Bridge | Fergus | | 2002 - 2006 | |
| 27070 | Baunkyle | L. Inchiquin | | | 1976 - 2004 |

** Details of FSU AMAX only recorded if no flow or level annual maxima data is available from the OPW.*
*** Tidal stations*

***Table 3-F Annual maximum flow and level data for hydrometric gauges located within UoM 27 (NB: FSU AMAX flow series only listed if AMAX flow series was not available from the OPW)***

### 3.5.6 Hydrometric Station Rating Reviews

A rating curve defines the relationship between water levels and flows for a given location. The rating curve is usually established as the line of 'best fit' to check gaugings measured at the gauged location throughout a range of flows and levels.The rating is often described using one or more rating equations, so that flows can be estimated for any water level (within the range). Abrupt changes in the cross section width (e.g. where the cross section changes from in-bank to out-of-bank) may result in transitions (in the form of 'kinks') in the rating curve. Multiple rating equations may be required to adequately describe the segments of the rating curve between these transition points. There may not be a consistent relationship between flows and levels. This can be a result of an unstable cross-section, where the rating may change over time, making the rating equations invalid until new equations are established. Actual flows may vary for a given water level as a result of hysteresis, blockage, instability of the cross-section, or hydraulic backwater effects.

Table 3-G and Figure 7 illustrate the gauging stations for which rating reviews are required. Table 3-G also details stations for which rating equations and check gaugings have been provided.

| Station number | Station name | River | Rating review required by the OPW? | Rating equations received? | Check flow gaugings received? |
|---|---|---|---|---|---|
| 27001 | Inch Br. | Claureen | **Yes** | **Yes** | **Yes** |
| 27002 | Ballycorey | Fergus | No | **Yes** | **Yes** |
| 27003 | Corrofin | Fergus | No | **Yes** | **Yes** |
| 27004 | Carnelly | Manus | No | **Yes** | **Yes** |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | **Yes** | **Yes** | **Yes** |
| 27023 | Victoria Bridge | Fergus | No | No | **Yes** |
| 27026 | Tulla Road Bridge | Fergus | No | No | **Yes** |
| 27066 | Ennis Br. | Fergus Esty | No | **Yes** | **Yes** |

***Table 3-G Summary of gauging station rating reviews required and rating equations and check gaugings provided.***

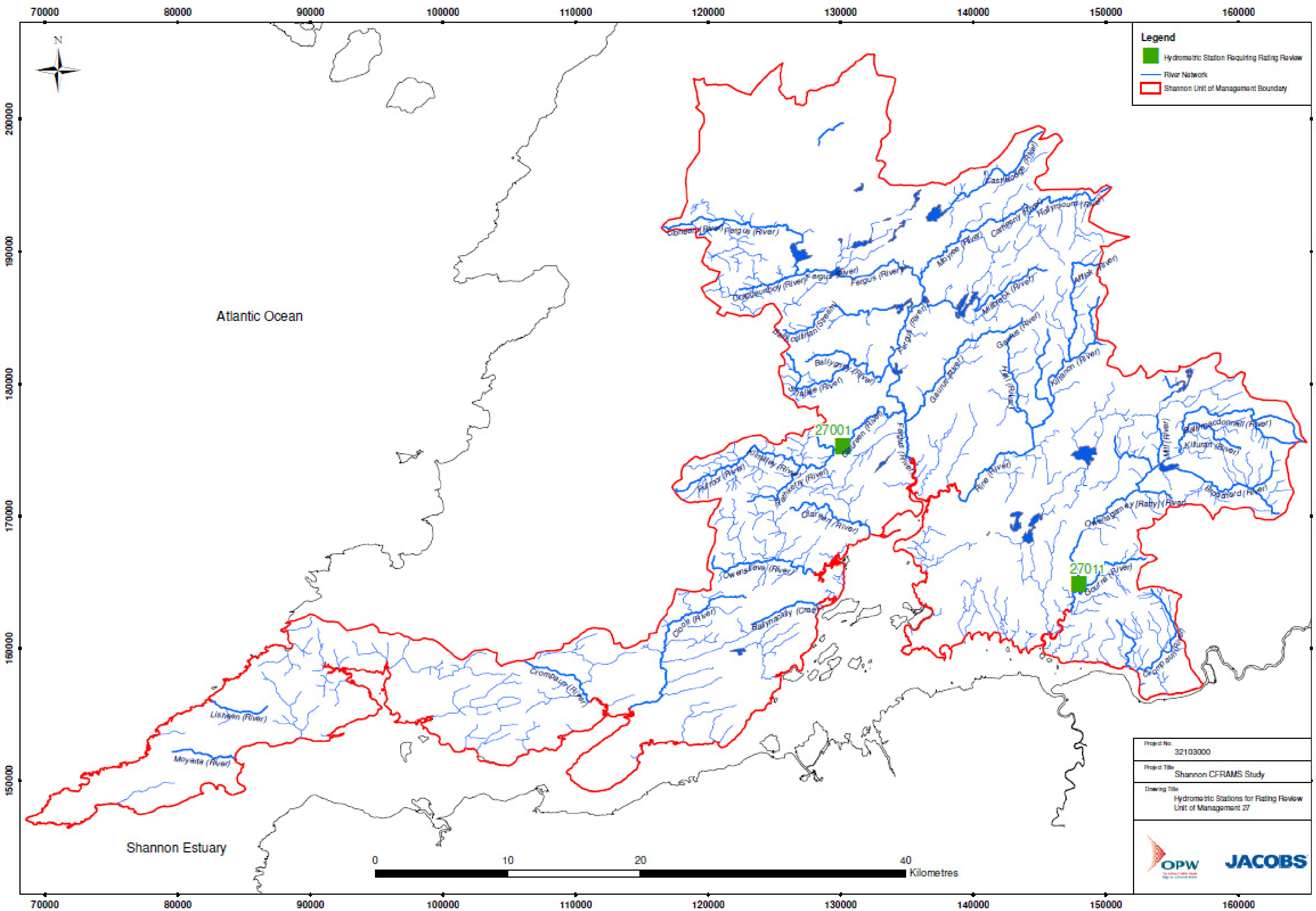



*Figure 7 Hydrometric gauging stations within Shannon Estuary North requiring a rating review*

### 3.5.7 Check Gaugings

Frequent check gaugings or spot flows, are required across a range of flows to establish and maintain a rating relationship. For this study, where flood flows are of particular significance, frequent check gaugings at high flows are essential to ensure confidence in flood flow estimates.

Check gaugings will be reviewed in association with the rating equations as part of the rating reviews and high flow suitability assessments to be undertaken later in the project.

A summary of stations for which check gaugings have been provided is given in Table 3-G.

### 3.5.8 Gauging Station Visits

Hydrometric gauging stations requiring a rating review as stated in the OPW brief (Table 3-G) were visited by Jacobs staff and observations recorded on the Gauging Station Summary Sheets (Appendix H).

## 3.6 Coastal Data

OPW have provided the results from the Irish Coastal Protection Strategy Study (ICPSS). This gives extreme tidal peak levels for the following annual probabilities: 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.1% for the south western coast and the Shannon Estuary.

OPW has also provided results from the ICWWS (Irish Coastal Wave & Water Level Modelling Study) screening analysis which highlight coastal locations potentially vulnerable to wave overtopping for the south western coast and the Shannon estuary.

For these locations, detailed wave and still water level model outputs are available in the form of shoreline prediction points and their associated predicted water level and wave climate (wave height $H_{mo}$, period $T_p$ and mean direction) combinations for a range of annual probabilities (50%, 20%,10%, 5%, 2%, 1%, 0.5% and 0.1%). These outputs include both the current condition and two future scenarios (Mid Range Future Scenario [MRFS] and High End Future Scenario [HEFS]).

## 3.7 Flood Studies Update

Following its publication in 1975 (NERC) the Flood Studies Report was adopted as the standard approach for flood estimation in Ireland. In 2004, the Flood Policy Review Group recognised that, with advances in flood estimation along with an additional 30 years of flow data, the development of new or recalibrated flood estimation methods could significantly improve the quality and facility of flood estimation in Ireland. Since 2005, the OPW have been implementing the Flood Studies Update (FSU) programme. Revised methodologies arising from the study have not yet been publicly distributed, but the package of works is complete and will be tested within this study.

A summary of the main work packages relevant to this study is outlined below:

### 3.7.1 Work Package 1.2 – Estimation of Point Rainfall Frequencies

A rainfall depth duration frequency model was developed for Ireland that allows point rainfall estimates to be made for durations from 15 minutes to 25 days and for return periods up to 0.2% Annual Exceedance Probability (AEP) (1 in 500) (0.4% AEP (1 in 250) for durations less than 24 hours). The model uses median rainfall as the index rainfall and log-logistic growth curves to determine rainfall with other frequencies. The associated software will allow annual exceedance probability of rainfall to be mapped at a 2 km grid and rarity estimates to be made for point measurements (on a sliding scale). These estimates are used within this study to assess extreme rainfall events and to inform the assessment of flood events. At a sample of sites the Depth Duration Frequency (DDF) estimates will be compared to measured rainfall frequency (ref. Section 6.7).

### 3.7.2 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-H).

| 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-H FSU gauging station classification (from Hydrologic, 2006)***

No indication is given in the report as to the total number of gauging station reviewed, only the number of sites selected as A1, A2 and B and therefore considered suitable for flood analysis, as summarised in Table 3-I. Please note some stations have their records split over different periods of time in which case each period is classified separately as a record.

| FSU Classification | Total number of records | Number of records in Shannon RBD | Number of records in UoM 27 |
|---|---|---|---|
| **A1** | 75 | 18 | 2 |
| **A2** | 119 | 22 | 3 |
| ***Total A sites*** | *194* | *40* | *5* |
| **B** | 103 | 11 | 0 |

***Table 3-I Number of records suitable for flood flow analysis classified A1, A2 or B***

This FSU classification has been borne in mind when reviewing flood flows and will form the basis of high flow quality assessments undertaken later in the project. Table 3-J summaries the five FSU rating reviews and classifications for the separate periods of record within UoM 27.

| Station Number | Station Name (period of record) | River Name | FSU Classification | Rating Remarks (limit of reliable extrapolation, stability, concerns over particular gaugings, assumptions made etc) |
|---|---|---|---|---|
| 27001 | Inch Bridge (01/07/93 to date) | Claureen | A2 | Use RC3 for the period from 01/07/93 when channel works were undertaken to date. Extrapolate to 1.65m |
| 27001 | Inch Bridge (11/02/1972 to 01/07/93) | Claureen | A2 | Use RC2 for the period from 11/02/1972 (Metrification) to 01/07/93 when channel works were undertaken. Extrapolate to 1.65m |
| 27002 | Ballycorey (pre 01/11/1972) | Fergus | A1 | Stable, reliable rating, maximum extrapolation 2.47m (HGF). |
| 27002 | Ballycorey (post 01/11/1972) | Fergus | A1 | OK rating, considerable amount of scatter at high flows. Cannot extrapolate beyond 2.29m (HGF). |
| 27003 | Corrofin | Fergus | A2 | Not confident in extrapolating beyond HGF (1.92m). |

***Table 3-J Summary of FSU Rating Classification for hydrometric stations within UoM 27.***

### 3.7.3 Work Package 2.2 Flood Frequency Analysis

Work Package 2.2 covers the development of techniques with which to estimate the design flood for a range of exceedance probabilities for rivers in Ireland. The recommended methods are broadly analogous to those specified in the UK Flood Estimation Handbook but with Ireland specific equations to reflect the differing hydrological conditions. These differences are expressed in the AMAX data having a lower variability and skewness than commonly found elsewhere.

The procedures are based on the AMAX series from approximately 200 gauging station records with lengths ranging from 10 to 55 years. A subset of these, made up of 85 sites with the best records, was used for the most detailed analyses.

Guidance is provided on the estimation of design flows at gauged and ungauged locations and on the estimation of uncertainty. It recommends the use of Qmed as the index flood. Gauged site data is preferred over any estimate from catchment descriptors. However synthetic estimates from catchment characteristics at a ungauged site can be significantly improved by using pivotal sites (i.e. a gauge that can be used to assist in deriving flood estimates based on the hydrological similarity between the gauged catchment and the ungauged catchment to the site for which flows must be derived). The use of growth curves or factors are applied to the index flood derived from regional pooling groups. The report concludes that whilst no single statistical distribution can be considered to be 'best' at all locations both the Extreme Value Type 1 (Gumbel) and the lognormal distributions provide a reasonable model for the majority of stations.

### 3.7.4 Work Package 3.2 Hydrograph Width Analysis

Methods are developed to produce the 'design flood hydrograph' of given return period at gauged and ungauged sites in Ireland. For each site, the peak flow of the hydrograph so produced matches the corresponding 'design flow' provided by Work-Package WP2.2: Flood Frequency Analysis' for the same return period.

In the case of a gauged site, a non-parametric approach is applied to a set of observed flood hydrographs to estimate the characteristic flood hydrograph for the station. An alternative parametric form of 'derived' hydrograph is also developed whereby the non-parametric form is fitted by a 3-parameter curve.

For an ungauged site, regression-based expressions are used to estimate the values of relevant hydrograph descriptors which are then applied, following a parametric approach, to produce its characteristic flood hydrograph.

Characteristic flood hydrographs are, by rescaling, developed into the required design flood hydrograph.

## 3.8 Historic Flood Events

The flood history of the Communities at Risk and Individual Risk Receptors has been examined primarily using the www.floodmaps.ie website. Further details are presented in Section 8.

## 3.9 Outstanding Data and Recommendations

No outstanding data has been identified at this stage.

JACOBS

# 4 Hydrological Estimation Points

## 4.1 Introduction

Section 6.5.3 of the Generic CFRAM Study Brief ‘Hydrological Estimation Points’ states that:
“*The consultant shall derive best estimate design fluvial flood parameters based on the methods referred to above at Hydrological Estimation Points. The Hydrological Estimation Points shall include all of the following:*

- *points on the HPW that are central within each APSR, and immediately upstream and downstream of the APSR,*
- *all hydrometric gauging stations (as specified in the tender documentation of the Specific Tender Stage [Stage II]).*
- *points upstream and downstream of the confluences of all tributaries that potentially contribute more than 10% of flow of the main channel immediately upstream of the confluence for a flood event of a particular AEP,*
- *upstream boundaries of hydraulic models, and,*
- *other points at suitable locations as necessary to ensure that there is at least one Hydrological Estimation Point every 5kms along reaches of all modelled river (i.e. either HPW or MPW).*”

Following Jacobs’ Technical Note TD010, which detailed the proposed methodology and timing of defining the Hydrological Estimation Points (HEPs), a trial was carried out to identify potential issues related to the proposed methodology.

## 4.2 Methodology

For the reasons outlined in Section 4.0 of Jacobs’ Technical Note TD010, to avoid reworking of the data, the derivation of HEPs within the study area and corresponding catchments boundaries will be completed after the Inception Report Phase, but within 2 months of Jacobs receiving a final list of APSRs and resolution to any catchment area discrepancies.

To aid the identification of any problems with the proposed methodology, the HEP definition process was trialled for the whole of Unit of Management 24.

In this trial HEPs were determined applying the criteria set out in Section 6.5.3 of the Generic Brief, using the preliminary APSR boundaries. It should be noted that HEPs are only required along watercourses for which a hydraulic model is proposed (confirmed by OPW on 24$^{th}$ June 2011). For ease of application of the FSU design flood methods, HEP locations were chosen to be coincident with the nodes used in FSU to define catchment descriptors where this was reasonable. Where the catchment area to a HEP (upstream, centre and downstream of APSRs, upstream and downstream of confluences, gauging station locations, upstream boundaries of hydraulic models) differed from that to the nearest FSU node by more than 10% of the catchment area, the HEP location was moved to the precise critical location.

The HEPs for UoM 24 were defined in a point shapefile, and given an attribute field specifying the reference number of the FSU ungauged subcatchment that the HEP was coincident with. This will allow for a fast process of attributing FSU catchment descriptors to HEPs. HEPs that are not coincident with FSU nodes did not get a reference in the attribute field; however, this constitutes only a small number of

HEPs (4 for this trial). Catchment descriptors for these HEPs will have to be attributed manually.

The trial HEPs have been provided to OPW using the Sharepoint file sharing system.

## 4.3 Lessons Learned

The HEP definition trial resulted in the following lessons learned:

1. Generally the HEPs at the critical locations (i.e. hydrometric stations, confluences, etc.) were chosen coincident with the nearest FSU node available. An exception applies where moving the HEP to the nearest FSU node would result in a change in catchment area of 10% or more, in which case the HEP was placed at the critical location.
2. At confluences, it was generally found that three FSU nodes are coincident, representing the two contributing catchments and the combined catchment. It was decided that the HEPs would be positioned at the next FSU node upstream and downstream along the watercourse with the largest upstream catchment (where the difference in catchment area from the upstream node to the confluence was not more than 10%), and in the confluence itself for the watercourse with the smallest upstream catchment. If moving a HEP from the confluence to the nearest upstream or downstream FSU node would have resulted in a change in catchment area of 10% or more, then the HEP was placed in the confluence. To make it clear which HEP belongs to which subcatchment (watercourse), any HEP placed “in” a confluence was actually positioned approximately 10m upstream or downstream of the confluence dependent of whether it represents one of the tributary catchment or the combined catchment respectively.
3. At a confluence of watercourses which were both part of the proposed model extent, a HEP was defined for each tributary, even if one of the tributaries contributes less than 10% in catchment areas.
4. When the rules for HEP definition would result in the definition of two HEPs for one FSU node, then only one HEP was defined.

## 4.4 Conclusions

Based on the HEP definition trial, it was concluded that:

1. The trial allowed Jacobs staff to obtain experience in defining Hydrological Estimation Points (HEPs) along the proposed model extents.
2. Based on the experience obtained during the trial, the proposed methodology provided a good basis for the HEP definition work, noting the lessons learned described in Section 4.3 above.

## 4.5 Recommendations and Way Forward

Once the APSRs are agreed, and the HEP catchment boundaries have been confirmed following a review of FSU catchment boundaries by Jacobs (see Chapter 5 below), it is recommended that the HEPs are defined following the agreed methodology, noting the lesson learned as described in Section 4.3 above.

# 5 Catchment Boundaries

## 5.1 Introduction

This chapter details the findings of the comparison of different catchment boundary datasets for catchment UoM 27, which was carried out using the methodology set out in Technical Note TD010.

## 5.2 Data

The datasets in Table 5-A were compared.

| Title | Description | Comments |
|---|---|---|
| WFD Areas | Water Framework Directive River Basin District boundaries. Used to define Units of Management. | Identical to Units of Management Boundaries. Derived from 20m H-DTM (the hydrologically corrected DTM) with some manual correction. |
| Automatic Gauged Catchment Boundaries | Automatically generated outlines for the gauged areas | Automatically derived from 20m H-DTM (the hydrologically corrected DTM). |
| Automatic Ungauged Catchment Boundaries | Automatically generated outlines for the ungauged areas at FSU nodes. | Automatically derived from 20m H-DTM (the hydrologically corrected DTM). |
| Adjusted Gauged Catchment Boundaries | Manually adjustments applied to catchments where area derived from the automatic gauged boundaries varied by more than 5% from the hard copy OPW catchment area maps. | Provided by OPW (from Oliver Nicholson via Rosemarie Lawlor). We understand that manual corrections have been applied to 36 of the 216 catchments used in the FSU. |
| OPW National Digital Height Model (NDHM, Intermap 2009) | Digital Terrain Model provided by OPW, 5m grid, IFSAR data with a vertical RMSE of approximately 0.7m on slopes smaller than 20 degrees | Detailed but large amount of data and hence cumbersome. Not hydrologically corrected. |

***Table 5-A Catchment boundary and topographical data available for Shannon CFRAM study***

The OPW also provided a river network shapefile. This network was also used to assess the local credibility of catchment boundaries.

In an email to Jacobs on 19th May 2011 Rosemary Lawlor from OPW explained the FSU (adjusted) dataset as follows:

"*As part of the Flood Studies Update 216 gauges were identified as being suitable for use in the FSU analysis (FSU Stations). The areas of the catchments that were delineated by Compass Informatics were compared with the catchments areas that the OPW had on file for all of the 216 catchments. Where it was found (that) the areas differed by more than 5% it was decided that the OPW catchment boundaries would be used in preference to the Compass Informatics boundaries. This was the case for 36 FSU stations. The OPWs boundaries were digitised from paper maps for these 36 stations and were used to replace the compass informatics boundaries for these stations. The FSU end product was effectively a combination of 180 catchment boundaries (from compass informatics) merged with the 36 OPW catchment outlines. This makes up the final FSU catchment outlines*"

## 5.3 Methodology

It is important that the catchment areas are checked and a definitive set of catchment boundaries agreed with the OPW to allow:

- Accurate definition of catchment areas and hence design flows at each HEP;
- Interfaces with adjacent CFRAMS project areas to be consistent;
- Allow FSU automated procedures to be used to derive design floods as appropriate (and allow any adjustments necessary to be properly documented).

We have undertaken a review of the catchment areas to the gauged locations as detailed below:

1. A map for Unit of Management 27 was produced to allow comparison of the Water Framework Directive (WFD) and Flood Studies Update (FSU) boundaries to the hydrometric gauging stations and identify discrepancies.
2. The WFD boundary (equal to the Unit of Management 27 boundary) was compared with the automatic gauged catchment outlines, paying particular attention to the areas where manual correction has been applied (as denoted by the manually adjusted gauged catchment boundaries).
3. Detailed plans were produced for areas where significant discrepancies were found. These maps present the WFD boundary where available, the automatic and manually adjusted boundaries, and contours based on the OPW National Digital Height Model (NDHM, Intermap 2009).
4. An additional random check was undertaken to satisfy ourselves that the automatic ungauged catchment boundaries are reasonable compared to the NDHM.

This review has been undertaken with the aim of identifying differences in catchment areas of 10% or more as there is no one definitive catchment outline and all the datasets have some uncertainty associated with them. At the time of writing this preliminary hydrological assessment the Flood Risk Review (FRR) had not been completed. This analysis is therefore only based on discrepancies of 10% or more in catchment sizes to hydrometric stations, and Communities at Risk (CARs) and Individual Risk Receptors (IRRs) identified in the Shannon CFRAM Study Stage II Brief. It is possible that the Flood Risk Review will recommend the inclusion of other locations to be designated as Areas of Potential Significant Risk (APSR) and this may lead to further discrepancies being identified. It is therefore advised that the catchment boundary comparison is revisited once the FRR has been completed.

## 5.4 Results of Analysis

Figure 8 overleaf shows a comparison of the Water Framework Directive (WFD) boundary, the automatic boundaries and the manually adjusted (FSU) boundaries in area UoM 27. The area is characterised by a large number of differences between the WFD and the FSU boundaries. Most of these differences are too small to be significant (for this study defined as smaller than a 10% difference to a catchment area), but two discrepancy areas were found to be significant. Their locations are indicated on Figure 8. These areas have been investigated further, as described below.

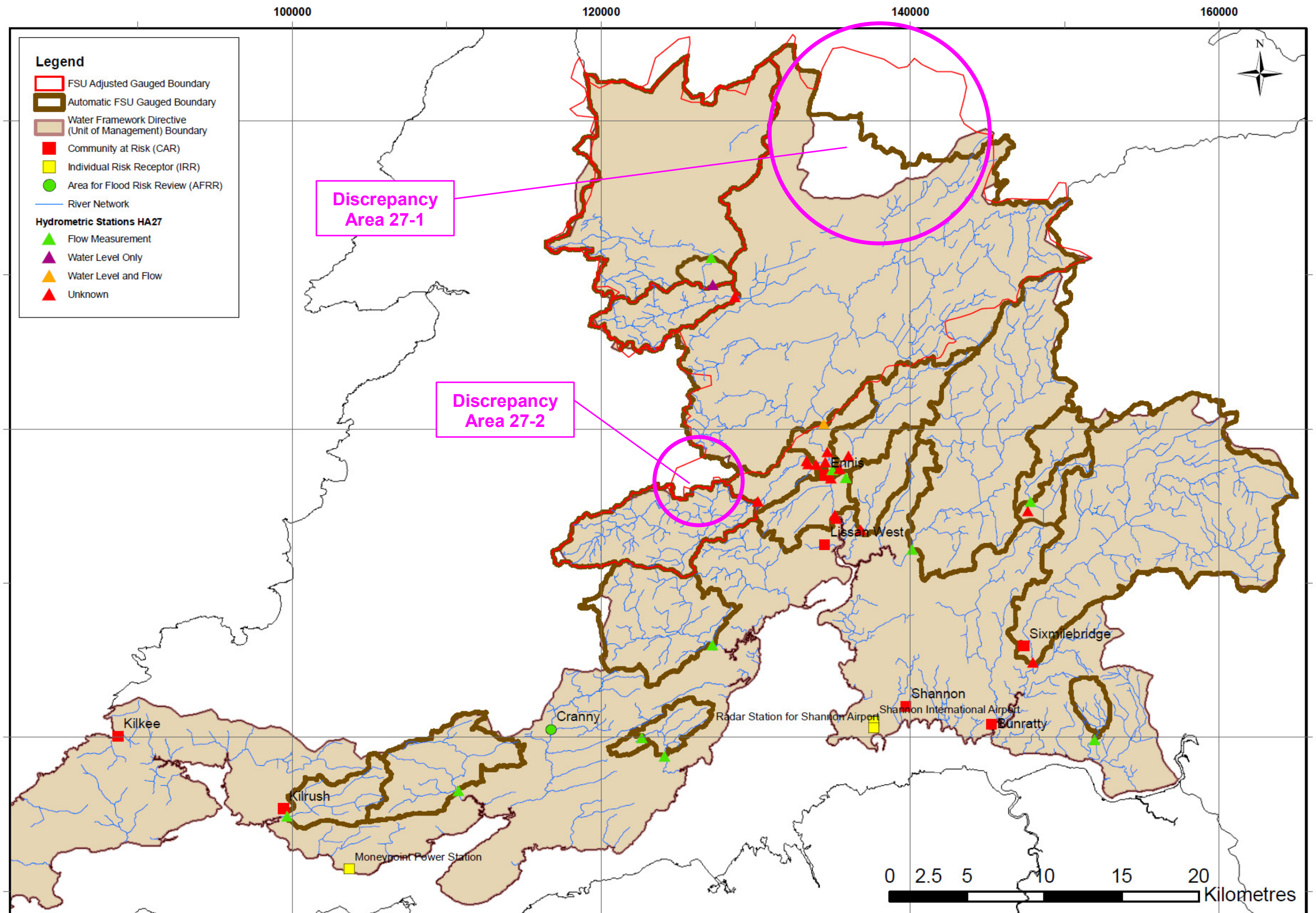



*Figure 8 Unit of Management 27 – Comparison FSU and WFD Boundaries*

### 5.4.1 Discrepancy Area 27-1 – Burren National Park

The biggest discrepancy area in Unit of Management 27 is characterised by discrepancies between all three (gauged) boundary datasets (Figure 9). Apart from several smaller differences between the boundary datasets, the main differences are that the WFD boundary excludes the areas A and B (highlighted in pink on Figure 9) from the Unit of Management, whilst including area C. The automatic boundary includes areas B and C but excludes area A. The manually adjusted (FSU) boundary includes all three areas A, B and C. Area B alone is 29 $km^2$.

Five metre contours were created from the National Digital Height Model (NDHM, from 2009) and overlain on Figure 9. The area north of the 200,000m northing (and east of the 135,000m easting) is not covered by the NDHM data provided as part of the Shannon River Basin District, however the OSi base mapping provides 10m contours which are generally consistent with the NDHM contours where these are available.

Based on the NDHM contours, it would appear that the majority of area C runs off to area B, suggesting that the WFD boundary is unlikely to be correct. The contours and lake levels on the OSi mapping suggests that the area north of the automatic boundary (area A) is unlikely to drain into the river network of Unit of Management 27. It is therefore unlikely that the manually adjusted (FSU) boundary is correct.

The part of the discrepancy area south of the automatic boundary, but outside the WFD boundary for Unit of Management 27 (area B) includes six large lakes plus some small lakes. Runoff from the area drains to the lakes, but the NDHM contours do not decisively show where the lakes drain to. Some of the lakes are shown to be connected to each other on the OSi mapping, but the mapping does not show watercourses connecting the lakes to the river networks of either Unit of Management 27 or the unit of management to the north (UoM 29).

The largest of the lakes in this discrepancy area is Lough Bunny. A brief Internet search for Lough Bunny provided an abstract of an article by Ragneborn-Tough et al (1999). The abstract details: '*The lake has no riverine inflow or outflow but is fed from springs and drains through sinkholes at the northern end of the lake. Studies by other workers have shown that this water discharges into the Rockvale river. Accordingly, Lough Bunny should be considered as part of Hydrometric Area number 29, the Galway Bay South East catchment*.' The article also specifies that the Burren National Park is in a Carboniferous limestone region, as is apparent from Figure 2.

Although the WFD boundary excludes area B from Unit of Management 27 correctly, it would appear that area C should be excluded from the Unit of Management as well, such that Areas A, B and C are all considered to drain into Unit of Management 29 to the north. None of the boundaries reflect this. It is therefore proposed that a new boundary is delineated for this discrepancy area using the NDHM dataset, based on the assumption that all the lakes within the discrepancy area are draining northwards. It should be noted that this assumption cannot be verified by a site visit, as it would appear from Ragneborn-Tough *et al* (1999) that complex, poorly understood underground flows dominate the runoff from the lakes.

JACOBS

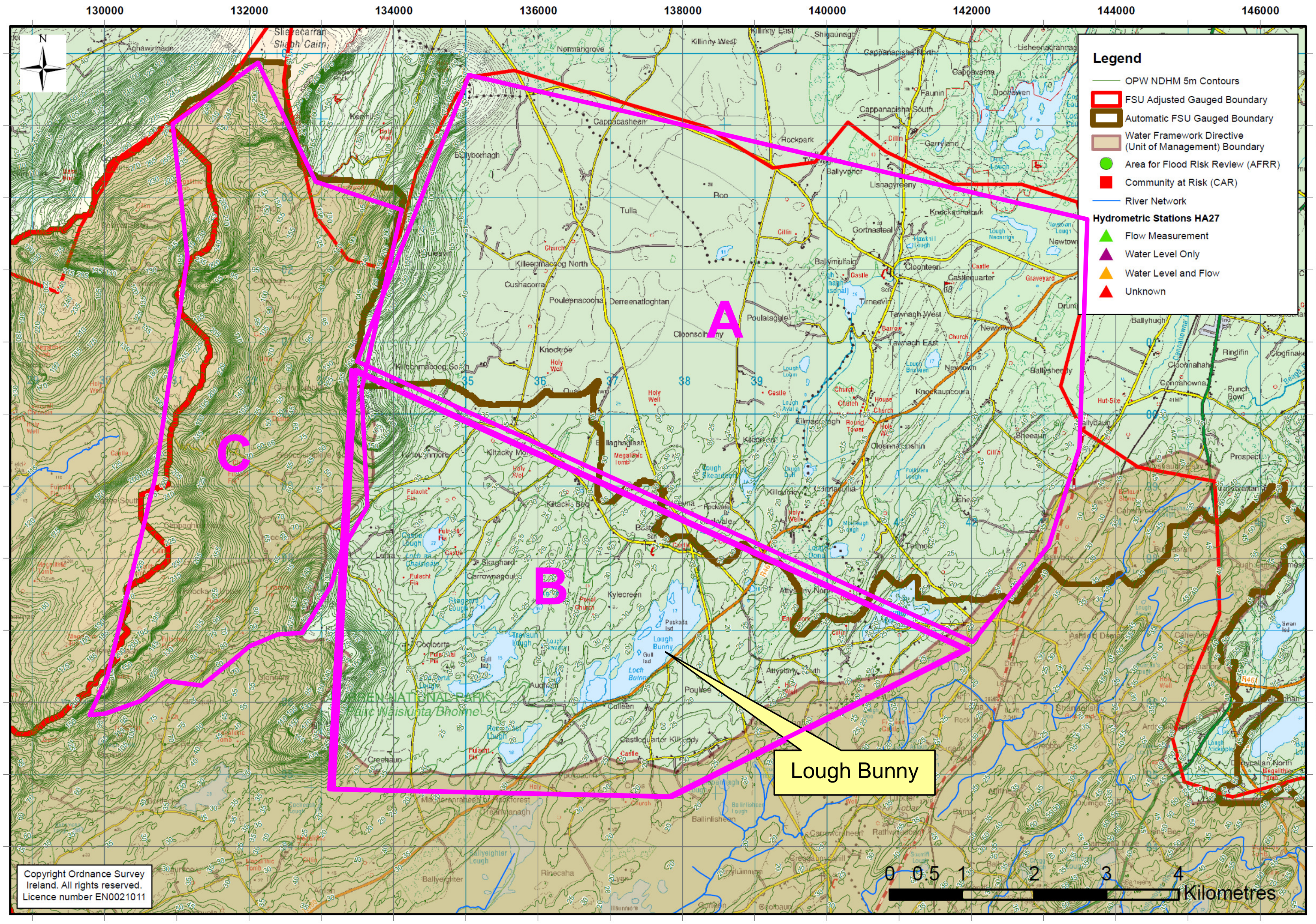



*Figure 9 Discrepancy Area 27-1 (Burren National Park)*

### 5.4.2 Discrepancy Area 27-2 – Knockadangan

In this discrepancy area of approximately 7 km$^2$ the automatic and WFD boundaries are broadly similar, but the manually adjusted boundary reflects an amendment to the automatic boundary in a north-westward direction (Figure 10).
The NDHM contours have been compared to the contours on the OSi mapping, and found to be well matched. The NDHM contours have been omitted from Figure 10 to avoid cluttering the figure in this hilly area.

NDHM-derived 5m contours and the river alignments on the 1:50,000 scale OSi mapping both suggest that the adjustment made to the FSU boundary is incorrect. This may be confirmed by a site visit if necessary.

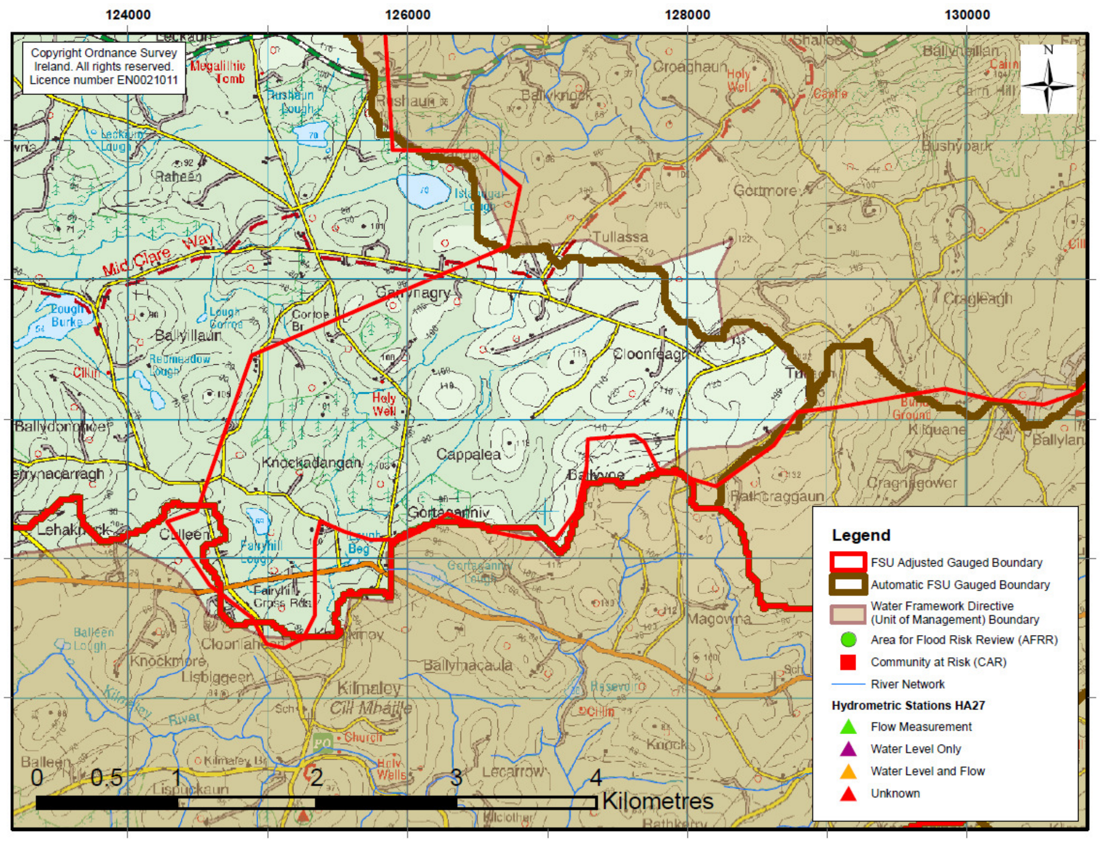



*Figure 10 Discrepancy Area 27-2 (Knockadangan)*

## 5.5 Conclusions

Based on an assessment of Unit of Management 27 alone, it can be concluded that:

1. Two significant discrepancies were found in Unit of Management 27. For discrepancy area 27-1 it is recommended that manual adjustments are made to the catchment boundaries to downstream HEPs. It is proposed that the adjusted boundary is derived from the NDHM using the assumption that the lakes in the discrepancy area drain northwards into Unit of Management 29. For discrepancy area 27-2 it is proposed that the WFD or automatic gauged boundary is adopted.

2. Random checks were made to the ungauged boundaries, which did not reveal any significant discrepancies.

## 5.6 Recommendations

It is proposed that Jacobs and OPW have a discussion regarding the catchment boundary discrepancies after all Units of Management within the Shannon River Basin District have been analysed (UoM 23, 24, 25/26, 27 and 28), so that the discrepancies can be addressed with a consistent approach for the whole River Basin District.

It is recommended that the discrepancy areas found in this analysis are investigated following the review of all discrepancies in the River Basin Districts. OPW is to advise Jacobs of the catchment boundaries to be applied to identify the HEP catchments. If it is decided that adjustments have to be made to the automatic boundaries, then it is important that these adjustments are made consistently, i.e. that boundaries are correctly nested and that neighbouring catchments share one boundary. The manually adjusted (FSU) boundary dataset does not satisfy that requirement.

# 6 Review of Meteorological Data

## 6.1 Introduction

Rainfall analysis has focussed on the daily rainfall data provided to Jacobs by Met Éireann, either through a direct data request or via the OPW (refer to Table 3-B).

## 6.2 Distribution of Raingauges within Shannon Estuary North

Daily read raingauges are fairly well evenly distributed across the Shannon Estuary North (refer to Figure 5). Two raingauges are located along the coastline in the west of UoM 27; 5311 on the Shannon Estuary and 517 on the Atlantic coast. Three gauges are located within the catchment of the River Fergus and the remaining two in the River Rine catchment. The addition of the sub-daily raingauge at Shannon Airport extends coverage to the south.

## 6.3 Data Review

It was assumed that rainfall data provided by Met Éireann was fully quality assured prior to being distributed. To obtain some understanding of the completeness of the rainfall record and its long-term consistency, a brief review was undertaken on receipt of the data. Firstly, the number of missing days was counted. Subsequently, data for similar periods from adjacent stations were plotted against each other on double mass plots to highlight any obvious inconsistencies in the records.

A count of missing data reveals that gauges 418 (Dromoland Castle), 517 (Kilkee G.S.) and 718 (Corofin) have large portions of missing data, 31%, 18% and 16% respectively (Table 6-A). Whereas stations 1218 (Tulla) and 2118 (Crusheen (Caherphuca)) have either no or minimal missing data.

| Rain gauge no. | Name | Record start | Record end | Total number of days | Missing days | % of data missing |
|---|---|---|---|---|---|---|
| 418 | Dromoland Castle | 01/01/1941 | 31/12/2009 | 24502 | 6903 | 28 |
| 517 | Kilkee G.S. | 01/06/1943 | 30/04/2010 | 23955 | 4250 | 18 |
| 718 | Corofin | 01/06/1943 | 28/01/2010 | 34349 | 5506 | 16 |
| 1218 | Tulla | 15/07/1943 | 28/02/2011 | 24701 | 273 | 1 |
| 2018 | Carheeny Beg | 03/10/1993 | 31/08/2010 | 6177 | 255 | 4 |
| 2118 | Crusheen (Caherphuca) | 01/01/1994 | 31/12/2006 | 4748 | 0 | 0 |
| 5311 | Moneypoint E.S.B. | 01/07/1986 | 31/03/2009 | 8310 | 789 | 9 |

***Table 6-A Summary of rainfall data, period of record and missing days***

Double mass plots were created to ensure each raingauge was reviewed at least once (ref. Appendix B for plots). In general the plots confirmed that long term rainfall relationships between raingauges were fairly consistent across the catchment. However, it did serve to highlight the scale of missing data from records 418 and 517.

Cumulative totals for all raingauges between 1 January 1994 and 31 December 2006 (the period for which data was available at all raingauges) indicates that rainfall is fairly uniform over the Unit of Management. It is not possible to discern any further geographical distribution due to the amount of missing data (Table 6-B and Figure 11), especially evident at station 517, as demonstrated by the flattening of the gradient of the line for station 517 in Figure 11.

The raingauge recording the highest total rainfall was 718 at Corofin with a total of 16928 mm for that period.

| Station No. | Cumulative total rainfall (mm) |
|---|---|
| 418 | 12058 |
| 517 | 8314 |
| 718 | 16928 |
| 1218 | 14045 |
| 2018 | 14990 |
| 2118 | 15908 |
| 5311 | 13957 |

***Table 6-B Cumulative rainfall for stations in Shannon Estuary North between 1 January 1994 and 31 December 2006.***

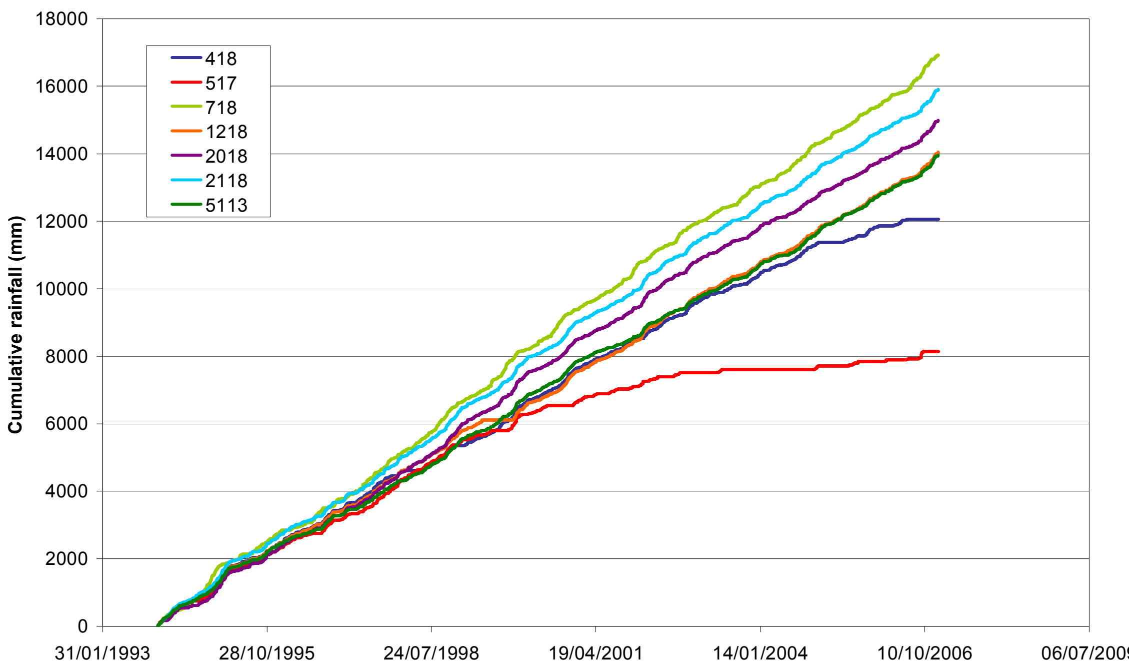



***Figure 11 Cumulative rainfall between 1 January 1994 and 31 December 2006***

## 6.4 Raingauge Selection

Following the data review a selection of raingauges were chosen for further analysis, in which depth, duration and frequency estimates derived from local data were compared with the theoretical values derived for the FSU. Due to the close proximity of the raingauges within the Unit of Management, it was not deemed necessary to review all raingauge data. The following raingauges were selected based on location, completeness of data and quality of record:

Daily raingauges:
- 1218 – Tulla
- 2018 – Carheeny Beg
- 5311 – Moneypoint E.S.B

Hourly raingauges:
- Shannon Airport

Raingauge 5311 is located just east of Kilrush on the Shannon Estuary; 2018 is located close to the northern boundary of the unit of management in the upstream reaches of the Fergus catchment; 1218 is located in the headwaters of the Rine catchment approximately 15km south-southeast of 2018.

Shannon Airport hourly raingauge is located just west of Shannon on the Shannon Estuary.

## 6.5 Rainfall Probability Plots

For the three daily raingauges selected in Section 6.4, 1 day total annual maxima and a 4 day total annual maxima series were created. Any years with greater than 30 days of missing data were excluded and this left 1218, 2018 and 5311 with 66, 12 and 14 years respectively.

For the hourly raingauge identified in Section 6.4, Shannon Airport, the 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 96 hour annual maxima series were created. Two years (1945 and 2010) were excluded from the record as they were incomplete and this left a record of 64 years.

The annual maxima series were ranked in decreasing order of magnitude. The probability of exceedance was derived according to Gringorten, where *P(X)* is the probability of exceedance and is calculated for each value of *X*, *r* is the rank and *N* is the total number of annual maxima values.

$$P(X) = \frac{r - 0.44}{N + 0.12} \qquad (6.1)$$

The EV1 distribution was fitted to the observed annual maxima series of rainfall totals using the method of moments described in formulas 6.2 – 6.4 below, where F(X) is the probability of an annual maximum $Q \leq X$ and *a* and *b* are parameters with $\mu_Q$ being the mean and $\sigma_Q$ the variance.

$$F(x) = \exp\left[-e^{-b(X-a)}\right] \qquad (6.2)$$

$$a = \mu_Q - \frac{\gamma}{b} \tag{6.3}$$

$$b = \frac{\pi}{\sigma_Q \sqrt{6}} \tag{6.4}$$

The subsequent distribution fits (Appendix C) were used to derive estimates of annual exceedance probability for historic events to ensure a coherent relationship between estimates. However note that the annual exceedance probabilities could have been estimated directly from the plotted local data. The actual fit with the chosen distribution has little relevance for this independent check of the FSU DDF method.

## 6.6 Events of Interest

Severe rainfall events were identified in conjunction with the annual maxima flow series. The three rainfall stations identified in 6.4 will be the focus for the analysis. For consistency the same events selected for fluvial analysis will be reviewed here also. Event selection is detailed in Sections 7.6. The two events selected are:

- 24 – 28 December 1999
- 19 – 24 November 2009.

For each event the maximum depth of rainfall for a range of durations; 1 day, 2 days and 4 days were obtained. Rainfall depths for each duration were produced by summing the daily rainfall total for the corresponding x number of preceding days. Maximum values were selected from within a 10 day period up to and including the date of the largest peak flow within the catchment. The results are presented below in Sections 6.6.1 to 6.6.2 inclusive.

To put the rainfall depths into context annual exceedance probabilities were derived for the 1 day and 4 day rainfall totals based on the probability plots outlined in Section 6.5.

### 6.6.1 Event of 24 – 28 December 1999

High fluvial flows recorded between the 24$^{th}$ and 28$^{th}$ December 1999 appear to have been the result (Figure 12) of prolonged rainfall, punctuated with two days of more intense rainfall (21$^{st}$ December and 24$^{th}$ December). Daily rainfall totals at Shannon Airport were obtained from hourly totals over an equivalent time period (19$^{th}$ December 1999 09:00 to 28$^{th}$ December 1999 08:00). Rainfall totals at Shannon Airport are consistently lower than those recorded at daily storage raingauges further inland. Soil moisture deficit (SMD) values estimated at Shannon Airport, put the SMD on 19$^{th}$ December 1999 as zero indicating a saturated catchment

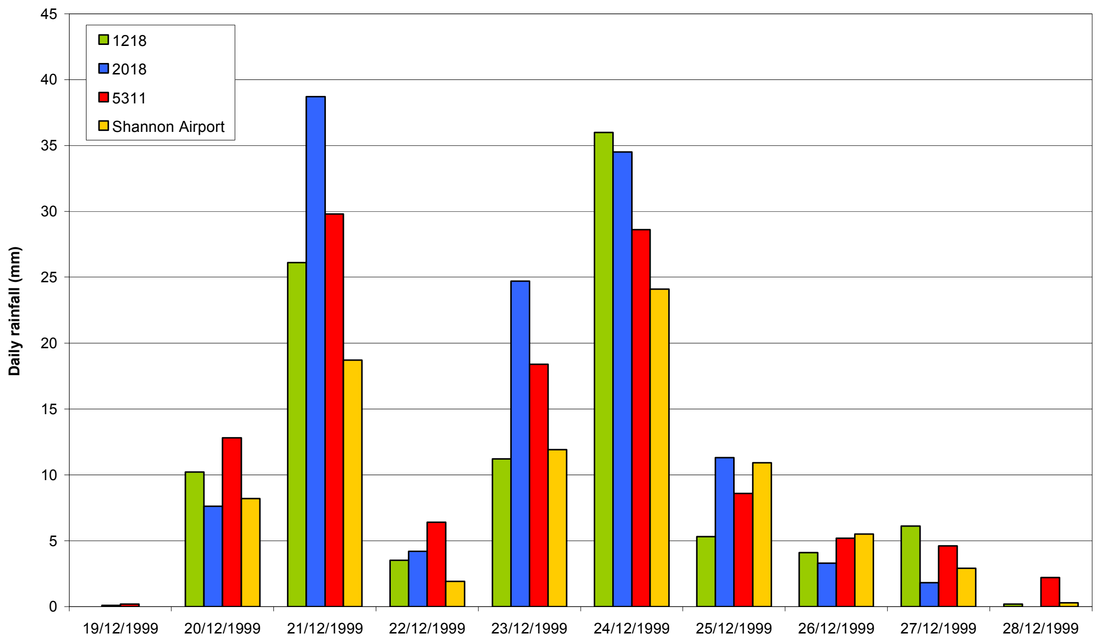



***Figure 12 Daily rainfall – 19th December to 28th December 1999***

Annual exceedance probabilities (AEPs) for the maximum rainfalls over the event are presented in Table 6-C. AEPs estimated from the 1-day and 4-day rainfall probability plots indicate this was a less frequent event for the 4 day duration compared to the shorter 1-day duration. Values derived for the 4 day duration at raingauges 1218, 2018, 5311 and Shannon Airport indicate that this event has annual exceedance probability of 12%, 7%, 11% and 25% respectively. Data from Shannon Airport indicates that rainfall totals over daily and sub-daily durations was not particularly significant and would be expected on an approximately annual basis.

| | Dec-99 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rainfall Duration | 1218 Rainfall depth (mm) | 1218 AEP (%) | 2018 Rainfall depth (mm) | 2018 AEP (%) | 5311 Rainfall depth (mm) | 5311 AEP (%) | Shannon Airport Rainfall depth (mm) | Shannon Airport AEP (%) |
| 1 hour | | | | | | | 5.8 | 86 |
| 2 hours | | | | | | | 8.5 | 93 |
| 6 hours | | | | | | | 14.5 | 91 |
| 12 hours | | | | | | | 22.0 | 85 |
| 1 day (or 24 hours) | 36.0 | 41 | 38.7 | 50 | 29.8 | 56 | 25.3 | 92 |
| 2 day | 47.2 | | 59.2 | | 47.0 | | | |
| 4 day (or 96 hours) | 76.8 | 12 | 102.1 | 7 | 83.2 | 11 | 63.8 | 25 |
| 10 day | 129.3 | | 161.3 | | 148.4 | | | |

***Table 6-C Maximum rainfall depths for 1 hour, 2 hour, 6 hour, 12 hour and 1 day/24 hour, 4 day and 10 day durations with corresponding AEP for 1 hour, 2 hour, 6 hour, 12 hour, 1 day/24 hour and 4 day durations (December 1999)***

### 6.6.2 Event of 19 - 24 November 2009

High fluvial flows recorded between the 19th and 24th November 2009 appear to have been the result of prolonged intense rainfall (Figure 13). Daily rainfall totals at Shannon Airport were obtained from hourly totals over an equivalent time period (19th November 2009 09:00 to 25th November 2009 08:00). Rainfall totals at Shannon Airport are consistently lower than those recorded at daily storage raingauges further inland. Soil moisture deficit (SMD) values estimated at Shannon Airport, put the SMD on 15th November 2009 as zero indicating a saturated catchment. Daily rainfall totals at 1218 and 2018 peaked on 18th November. No rainfall data was available for this event at station 5311.

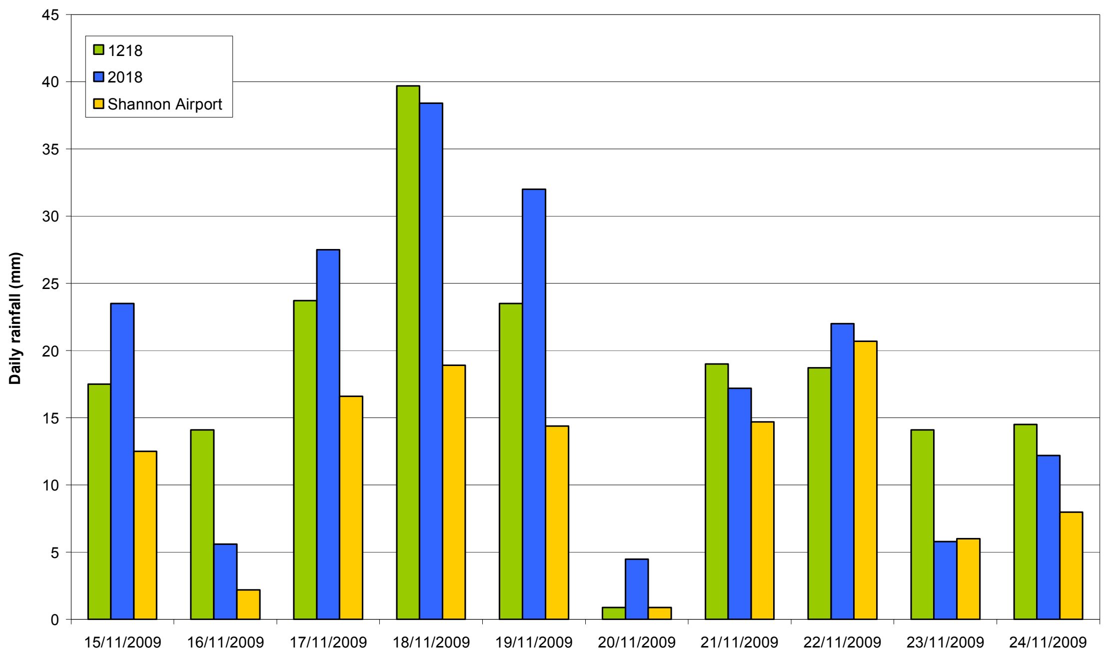



***Figure 13 Daily rainfall – 15th November to 24 November 2009***

Annual exceedance probabilities (AEPs) for the maximum rainfalls over the event are presented in Table 6-D. AEPs estimated from the 1-day and 4-day rainfall probability plots indicate this was a less frequent event for the 4 day duration compared to the shorter 1-day duration. Values derived for the 4 day duration at raingauges 1218, 2018 and Shannon Airport indicate that this event has annual exceedance probability of 1%, 7% and 32% respectively. Data from Shannon Airport indicates that rainfall totals over daily and sub-daily durations was not particularly significant and would be expected on an approximately annual basis. This indicates that the rainfall event was localised in nature, both from the wide spread of indicative AEPs across the catchment (from 1% to 32%) and the absence of a trend based on location i.e. there is no north-south or east-west trend.

| | Nov-09 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rainfall Duration | 1218 Rainfall depth (mm) | 1218 AEP (%) | 2018 Rainfall depth (mm) | 2018 AEP (%) | 5311 Rainfall depth (mm) | 5311 AEP (%) | Shannon Airport Rainfall depth (mm) | Shannon Airport AEP (%) |
| 1 hour | | | | | | | 5.8 | 86 |
| 2 hours | | | | | | | 8.2 | 94 |
| 6 hours | | | | | | | 14.4 | 95 |
| 12 hours | | | | | | | 23.2 | 78 |
| 1 day (or 24 hours) | 39.7 | 26 | 38.4 | 52 | | | 29.0 | 75 |
| 2 day | 63.4 | | 70.4 | | | | | |
| 4 day (or 96 hours) | 101.0 | 1 | 103.5 | 7 | | | 61.1 | 32 |
| 10 day | 185.7 | | 190.7 | | | | | |

***Table 6-D Maximum rainfall depths for 1 hour, 2 hour, 6 hour, 12 hour and 1 day/24 hour, 4 day and 10 day durations with corresponding AEP for 1 hour, 2 hour, 6 hour, 12 hour, 1 day/24 hour and 4 day/96 hour durations (November 2009)***

## 6.7 Flood Studies Update Rainfall Comparison

Theoretical point rainfall depths, created for the Flood Studies Update were extracted from GIS raster layers for a range of Annual Exceedance Probabilities (AEPs) between 50% and 0.5% at the 24 hour and 4 day durations for daily raingauges 1218, 2018 and 5311. At Shannon Airport where hourly rainfall is recorded, rainfall depths for 1, 2, 6 and 12 hour durations and for the same AEPs were also obtained. Output values are presented in Table 6-E and 6-F.

| Duration | Return Period (years) | Annual Exceedance Probability (%) | Rainfall depth (mm) | | |
|---|---|---|---|---|---|
| | | | 1218 | 2018 | 5311 |
| 24 hour | 2 | 50 | 37.06 | 36.46 | 36.70 |
| 24 hour | 5 | 20 | 44.38 | 46.65 | 45.22 |
| 24 hour | 10 | 10 | 49.29 | 53.91 | 51.12 |
| 24 hour | 20 | 5 | 54.30 | 61.59 | 57.18 |
| 24 hour | 30 | 3 | 57.35 | 66.40 | 60.98 |
| 24 hour | 50 | 2 | 61.36 | 72.89 | 66.00 |
| 24 hour | 100 | 1 | 67.22 | 82.65 | 73.40 |
| 24 hour | 200 | 0.5 | 73.59 | 93.60 | 81.52 |
| 4 day | 2 | 50 | 61.55 | 61.81 | 61.72 |
| 4 day | 5 | 20 | 71.97 | 75.40 | 73.58 |
| 4 day | 10 | 10 | 78.88 | 84.77 | 81.48 |
| 4 day | 20 | 5 | 85.79 | 94.46 | 89.54 |
| 4 day | 30 | 3 | 89.99 | 100.35 | 94.50 |
| 4 day | 50 | 2 | 95.46 | 108.24 | 100.96 |
| 4 day | 100 | 1 | 103.32 | 119.79 | 110.36 |
| 4 day | 200 | 0.5 | 111.83 | 132.46 | 120.52 |

***Table 6-E Rainfall depths for a range of durations and frequencies obtained from grids corresponding to the locations of raingauges 1218, 2018, and 5311.***

| Duration | Return Period (years) | Annual Exceedance Probability (%) | Rainfall depths estimated at Shannon Airport (mm) |
|---|---|---|---|
| 1 hour | 2 | 50 | 11.75 |
| 1 hour | 5 | 20 | 15.16 |
| 1 hour | 10 | 10 | 17.62 |
| 1 hour | 20 | 5 | 20.24 |
| 1 hour | 30 | 3 | 21.89 |
| 1 hour | 50 | 2 | 24.13 |
| 1 hour | 100 | 1 | 27.50 |
| 1 hour | 200 | 0.5 | 31.35 |
| 2 hour | 2 | 50 | 14.83 |
| 2 hour | 5 | 20 | 18.98 |
| 2 hour | 10 | 10 | 22.02 |
| 2 hour | 20 | 5 | 25.25 |
| 2 hour | 30 | 3 | 27.29 |
| 2 hour | 50 | 2 | 30.02 |
| 2 hour | 100 | 1 | 34.11 |
| 2 hour | 200 | 0.5 | 38.76 |
| 6 hour | 2 | 50 | 21.27 |
| 6 hour | 5 | 20 | 27.20 |
| 6 hour | 10 | 10 | 31.36 |
| 6 hour | 20 | 5 | 35.79 |
| 6 hour | 30 | 3 | 38.56 |
| 6 hour | 50 | 2 | 42.30 |
| 6 hour | 100 | 1 | 47.90 |
| 6 hour | 200 | 0.5 | 54.20 |
| 12 hour | 2 | 50 | 26.78 |
| 12 hour | 5 | 20 | 34.05 |
| 12 hour | 10 | 10 | 39.20 |
| 12 hour | 20 | 5 | 44.66 |
| 12 hour | 30 | 3 | 48.03 |
| 12 hour | 50 | 2 | 52.59 |
| 12 hour | 100 | 1 | 59.51 |
| 12 hour | 200 | 0.5 | 67.13 |
| 24 hour | 2 | 50 | 33.26 |
| 24 hour | 5 | 20 | 42.16 |
| 24 hour | 10 | 10 | 48.36 |
| 24 hour | 20 | 5 | 54.96 |
| 24 hour | 30 | 3 | 59.07 |
| 24 hour | 50 | 2 | 64.57 |
| 24 hour | 100 | 1 | 72.76 |
| 24 hour | 200 | 0.5 | 81.94 |
| 4 day | 2 | 50 | 53.52 |
| 4 day | 5 | 20 | 65.09 |
| 4 day | 10 | 10 | 73.01 |
| 4 day | 20 | 5 | 81.15 |
| 4 day | 30 | 3 | 86.18 |
| 4 day | 50 | 2 | 92.80 |
| 4 day | 100 | 1 | 102.53 |
| 4 day | 200 | 0.5 | 113.17 |

***Table 6-F Rainfall depths for a range of durations and frequencies obtained from FSU grids corresponding to location of Shannon Airport***

As stated previously, comparison of daily rainfall data and 24 hour data (i.e. stations 1218, 2018, 5311 and Shannon Airport) may not be a precise or even a fair comparison due to the possible underestimation of maximum daily rainfall values should an event straddle 09:00 hours. To ensure the fairest comparison, daily totals for Shannon Airport were aligned to cover the same time period as the daily storage raingauges, with each day starting at 09:00 hours and ending at 08:00 hours the following day.

Depth, duration and frequency estimates derived from actual data were compared with the theoretical values derived for the FSU (ref. Section 3.7.1). To assist, FSU rainfall depths for varying durations were plotted against Annual Exceedance Probabilities between 50% and 0.5% (ref. Appendix D). The resulting plots were used to estimate the FSU AEP of the actual rainfall depths. Results of this analysis are presented for each raingauge below (Tables 6-G, H, I and J), with the FSU estimates of equal or less than 50% highlighted in bold for ease of reading.

As expected there is some difference between the two estimates of AEP for the same rainfall depth and duration. However, the differences below are not as notable as observed at other raingauges across the Shannon River Basin District.

At raingauge 1218 the 1 day rainfall AEPs derived for the FSU were higher than those estimated from the rainfall record. However, precisely the same AEP estimates were derived from each source for the 4-day rainfall. Sixty-six years of annual maxima data are available at station 1218, which will improve the confidence of any AEPs derived from the actual data. This in turn improves any confidence in FSU estimates.

For raingauges 2018 and 5311 where AEP estimates are greater than 50%, the FSU approach underestimates the AEP estimates derived from actual data i.e. the FSU suggests that the event is slightly rarer than the estimate derived from the data. The most significant difference is for the November 2009 event 4-day rainfall at station 2018 where an AEP of 7% was estimated from the actual data (12 years annual maxima series) versus an estimate of 2% from the FSU data. This is a considerable disparity.

At Shannon Airport the estimated AEPs and FSU AEPs are greater than 50% for all durations with the exception of 96 hours, where for both events the estimated AEP and the FSU AEP are the same or very close (Table 6-J). The higher AEP estimates at daily and sub-daily durations indicates that the rainfall depths recorded were not remarkable and were recorded on an approximately annual basis.

| 1218 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Dec-99 | 36.0 | 41 | >50 | **76.8** | **12** | **12** |
| Nov-09 | **39.7** | **26** | **39** | **101.0** | **1** | **1** |

***Table 6-G 1 day and 4 day rainfall and associated Annual Exceedance Probability (AEP) for raingauge 1218***

| 2018 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Dec-99 | **38.7** | **50** | **43** | **102.1** | **7** | **3** |
| Nov-09 | **38.4** | **52** | **44** | **103.5** | **7** | **2** |

***Table 6-H 1 day and 4 day rainfall and associated Annual Exceedance Probability (AEP) for raingauge 2018***

| 5311 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx)> | FSU AEP (%) |
| Dec-99 | 29.8 | 56 | >50 | **83.2** | **11** | **8** |
| Nov-09 | | | | | | |

***Table 6-I 1 day and 4 day rainfall and associated Annual Exceedance Probability (AEP) for raingauge 5311***

| Shannon Airport | 1 hour | | | 2 hour | | | 6 hour | | |
|---|---|---|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) |
| Dec-99 | 5.8 | 86 | >50 | 8.5 | 93 | >50 | 14.5 | 91 | >50 |
| Nov-09 | 5.8 | 86 | >50 | 8.2 | 94 | >50 | 14.4 | 95 | >50 |

| Shannon Airport | 12 hour | | | 24 hour | | | 4 day | | |
|---|---|---|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Dec-99 | 22.0 | 85 | >50 | 25.3 | 92 | >50 | **63.8** | **25** | **23** |
| Nov-09 | 23.2 | 78 | >50 | 29.0 | 75 | >50 | **61.1** | **32** | **32** |

***Table 6-J 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 4 day rainfall and associated Annual Exceedance Probability (AEP) for raingauge at Shannon Airport***

## 6.8 Conclusions

Seven Met Éireann daily storage raingauges have been identified within the Shannon Estuary North Unit of Management. Sub-daily rainfall data was available at one location, Shannon Airport.

Two rainfall events across the unit of management have been studied; December 1999 and November 2009.

Rainfall depths calculated for a range of durations 1 hour, 2 hour, 6 hour, 12 hour (at Shannon Airport only) and 1-day (or 24 hour at Shannon Airport), 2-day, 4-day (or 96-hour at Shannon Airport) and 10-day, suggest that both events were the result of winter depressions, characterised by a moderately intense rainfall event preceded by prolonged rainfall.

Annual exceedance probabilities for the 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 96 hour were estimated at Shannon Airport and for 1 day and 4 day durations estimated at the three daily raingauges, based on probability plots developed from annual maxima series derived from the rainfall record. The analysis indicates that the majority of rainfall events were typically around the annual or median (2-year) events with an AEP of around 50% or greater. The lowest annual exceedance probability estimated was 1% for a 4 day rainfall depth at station 1218 during the December 2009 event. AEPs estimated for the daily and sub-daily rainfall durations at Shannon Airport indicate that the rainfall totals recorded during the December 1999 or November 2009 were relatively frequent events and that it was the longer 96-hour rainfall totals which were more infrequent.

Annual exceedance probabilities estimated from actual data for the 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 96 hour durations at Shannon Airport and 1 day and 4 day durations at the remaining three daily raingauges. These AEPs were compared to theoretical AEPs for the corresponding 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 4 day durations created for the Flood Studies Update. FSU AEPs were higher for the 1 day and identical for the 4-day rainfall depths at station 1218 and lower at 2018 and 5311. At Shannon Airport the estimated AEPs and FSU AEPs were greater than 50% for all durations with the exception of 96 hours (or 4 days), where for both events the estimated AEP and the FSU AEP were the same or very close. Any differences in AEP estimates appear to suggest that the FSU DDF estimates do not accurately reflect the DDF relationship at the three rainfall stations considered.

# 7 Review of Fluvial Data

## 7.1 Introduction

Those gauging stations located within the Shannon Estuary North Unit of Management (UoM 27) and for which any instantaneous, daily mean or annual maxima (AMAX) flow or level data was received are listed previously (Tables 3-A, 3-C and 3-F). The subsequent review and analysis of fluvial data has been limited to these stations.

As outlined previously, the majority of all flow and level gauges within the Shannon Estuary North Unit of Management are located on the River Fergus and its tributaries, with a cluster of gauges in and around Ennis. Six gauges are located on watercourses draining into the Shannon estuary and a further three gauges on the Owenogarney (or Ratty) River and its tributaries.

The Shannon CFRAM study is primarily concerned with flooding, therefore good quality high flow and level data are required. The objective of this data review is to assemble the fluvial data available and understand its suitability for the use in the CFRAM study.

Not all the data requested was issued promptly and a cut off date was required to ensure completion of the preliminary review. A cut off of 21 June 2011 was selected and any data received after this date will be acknowledged but excluded from any review or analysis presented herein.

## 7.2 Distribution of Flow and Level Gauging Stations within UoM 27

Of the 15 non-tidal hydrometric stations located within the Shannon Estuary North unit of management, 13 are located within the Fergus catchment or drain into the Fergus Estuary. Of these 13 gauges, eight are located in and around Ennis on the River Fergus (27002 and 27026) and its tributaries, the River Claureen (or Inch) (27023, 27024, 27025 and 27066) and River Gaurus (27028 and 27092). The purpose of such a dense network of monitoring is not clear, however, it is likely to be a combination of factors related to:

- the flood history in Ennis from a variety of sources (see section 8.3.1); and
- the complex interaction of fluvial and groundwater flows in the area.

It is noted from discussions with Clare County Council that as part of the Ennis Main Drainage Report and Flooding Study there are detailed Hydrological and Hydrogeological volumes available. These have been requested but have not yet been received.

Outside Ennis, a further gauge is located on the River Claureen at Inch Bridge (27001). Three further gauges are located in the headwaters of the Fergus catchment, 27070 on Lough Inchiquin, 27003 on the River Fergus and 27073 on Inchicronan Lough. The two gauges located on Loughs record level only and will therefore have limited use within the context of future hydrological studies in particular the derivation of the index flood.

Draining into the Fergus Estuary below Ennis, but upstream of the River Rine confluence, station 27004 is located on the River Manus at Carnelly.

The two stations outside of the Fergus catchment are located in the Owenogarney catchment, 27071, a water level only station, is located on Lough Cullaun in the headwaters of the catchment, whilst 27011 is located downstream of Sixmilebridge in the lower catchment.

## 7.3 Data Review

It was assumed that data was provided by the OPW or EPA quality assured. In order to gain an understanding of the completeness and the quality of data at each gauged location, flows and level records were reviewed upon receipt of the data. This assessment was aimed at providing an overview of the quality of data based on a visual inspection of daily mean flow (or level) records, a count of quality codes (where available), completeness of record and a visual assessment of long-term trends which may impact on the confidence given to QMED. Daily mean flows were inspected in preference to instantaneous data to focus the review on gross errors and long-term trends. A summary of the review findings can be found in Table 7-A, whilst a more detailed summary is documented in Appendix E.

An example of a typical observed trend in peak flows is shown in Figure 14 below.

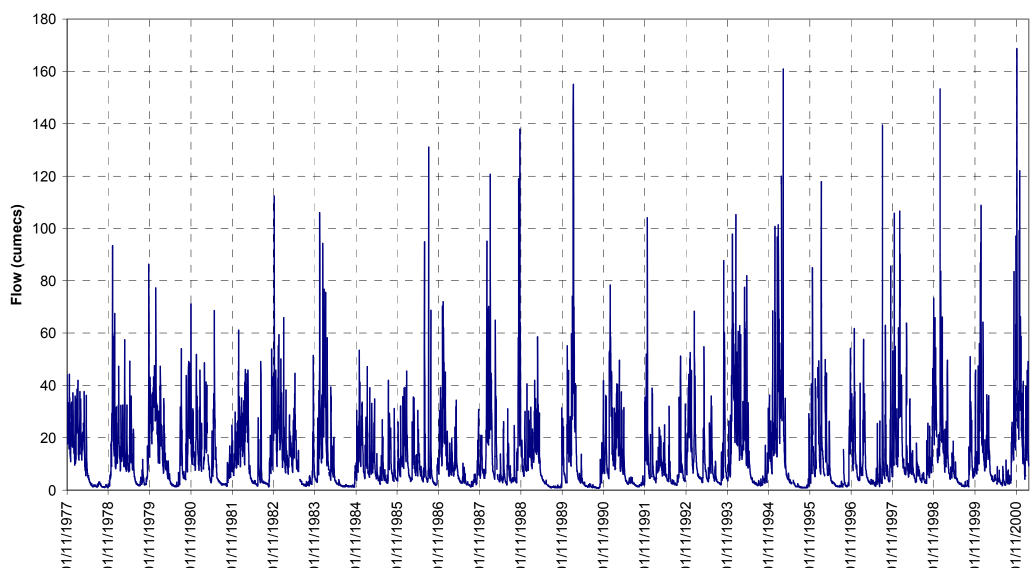



***Figure 14 Example of trend at station 24082***

All four daily mean flow and / or level records available were reviewed (ref. Table 3-D). Three of the stations (27001, 27002 and 27003) indicate trends of rising levels and/or flows at some period in the record. At 27001 the trend was only evident in the level series which suggests a change to the gauged cross-section possibly accounted for in the flow record by a revision of the rating. However, at 27003 the trend was only evident in the flow series. Trends in peak flows, either rising or declining are problematic as they disprove the assumption of homogeneity of a flow series; an assumption routinely made when undertaking any hydrological statistical analysis.

It is possible that the trends are indicative of climatological trends rather than site specific, although an analysis of the long term rainfall time series did not identify any such trends. Land use change is another potential contributing factor. Further investigation by OPW into the flow and level series is recommended to determine whether this is actually the case.

Analysis of the OPW quality codes (ref. Table 3-E) assigned to the data revealed that at two sites, 27001 and 27003 only 30 and 34%, respectively, of the daily flow series was considered to be of ‘good’ quality. One station, 27011 had 0% of the data flagged as good and 45% flagged as poor or cautionary. This low confidence in the data series suggests that it is not suitable for use in any hydrological estimation within this study and should be retained for reference levels only. It should be noted that a rating review is required for this station (27011), and it is possible this may lead to improved confidence in the data.

One daily flow gauge (27003) had 36% of data missing, which could potentially reduce the utility of a data series.

For locations where both flow and level data was available it was apparent that quality codes for the same site were, in general, not equivalent. This can partly be attributed to the differing classifications for flow and level series, but even where classifications were the same the counts for each were often dissimilar.

| | | | | Daily Flow data only | | | | Daily Level data only | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station no. | Station name | River | FSU Class | % of good days | % of poor or cautionary days | % of missing days | Total number of days | % of good days | % of cautionary days | % of missing days | Total number of days | Further investigation recommended |
| 27001 | Inch Br. | Claureen | A2 (2 records both A2) | 30 | 29 | 8 | 13859 | 93 | 0 | 6 | 13859 | Yes - trend of rising levels 1972 to 1991, followed by step change. Possible reduction in high flows post-1991 |
| 27002 | Ballycorey | Fergus | A1 (2 records both A1) | 98 | 0 | 2 | 19736 | 98 | 0 | 2 | 20315 | Yes - trend of rising flows and levels over POR. |
| 27003 | Corrofin | Fergus | A2 (2 records both A2) | 34 | 10 | 36 | 9953 | 89 | 0 | 10 | 11838 | Yes - step change in 1984 evident in flow series only. |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | | 0 | 45 | 19 | 2169 | 7 | 0 | 43 | 4967 | Possible discontinuity post-2007 |

***Table 7-A Summary of daily mean flow and level data review (see also Appendix E) (Grey squares indicate no data)***

## 7.4 Annual Maxima Flow and Level Series

Annual maxima data for the nine fluvial stations in the Shannon Estuary North (excluding the short record of 24100) (ref. Table 3-F) were ranked to identify the top 5 and top 10 events at each gauging station. In Table 7-B, the top 5 events at each location are identified by the letter A and yellow shading; those ranked 6-10 are identified by the letter 'B' and green shading. Due to the manual extraction of selected peak flows the rank of flow and level for a given event could differ at the same location. Therefore, where both flow and level annual maxima series were available, the flow series was used in preference. The subsequent matrix of annual maxima provided an overview of the most significant events across the catchment (Table 7-B). It is worth noting, however, that both the period of record and length of an annual maxima series can skew the data and therefore should be used as one of a series of approaches for assessing severe events.

| | Flow 27001 | Flow 27002 | Level 27003 | Level 27004 | Flow 27011 | Level 27025* | Level 27026* | Level 27066 | Flow 27070 |
|---|---|---|---|---|---|---|---|---|---|
| 30 December 1959 | | A | B | | | | | | |
| 8 October 1964 | | | B | | | | | | |
| 25 December 1968 | | | A | | | | | | |
| 29 November 1973 | A | | | | | | | | |
| 29 January 1975 | | B | | | | | | | |
| 15 November 1978 | B | | | | | | | | |
| 15 December 1978 | | | | | | | | | B |
| 27 November 1979 | | | | | | | | | A |
| 20 September 1981 | | | | | | | | | A |
| 15 December 1981 | | | | | | | | | A |
| 18 June 1982 | B | | | | | | | | |
| 15 December 1982 | | | | | | | | | A |
| 6-10 October 1983 | | | B | | | | | | B |
| 21 November 1984 | | | | A | | | | | |
| 14-15 August 1985 | A | | | | | | | | A |
| 6-7 August 1986 | A | | | | | | | B | B |
| 5 February 1988 | | | | B | | | | | |
| 9-12 February 1990 | | B | | B | | | | | |
| 29 December 1991 | | | | B | | | | | |
| 5 January 1992 | A | | | | | | | | |
| 18 December 1993 | | | | A | | | | | |
| 23 December 1993 | | B | B | | | | | | |
| 27 December 1994 | | | | | | | | | B |
| 27 January -1 February 1995 | B | A | A | A | | | | A | |
| 8 January 1998 | | | | B | B | | | | |
| 4 January 1999 | | | | | | | | B | |
| 9 December 1999 | | | | | A | | | | |
| 25-27 December 1999 | | A | A | A | | | | A | |
| 6 November 2000 | | | | | B | | | | |
| 18 January 2002 | | | | | B | | | | |
| 1 February 2002 | | | | | | | | A | |
| 11 February 2002 | | B | | | | | | | |
| 3 November 2002 | | | | | | A | | | |
| 7-12 January 2005 | B | | | B | A | | A | B | B |
| 13 January 2006 | | | | | B | | | | |
| 22 September 2006 | | | A | | | B | B | | |
| 12 October 2006 | | | | | B | | | | |
| 7-8 December 2006 | | | | | | A | A | B | |
| 22 December 2006 | | B | | | | | | | |
| 23 January 2008 | | A | | | A | A | A | A | |
| 25 October 2008 | | | | | A | | | | |
| 17 August 2008 | | | B | | | | | | |
| 25 January 2009 | | | | | | A | A | | |
| 23 August 2009 | B | | | | | | | B | |
| 2 November 2009 | | | | | | A | | | |
| 19-26 November 2009 | A | A | A | A | A | | A | A | |

** Short record*

***Table 7-B Top 5 (A) and Top 6-10 (B) AMAX flow or level for hydrometric gauging stations within UoM 27.***

## 7.5 Flow and Level Flood Frequency Curves

Where an AMAX series was available for a continuous flow series with a period of record greater than 10 years a flood frequency plot was developed. Research documented in FSU guidance (Work package 2.2) concluded that no single distribution could be considered a 'best fit' to all locations across Ireland. However, it was reported that the use of either a lognormal or Extreme Value Type 1 (EV1 or Gumbel) distribution provided a reasonable fit for the majority of stations.

Based upon this recommendation and for the benefit of consistency, one distribution will be selected as the distribution to be fitted to all applicable AMAX series in this Inception reporting phase of the study. The most likely candidates for this distribution are the lognormal and EV1 distributions. The selection of the distribution will be carried out after the rating review phase when the reliability of the available AMAX data has been assessed and possibly improved.

As part of this preliminary hydrological analysis flood frequency curves were developed following the procedure outlined in Section 6.5 based on an EV1 distribution and plotted according to Gringorten.

The subsequent flood frequency curve was used to derive estimates of annual exceedance probability for historical events rather than from data directly to ensure a coherent relationship between estimates.

Flood frequency plots were derived for eight hydrometric gauging stations located in the Shannon Estuary North Unit of Management for which an AMAX series greater than 10 years was available.

Flood frequency plots can be found in Appendix F and on the Gauging Station Summary Sheets in Appendix H. The reasons for the shapes of the plots and the locations of any outliers, or extended "flat" rating curves, will be given due consideration following the completion of the gauging station reviews and the re-working of the AMAX series as necessary, recognising that an unusual shape can be a result of physical reasons, data limitations, or simply the statistical distribution of floods that has occurred over the data record.

## 7.6 Event Analysis

Two flood events have been selected and will form the basis of a detailed hydrological analysis of hydrograph shape, duration, volume of flow, runoff and estimated probability of the event.

Events were selected based on a review of the AMAX series from gauges across the catchment (ref. Table 7-B) in conjunction with the occurrence of historic flood events as documented on the floodmaps.ie website. Emphasis has been placed on the selection of events which have occurred in the past 15 years primarily to increase the chance of data availability.

The following events were selected to represent severe flood events within the Shannon Estuary North unit of management:

- 24 - 28 December 1999;
- 19 - 24 November 2009;

The following gauging stations located on the Fergus and Owenogarney catchments represent the instantaneous flow series available within this unit of management (ref. Table 3-C) and are therefore used in subsequent analysis:

27001 Claureen at Inch Bridge
27002 Fergus at Ballycorey
27003 Fergus at Corrofin
27011 Owenogarney at Owenogarney

Of these stations, 27001, 27002 and 27003 are located within the same catchment.

### 7.6.1 Event of 24 – 28 December 1999

Flow data was extracted from the 15 minute series at four gauging stations between 2nd December 1999 (00:00 hours) and 31st January 2000 (00:00 hours). A summary of the data is presented in Table 7-C below and graphically on Figure 15a.

| Station No. | Peak flow ($m^3/s$) | Time of peak flow | Start time | End time | Volume of flow ($m^3$) | Duration (days, hours, minutes) |
|---|---|---|---|---|---|---|
| 27001 | 19.7 | 25/12/1999 00:45 | 21/12/1999 19:45 | 11/01/2000 13:15 | 8,322,861 | 20:17:30 |
| 27002 | 53.6 | 28/12/1999 01:45 | 22/12/1999 03:15 | 12/01/2000 00:15 | 75,771,907 | 20:21:00 |
| 27003 | 29.2 | 27/12/1999 13:00 | 21/12/1999 21:00 | 11/01/2000 18:00 | 35,612,221 | 20:21:00 |
| 27011 | 20.6 | 24/12/1999 18:30 | 21/12/1999 20:15 | 11/01/2000 18:00 | 21,632,379 | 20:21:45 |

***Table 7-C Summary of timings and flows for the flood event 24 – 28 December 1999***

Hydrographs from the four locations, indicate a range in the timing of peak flows, from the fast and flashy response from station 27001 to the slow lagged response from station 27002, indicative of a high baseflow component, and the larger catchment. Such a variation in response makes selecting the start and end date for the event challenging and arbitrary, especially as individual events are lost within the hydrograph of 27002. Therefore, to ensure some meaningful comparison of volumes and runoff a start and end date spanning approximately 21 days was chosen encompassing several events.

Three of the hydrographs (27001, 27003 and 27011) peaked more than once over the 21 day period, however, station 27002 peaked only once (Figure 15a).

The timings of the gauges within the Fergus catchment indicate that 27001 peaked first, followed by 27003 and 27002 peaked last, over three days after the peak flows were recorded at station 27001.

Based on the annual maximum flow series fitted with a Gumbel distribution as detailed in Section 7.5 annual exceedance probabilities (AEPs) were estimated for the event at each location (Table 7-D). Peak flows obtained for station 27011 from both the instantaneous record and the AMAX series differ marginally, $20.6m^3/s$ versus $21.73m^3/s$, but both records have been included for completeness. In the Shannon brief, the OPW advised that the annual maxima series had been manually extracted rather than being derived directly from digitised data and where any discrepancies between the two datasets arise the annual maxima values would

typically be more reliable. Therefore, any subsequently estimated AEP from the annual maxima peak flow should be more reliable than that obtained from the instantaneous flow record.

Results vary from 4% on the Fergus at Ballycorey to 59% on the Claureen at Inch Bridge. The 4% AEP estimated at Ballycorey suggests it was a relatively infrequent event. From discussions with Clare County Council, this event was noted to be a major event in Ennis in recent history, although not as bad as the event of November 2009.

| | | | Dec-99 | |
|---|---|---|---|---|
| Station No. | Station Name | Watercourse | Peak flow ($m^3/s$) | Estimated Annual Exceedance Probability (%) |
| 27001 | Inch Bridge | Claureen | 19.7 | 59 |
| 27002 | Ballycorey | Fergus | 53.6 | 4 |
| 27003 | Corrofin | Fergus | 29.2 | |
| 27011* | Owenogarney | Owenogarney | 20.6 | 17 |
| 27011** | Owenogarney | Owenogarney | 21.73 | 12 |

***Peak flow derived from instantaneous flow series***
***** Peak flow from AMAX series***

***Table 7-D Estimated Annual Exceedance Probabilities for peak flows during December 1999 event***

### 7.6.2 Event of 19 – 24 November 2009

Flow data was extracted from the 15 minute series at three gauging stations between 28th October 2009 (00:00 hours) and 25th December 2009 (23:45 hours). There are several periods of missing data at station 27001, totalling 3.25 hours and data was not available for station 27011. A summary of the data is presented in Table 7-E below.

| Station No. | Peak flow ($m^3/s$) | Time of peak flow | Start time | End time | Volume of flow ($m^3$) | Duration (days, hours, minutes) |
|---|---|---|---|---|---|---|
| 27001 | 26.8 | 19/11/2009 16:45 | 01/11/2009 03:15 | 25/12/2009 11:00 | 23,010,756 | 23:07:45 |
| 27002 | 80.6 | 24/11/2009 05:45 | 01/11/2009 05:00 | 27/12/2009 03:45 | 203,910,807 | 24:22:45 |
| 27003 | 48.9 | 24/11/2009 22:45 | 01/11/2009 03:45 | 25/12/2009 17:30 | 104,083,655 | 23:13:45 |
| 27011 | | | | | | |

***Table 7-E Summary of timings and flows for the flood event 19 – 24 November2009***

Hydrographs from the three locations present similar responses as noted for the December 1999 event (Figure 15b). However, the hydrograph peaks at stations 27002 and 27003 are questionable. This observation is supported by the data quality codes assigned to the data series at both locations for durations spanning the peak flow which classifies data as '*not available as it is missing, erroneous or of unacceptable quality*'. Therefore, any subsequent analysis of data is considered highly uncertain.

This uncertainty is compounded further by a comparison at gauge 27002 of the peak flow obtained from the instantaneous record with the annual maximum flow (or AMAX) which coincides with the same event. Flows differ greatly from 80.6m$^3$/s taken from the flow series, compared to 69.55m$^3$/s estimated for the AMAX series. In the CFRAM Study brief, the OPW advised that the annual maxima series had been manually extracted rather than being derived directly from digitised data and where any discrepancies between the two datasets arise the annual maxima values would typically be more reliable.

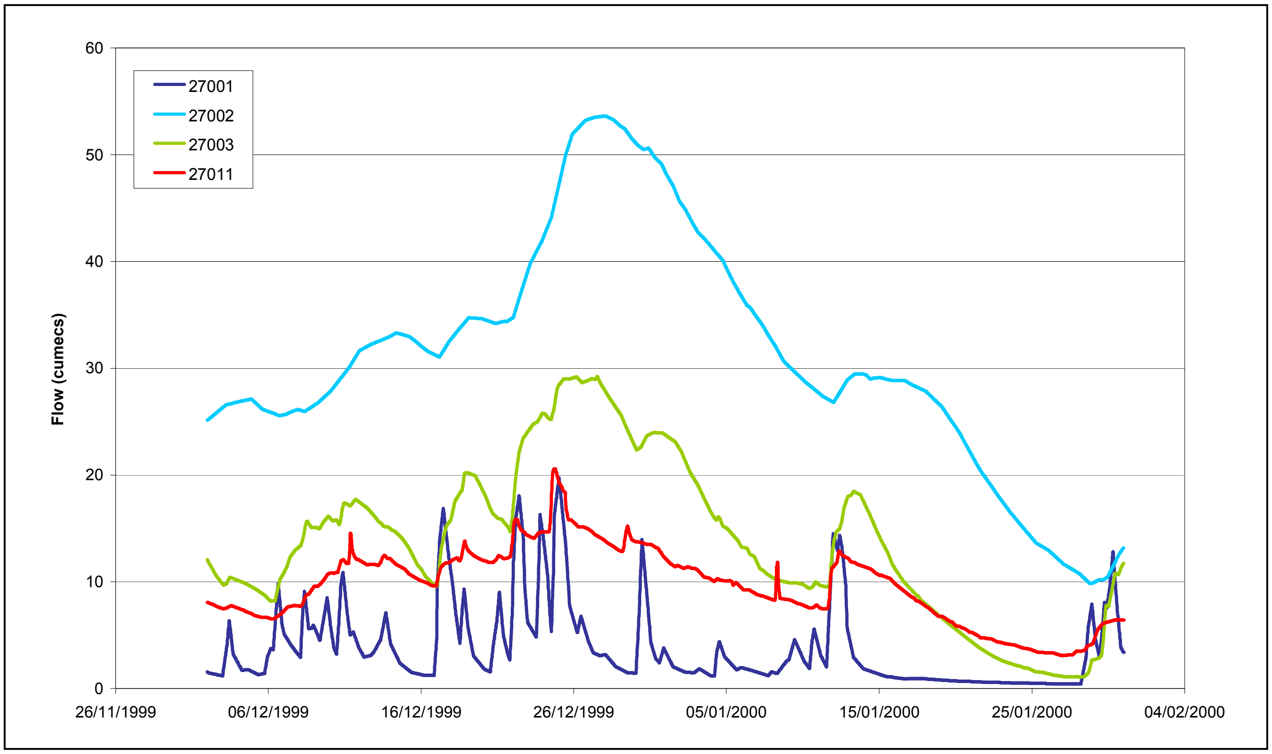
Based on the annual maximum flow series fitted with a Gumbel distribution as detailed in Section 7.5 annual exceedance probabilities were estimated for the event at each location. Both estimates of peak flows at 27002 have been included. Please note that the estimated AEP from the annual maxima peak flow will be more reliable than that obtained from the instantaneous flow record.

Both the AEPs estimated for the flows at 27002 (Table 7-F) indicate November 2009 was a rare event. Even the lower flow manually extracted for the AMAX series is the highest recorded at this site. This AEP estimate has been made based on 37 years data and considerably larger AMAX series would be required to give the AEP estimates any certainty.

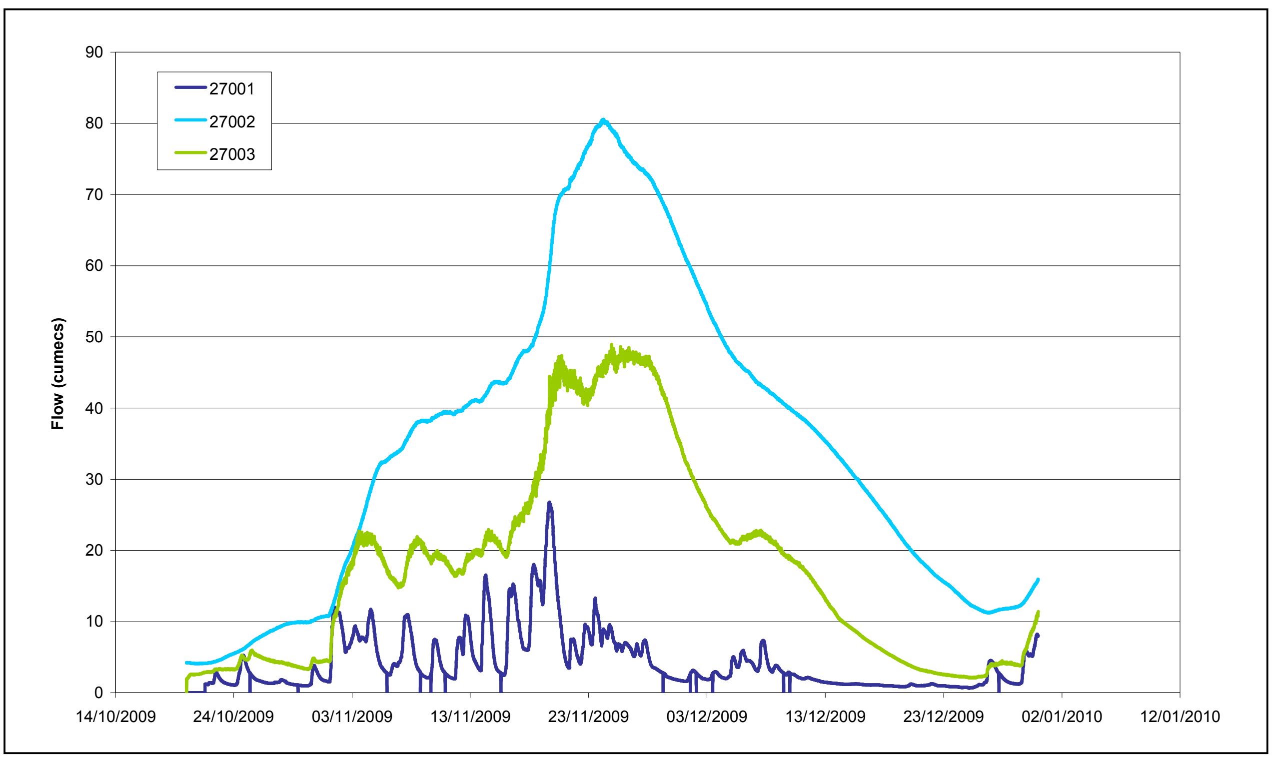
| | | | Nov-09 | |
|---|---|---|---|---|
| **Station No.** | **Station Name** | **Watercourse** | **Peak flow ($m^3/s$)** | **Estimated Annual Exceedance Probability (%)** |
| 27001 | Inch Bridge | Claureen | 26.8 | 8 |
| 27002* | Ballycorey | Fergus | 80.6 | *0.1* |
| 27002** | Ballycorey | Fergus | 69.55 | *0.5* |
| 27003 | Corrofin | Fergus | 48.9 | |
| 27011** | Owenogarney | Owenogarney | 27.35 | 2 |

**** Peak flow derived from instantaneous flow series***
***** Peak flow from AMAX series***

***Table 7-F Estimated Annual Exceedance Probabilities for peak flows during November 2009 event***




**a) Event of 24 – 28 December 1999**




**b) Event of 19 – 26 November 2009**

***Figure 15 Hydrographs for the two events in the Shannon Estuary North Unit of Management***

### 7.6.3 Event Discussion

Hydrographs from the two events highlight general trends in catchment response at the gauged locations. Flows gauged at 27001 are highly responsive as demonstrated by the steep rising limbs and steep recessions. Flows gauged at 27011 are a combination of a baseflow component with a flashy contribution superimposed. Loughs can be observed in the upstream reaches of the catchment which may provide the baseflow component, coupled with the groundwater influence in the area as a result of the presence of the limestone bedrock.

The contributing flows of 27003 can be clearly observed in the hydrograph at 27002, albeit smoothed. There is no flashy component to the hydrograph at 27002 indicating the likelihood of a strong baseflow component from groundwater flows as well as attenuation by an on-line waterbody. Further details of the gauge location and upstream catchment are required before any firm conclusions can be drawn.

Runoff values presented in Table 7-G provide a useful indication of catchment response for any given event. Due to the large difference in duration selected for the two events any comparison should be between gauges for the same event as between events the data will not be comparable. For both events runoff is greatest at gauge 27003, located on the River Fergus in its headwaters. Conversely, gauge 27002, located on the River Fergus just north of Ennis, has the lowest runoff values for each event. This can largely be explained by the attenuated flow which is indicative of a significant groundwater or storage component dominating flow characteristics at this location.

| | | Dec-99 | | | Nov-09 | | |
|---|---|---|---|---|---|---|---|
| Station No. | Catchment area (km$^2$) | Peak flow | Volume of flow (m$^3$) | Runoff (mm) | Peak flow | Volume of flow (m$^3$) | Runoff (mm) |
| 27001 | 46.7 | 19.7 | 8,322,861 | 178 | 26.8 | 23,010,756 | 493 |
| 27002 | 511.4 | 53.6 | 75,771,907 | 148 | 80.6 | 203,910,807 | 399 |
| 27003 | 166.4 | 29.2 | 35,612,221 | 214 | 48.9 | 104,083,655 | 626 |
| 27011 | 161.8 | 20.6 | 21,632,379 | 134 | | | |

***Table 7-G Peak flow, volume of flow and runoff for two events in the Shannon Estuary North unit of management.***

## 7.7 Conclusions

Fluvial data has been analysed for the Shannon Estuary North Unit of Management. Initially, daily mean flows, where available for four hydrometric gauging stations, were reviewed for long term errors or trends. Trends in water level and/or flow were observed at 27001 between 1972 and 1991 and over the entire period of record at 27002. A step change in 1984 is evident in the flow series at 27003. At station 27011 the flow series post-2007 appears to be higher following an extended period of missing data. The data from these gauges will be used with caution.

Instantaneous flow data was provided for four gauging stations. Two flood events were selected across the unit of management to analyse series in detail. Event selected were:

- 24 - 28 December 1999;
- 19 - 24 November 2009;

Hydrographs from 27001 indicate a highly responsive catchment as demonstrated by the steep rising limbs and recessions. Flows gauged at 27002, 27003 and 27011 indicate the presence of attenuating factors, likely to be both groundwater and on-line storage, such that the hydrograph at 27002 typically has no flashy component to it at all.

Highest peak flow in the three events was 80.6 m3/s recorded on the 24$^{th}$ November 2009 at Ballycorey on the River Fergus (27002).

Runoff within the Shannon Estuary North Unit of Management was highest at station 27003 located within the headwaters of the River Fergus.

Annual exceedance probabilities estimated for each event suggested a range of values across the catchment. Based on the annual maxima series, as advised by the OPW, the lowest AEP estimated was 0.5% for the River Fergus at Ballycorey for peak flows recorded during the November 2009 event. However, this is based on an annual maxima series of 37 years. The AEP estimated at 27001 (located on a tributary to the Fergus) was 8%.

.

# 8 Historical Flood Risk Review

## 8.1 Introduction

A substantial amount of historical flooding information has been gathered using "floodmaps" (www.floodmaps.ie), a web-based flood hazard mapping resource managed by the Office of Public Works (OPW). It contains historical flood events in various areas of the Republic of Ireland, with links to archived reports, photographs and newspaper articles collected from local authorities, other state bodies and members of the general public.

The historical data from this website is related to flooding caused by fluvial, tidal and coastal factors within the past 120 years. It does not deal with flood events arising as a result of other causes such as burst pipes, surcharged or blocked sewers etc.

Quality codes have been assigned to define the reliability of the sources of information. This, however, excludes the newspaper articles and information to which other quality assurance or coding processes apply e.g. the OPW hydrometric data. The reliability is classified and graded as follows:

| Code | Description |
|---|---|
| 1 | Contains, for a given flood event at a given location, reliably sourced definitive information on peak flood levels and/or maximum flood extents. |
| 2 | Contains, for a given flood event at a given location, reliably sourced definitive information on flood levels and/or flood extents. It does not however fully describe the extent of the event at the location. |
| 3 | Contains, for a given location, information that, beyond reasonable doubt, a flood has occurred in the vicinity. |
| 4 | Contains flood information that, insofar as it has been possible to establish, is probably true. |

***Table 8-A Quality codes assigned to data in floodmaps (OPW)***

The quality codes have been considered when summarising the historical flooding information with the priority given to data with quality code 1. The data with quality code 1 where available provides reliable information on peak flood levels and/or maximum flood extents and used in the analysis of the historical flood events. The detailed summary of all the historical flooding information for all the Communities at Risk (CAR) and Individual Risk Receptors (IRRs), together with the quality code, is shown in Appendix I. This is précised in the text and tables presented below.

Wherever the information is available in "floodmaps" the number and type of properties and infrastructure affected in a CAR by a historical flood event is stated in the sections below. However, due to qualitative nature of most of the information available in "floodmaps" it has often been found difficult to quantify these factors from the historical records.

The OPW recognises that the website is not a comprehensive catalogue of all past flood events and may not cover all flood events. The information included depends on the available records of the source bodies and is uploaded at their discretion.

Therefore, the absence of any records of past flood events in any given location does not allow us to conclude that flooding has never occurred in that area.

It is also emphasised that the summary of the historical flood events is, for the most part, a summary of the information provided from floodmaps, or from other sources where appropriate. It is not an independent verification of the date of an event, the extent of flooding, the number of properties or nature of the assets affected, or the mechanism of flooding.

## 8.2 Records of Historical Flood Risk

The list of the Communities at Risk (CARs) and Individual Risk Receptors (IRRs) in this unit of management is presented in Section 2. Seven CARs and three IRR have been identified in this area. One CAR is in the Fergus catchment, two in the Owenogarney (Ratty) catchment and four in the 'Other' (Tidal) catchment. All three IRRs are in the 'Other' (Tidal) catchment. The records of the historical flood risk are analysed and considered on a catchment by catchment basis.

Where possible a representative gauging station for each of the CARs has been identified and flow or water level data of the gauging station have been used to estimate the Annual Exceedance Probability (AEP) of historical flood events obtained from the "floodmaps" website. In the absence of any flow or water level estimates from a representative gauging station the AEP is estimated based on the order of magnitude of the similar events within the same catchment. This estimate can therefore be considered as indicative only and should be treated with caution.

The AEPs for particular events are derived using the flood frequency plots detailed in Section 7.5 and presented in Appendix F.

## 8.3 Fergus Catchment

CAR 28 Ennis is located within the Fergus catchment. The Fergus catchment is located within the central and eastern area of UoM 27. The location of Ennis and its associated level gauges used in this study are shown in Figure 4.

The mechanism of flooding for CAR 28 Ennis in the Fergus catchment is shown in Table 8-B below.

| CAR/IRR | County | River | Mechanism of Flooding |
|---|---|---|---|
| CAR 28 Ennis | Clare | Fergus | Fluvial and tidal: surface water network unable to discharge and also affected by strong winds |

***Table 8-B Flooding mechanism in the Fergus Catchment***

CAR 28 Ennis is affected by both fluvial and tidal flooding. In most cases, both high tides coincident with high fluvial discharges cause flooding and are influenced by the Clarecastle Barrage. Therefore, both the fluvial and tidal flood risks are described in Section 8.3.1 and 8.3.2 below.

### 8.3.1 Records of Historical Flood Risk

#### (a) CAR 28 Ennis

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD – Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | - | 3.02 (Knox's Bridge)[1]<br>2.89 (Tulla Road Bridge)[1]<br>6.39 (Ennis Bridge) | 7.8<br>11.8<br>1.7 | Extensive flooding in Ennis. Approximately 112 residential properties & some non residential properties flooded. | 1<br>1 (T)[2] |
| December 2006 | - | 2.89 (Knox's Bridge)[1]<br>2.82 (Tulla Road Bridge)[1]<br>5.87 (Ennis Bridge) | 16.5<br>18.8<br>20.4 | No flooding details available. | 2<br>5 (T) |
| February 2002 | - | 5.95 (Ennis Bridge) | 14.2 | Road and 2 properties flooded. | 4 (T) |
| December 1999 | - | 6.13 (Ennis Bridge) | 6.0 | Properties and roads at various locations in Ennis flooded. No houses in Fergus Park flooded. | 2 (T) |
| 1998 | - | 5.75 (Ennis Bridge) | 34.1 | No flooding details available. | 6 (T) |
| January/ February 1995 | - | 6.02 (Ennis Bridge) | 10.2 | Severe flooding in Ennis town centre and Fergus Park. Houses in Fergus Park flooded. | 3 (T) |
| 1993 | - | 5.73 (Ennis Bridge) | 36.9 | Serious flooding in Ennis. | 8 (T) |
| 1989/1990 | - | 5.74 (Ennis Bridge) | 35.5 | Serious flooding in Ennis. | 7 (T) |
| December 1959 | - | - | - | Flooding in Ennis and surrounding areas with 100 residential and commercial premises and vast area of land flooded. Road flooding between Ennis and Gort Road. St Flannan's College grounds and adjacent main road flooded. | - |
| 24-26 December 1968 | - | - | - | No flooding details available. | - |
| 1955 | - | - | - | Houses in many principal streets flooded. | - |
| 1947 | - | - | - | Similar flooding as 1959 event. | - |
| Recurring | - | - | - | Mill road a serious flooding black spot in Ennis town. Doora North Newpark flooded several times per year. No roads or houses affected. | - |

Note:
(1) Datum used by the OPW for both Knox's Bridge and Tulla Road Bridge gauging stations is Poolbeg. Other sources from the "floodmaps" indicated that the level should be to mOD (Malin).
(2) (T) denotes the ranking for tidal events.

***Table 8-C Summary of historical flood events in CAR 28 Ennis***

In Ennis, the mechanism for flooding is typically out of bank flows from both the Fergus and Claureen Rivers and the inadequacy of the flood walls in the town to contain the water when the river discharge exceeded 60m$^3$/s. The inadequacy was caused by a combination of porous walls and backflow through the surface water drainage outfalls. The surface water drainage from the urban area was unable to discharge to the river when the water level was high. Recent flood defence improvements have improved this situation.

A secondary cause of the flooding is the tidal effect. When high tides coincide with high river discharges, the barrage at Clarecastle is closed for up to seven hours during which time water level builds up in the Lower Fergus to a degree that causes a backwater effect in Ennis town centre. Historically, the corresponding water level fluctuations in the Woodquay area amounted to about 200mm during each tidal cycle.

Major floods also develop on the Fergus over a period of weeks in response to prolonged rainfall. Serious flooding has also occurred in the town if the Claureen River, which reacts to heavy rainfall much more rapidly than the Fergus, also peaks while the Fergus was in flood. The situation can be worsened by the effect of high tides, particularly if accompanied by low pressure and windy conditions.

Flood frequency estimates, derived from levels recorded on the Fergus at Knox's Bridge (27025) and Tulla Road Bridge (27026) gauging stations allow the estimation of the AEP of these recorded flood events at Fergus. The flood events pre-2006 have not been considered in the ranking and estimation of the AEP as there is only limited data available from the gauging stations. AEP estimates range from 7.8% (2009) to 16.5% (2006) based on a historical data record of 6 years (2002 to 2009) at Knox's Bridge and 11.8% (2009) to 18.8% (2006) based on a historical data record of 6 years (2005 to 2009) at Tulla Road Bridge. Please note this is based on flows at Knox's Bridge and Tulla Road Bridge and therefore can only be considered indicative at Ennis.

For the tidal flooding, flood frequency estimates were derived from levels recorded on the Fergus Estuary at Ennis Bridge (27066) gauging station. Estimates of the AEP ranged from 1.7% (2009) to 36.9% (1993) based on a historical data record of 30 years (1980 to 2009) at Ennis Bridge. Please note this is based on levels at the subject site at Ennis Bridge and therefore can only be considered as appropriate for Ennis, within the context of a limited data record for estimating the AEP of events.

### 8.3.2 Discussion

Major events are known to have occurred in the Fergus catchment that affected Ennis in November 2009, December 2006, December 1999 and January / February 1995.

In 1954, a tidal barrage was built some 200m upstream of the main N18 road bridge at Clarecastle. This barrage was a major feature in the flood protection strategy of Ennis town which aimed to protect Ennis from tidal flooding. Prior to the construction of the Clarecastle barrage, the tidal effect extended past the Tulla Road and past the railway bridge as far as Corravorrin Bridge.

The barrage prevented high tides from entering the river by means of large flap sluice gates. At low tide, river flow discharges underneath the barrage. However, at times of high river flow, the water that passed through Ennis on its way towards the

estuary has to be stored between the town and the barrage, between the river embankments in the Lower Fergus and on the Doora floodplain on the left bank of the Fergus, until the ebb of the high tide.

**November 2009**

The November 2009 flood event resulted from persistent and often heavy rain and saturated ground conditions. Rainfall totals for the November 2009 were the highest on record at most monitoring stations according to the Met Éireann Monthly Weather Summary. Rain or showers were recorded on almost every day, with between 22 to 27 wet days observed (days with 1mm or more rainfall), compared with the normal range of 13 to 20 wet days for the month of November.

Severe flood incidents were experienced throughout County Clare during the 2 week period from the 18$^{th}$ November to 2$^{nd}$ December. The rainfall for November in Ennis was approximately 5 times the average. The total rainfall recorded for November in Drumcliff, Ennis was 447mm. A very substantial increase in rainfall was experienced on the 18$^{th}$ and 19$^{th}$ November 2009 with 42mm being recorded on the 18$^{th}$ November and a further 40mm being recorded on the 19$^{th}$ November.

The flooding in Ennis town was considered to be due to the combination of prolonged intense rainfall over a period of several days coincident with high tides on the Fergus Estuary. The tide peak itself and the exacerbation of the tidal peak by south westerly winds at critical times apparently worsened the flooding situation and resulted in the highest water levels ever recorded on the River Fergus in the town centre. In most areas, flooding was associated with the high river levels which prevented the discharge of storm drains and thus backed up flow through open drains from the river. This also prevented the storm or combined sewers to discharge the rainfall. The high river levels also appear to have caused overflow across low level river embankments and walls and also groundwater movement.

Discussions with Clare County Council indicate that there was a double peak during this event. The first peak on 19$^{th}$ November was reported to be 80 $m^3/s$ downstream of the confluence with the Claureen River, and included a tidal influence. The flow from the Claureen was reported to be up to 25$m^3/s$. The Fergus peaked five days later on 23rd November, also at 80$m^3/s$ although with lower tide levels. Hence this event included both tidal and non-tidal influenced flooding.

During this event, approximately 112 houses in Ennis town and 12 properties in Ennis Environs were directly affected. Aerial photographs (ref. opm_re_JB_0000011233) showed the extent of flooding during this flood event. On the 19$^{th}$ November, a breach occurred at the river wall on Abbey Street which resulted in further flooding in part of the town centre.

The majority of works undertaken as part of the Ennis Certified Drainage (Upper) Scheme were substantially completed when this flooding occurred. These works performed well and met the design standards set out although not yet finalised at the time. Parnell Street car park area which had historically been an area of significant flooding was prevented from flooding.

**February 2002**

This flooding is reported as being caused by a combination of tidal and fluvial events. The flooding caused roads and two properties to be flooded to a depth of approximately 150mm. Sources from the OPW estimated that this event had an AEP of 50%.

**December 1999**

Rainfall amounting to 35mm was experienced on the 22nd December. During the 48 hours following 9am on December 23rd, rainfall intensity increased dramatically and during that period a total of 70mm of rain was experienced. The flooding event commenced on the 22nd December and had fully abated by the 31st December, a period of approximately 9 days. The total rainfall of 74mm was experienced in the 4 days prior to commencement of the 1999 flood. A further 122mm fell during the event, giving a total of 196mm in the period leading up to and including the 1999 flood.

The flooding in December 1999 appears to have been caused by the coincidence of high river flow and the high tide on the Fergus Estuary. The town was flooded continuously for a week. It was noted that in the absence of any tidal effect, flooding would still have occurred in December 1999 to the Middle and Lower Fergus reaches. The Ennis Flood Study Report (February 2004) estimated that this event had a peak flow of $60m^3/s$ with a corresponding AEP of 14%. (The hydraulic model indicated that overtopping of the existing floodwalls through the town occurred at approximately $65m^3/s$ (i.e. at an AEP of about 9%).

During this event, flooding in Ennis was recorded at Fergus Park and Lifford, primarily the result of seepage and backwater effects. In the town centre flooding was most notable in Parnell St, Woodquay and Mill road. Water levels in the River Fergus were tidally influenced up to Mill Bridge (max. water level recorded 4.02 mOD (Malin). Flooding was also observed on the Fergus Upper, on Drumcliffe Road and Knockannoura / Cappaghard, however no properties at any of these locations were flooded.

Further and more detailed information is available for this event along the Lower, Middle and Upper reaches of the Fergus at Ennis – this is included at the end of Appendix I.

Subsequent to the event, the Ennis Main Drainage and Flooding Study (June 2001) was carried out to provide a better understanding of the factors causing flooding in Ennis and to make recommendations to reduce the flooding impacts. This study involved extensive surveying, water level monitoring, hydrological and hydraulic modelling and consultation with both the public and their elected representatives. Various flood relief works were recommended in the study.

**January/February 1995**

The January/February 1995 event was apparently caused by a combination of prolonged intense rainfall coincident with the tidal peak on the Fergus Estuary. Severe flooding was experienced in Ennis town centre and Fergus Park. A rainfall depth of 74mm was experienced over a 3 day period (25th to 27th December 1994). During the course of these floods, a further 45mm to 50mm of rainfall was recorded giving a total of approximately 125mm over the 11 day period. A further 29mm of rainfall was experienced on the 30th January causing further flooding to Ennis. The

flooding reached significant peaks on two occasions, one on the 27th/28th January the other lasted for a longer period from 31st January to 1st February. The average rainfall leading up to and during the 1995 flood was 11.5mm per day. The floodmaps.ie website reported a peak level at Ennis of approximately 3.8mOD (Malin) on 31st January, but did not specify the location where this level was recorded.

In this flood event, Ennis town centre and Fergus Park experienced severe flooding. The flood water overflowed the bank at Fergus Park and some of the houses experienced flooding to a depth of 400 to 600mm (2.9 to 3.0mOD (Malin)). The lands at Knocknoura and Cappaghard were flooded to 1.46mOD (Malin).

Following the flooding incident, an embankment of about 1.5m high was constructed between Fergus Park and the River Fergus (along the northern bank from Knox's Bridge westwards as far as CBS School grounds).

At Knocknoura and Cappaghard, a relief pipe was also constructed which connected Dromcarronmore turlough to Spellisy's turlough to prevent water levels in Dromcarronmore from rising above a level of approximately 18.50mOD (Malin).

A new sump was provided in the Woodquay Car Park as part of the Mill Road upgrading project in 1995 to facilitate pumps to pump water to the drainage system.

A major study brief was also compiled for submission to the Department of the Environment and Local Government to facilitate a study to deal with all possible aspects of main drainage and flood management needs into the future. However, the brief was not approved until late 1998. The Ennis Main Drainage and Flood Study (June 2001) was subsequently carried out as mentioned above.

**December 1959**

The December 1959 flooding in Ennis occurred when exceptionally heavy rainfall, high tides and gale force south westerly winds coincided. The average daily rainfall in County Clare was 19mm for the two weeks preceding Christmas. The heavy rain on the 26th December coincident with the high tides apparently prevented the discharge of water through the sluice at Clarecastle Barrage resulting in flooding in Ennis and surrounding areas. The flooding was also associated with some underground streams and flood water backing up the sewers which discharged directly into the river.

A vast area of land which stretched 2 miles from Clarecastle to Ennis was under water. In Ennis town, 100 residential and commercial properties were flooded to a depth ranging from 50 to 300mm.

The worst affected area was between Parnell Street and the river. A small number of laneways from Parnell Street to the river wall and residences in those laneways were flooded to about 150mm. Parnell Street and Cornmarket Street were flooded to a maximum depth of approximately 300mm. Mill Road on the opposite bank was flooded to a depth of 450mm and water entered a number of houses there.

At Aughanteeroe Bridge, the Ennis – Gort Road was flooded. The flooding was apparently caused by the limited capacity of the bridge to accommodate the flood water. The flooding on the grounds of St Flannan's College and on the adjacent main road was believed to be coming from a swallow hole on the west of the grounds.

**1955**

In the December 1955 event, houses in many of the principal streets were flooded.

**1947**

This flood event was similar to the December 1959 event.

**Other Flooding Events**

Other flooding events are known to have occurred in December 2006, 1998, 1993, 1989/1990 and December 1968. However, little or no information of the extent or level of flooding is known.

**Recurrent Flooding**

According to the floodsmap website Mill Road, Ennis, is subject to repeated flooding. In December 1999, it was stated that a ‘small number of properties’ were affected.

Doora North Newpark is a large floodplain that acts as a flood storage basin and has been designed as such. The area is flooded several times per year but no roads or houses are affected. The flooding is apparently caused by rainfall/runoff exacerbated by tidal influence, specifically the closing of the gates on the River Fergus at Clarecastle Barrage.

## 8.4 Owenogarney (Ratty) Catchment

CAR 14 Bunratty and CAR 55 Sixmilebridge are located within the Owenogarney (Ratty) catchment. The Owenogarney catchment is located within the southeast area of UoM 27, north of Bunratty. The locations of Bunratty and Sixmilebridge (and the associated flow gauge for Siximilebridge used in this study) are shown in Figure 4.

The likely mechanism of flooding for CAR 14 Bunratty and CAR 55 Sixmilebridge in the Owenogarney catchment is indicated in Table 8-D below.

| CAR/IRR | County | River | Mechanism of Flooding |
|---|---|---|---|
| CAR 14 Bunratty | Clare | - | Tidal – surface water network unable to cope with runoff |
| CAR 55 Sixmilebridge | Clare | Owenogarney | Fluvial - surface water network unable to cope with runoff |

***Table 8-D Flooding mechanism in the Owenogarney Catchment***

### 8.4.1 Records of Historical Flood Risk

#### (a) CAR 14 Bunratty

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD – Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| January 2005 | - | 400mm (road flooding) | - | L3040 to Bunratty flooded due to surface runoff from the surrounding land and streams. | - |
| 01/02 February 2002 | - | - | - | Land flooded at Moyhill area. | - |
| 10 February 1997 | - | - | - | A dwelling at Moyhill was threatened with flooding. A stretch of wall was washed away. | - |
| January 1995 | - | 6.6[1] (Ferrybridge) | - | The lowest level in Bunratty Castle flooded. | - |
| 16-17 January 1965 | - | - | - | No flooding details available. | - |
| Recurring | - | 100mm (road flooding) | - | Road at Deerpark housing estate flooded once in 2 years. | - |

Note:
(1) Recorded tide level at Ferrybridge from the previous OPW Report to Regional Engineers (February 1995).

***Table 8-E Summary of historical flood events in CAR 14 Bunratty***

The mechanism of flooding in Bunratty has been reported as high tides overtopping the flood defence embankments. The flooding also appears to be associated with the inadequacy of the surface water drainage in the low lying areas.

There is no representative gauging station for the area and therefore no indicative annual probabilities for the historical flood events have been derived.

It is noted that several of the events noted above do not refer to flooding within Bunratty itself, but to locations up to a few kilometres from the village.

### (b) CAR 55 Sixmilebridge

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | 27.35 (Owenogarney) | - | 2.2 | Roads at Sixmilebridge flooded and impassable. | 1 |
| January 2005 | 20.70 (Owenogarney) | 450mm (R462 road flooding) | 16.2 | Road from Setrights Cross to Sixmilebridge (R462) and Rossmanagher Bridge flooded and impassable. R462 at junction with L7046 also flooded. Road and surrounding land at Bradford Road flooded. | 2 |
| January 1995 | | 7.46 to 8.01[1] (property flooding) | | Flood lasted for 14 days and affected 14 houses (6 flooded & 8 at immediate risk) and sewage treatment works. | |
| 1994 | | | | Severe flooding of houses in Sixmilebridge. | |
| 1991 | | | | Severe flooding in Sixmilebridge. | |
| December 1959 | | | | No flooding details available. | |
| Jan-Feb 1946 | | | | No flooding details available. | |

Note: OPW Mungret survey information (February 1995) indicated a level of 24.46 to 24.29 with no datum given to the levels. Comparison with the other sources indicated that the level should be to feet (Poolbeg).

***Table 8-F Summary of historical flood events in CAR 55 Sixmilebridge***

In Sixmilebridge, the mechanism for flooding appears to be out of bank flows from the Owenogarney River after heavy rainfall. The backing up of water in the small tributary between the county council sewage treatment plant and nearby houses when the Owenogarney River is high further contributes to the flooding of the houses.

Flooding appears to have been worsened by the release of flood water from a hole cut in the wall separating the mill pond (at the upstream end of the village) from the road, allowing water to flow down the road and into the village centre. The inadequacy of the surface water system and lack of culvert capacity in various locations also contributes to the flooding.

Flood frequency estimates, derived from flows recorded on the Owenogarney at Owenogarney (Rly) Bridge (27011) gauging station allow the estimation of the AEP of these recorded flood events at Sixmilebridge. The flood events of 1995 and before have not been considered in the ranking and estimation of the AEP. Estimates range from 2.2% AEP (2009) to 16.2% (2005) based on a historical AMAX record of 14 years (1997 to 2009). Note that this is based on flows at Owenogarney Bridge with a catchment area of approximately 162$km^2$ and therefore can only be considered indicative at Sixmilebridge, within the context of a limited data record for estimating the AEP of events.

### 8.4.2 Discussion

**November 2009**

There are no detailed reports for this event, however, the map prepared by Clare County Council showing flood events across County Clare during this event indicated roads (R462 and R471) at **Sixmilebridge** as being flooded and impassable. Whilst the full extent of the flood is not known, discussions with Clare County Council indicate that several commercial properties towards the upstream (northern) end of the town were affected by flooding from the Owenogarney River, but no residential properties were flooded.

In relation to **Bunratty**, the flood map of County Clare indicates that the local road north from Bunratty towards Deerpark was flooded and impassable, although the incident was not within Bunratty itself.

**January 2005**

***Bunratty***

The low lying area from the L3040 to Bunratty was flooded. The flooding was apparently caused by the surface water runoff from low lying land on both sides of the road overflowing the drains to the east of the road. The road was flooded to a maximum depth of 400mm and was impassable. According to the OPW Flood Hazard Mapping information, the AEP of this occurrence was around 10% to 20%

The L3040 road adjacent to Bunratty Castle was also flooded over a localised area due to high tide combined with high winds.

***Sixmilebridge***

The R462 road from Setright's Cross to Sixmilebridge was flooded a few kilometres south of Sixmilebridge and impassable with up to 450mm of water on the road close to the railway line. The flooding was apparently caused by the prolonged heavy rain resulting in surface runoff from the land to the east of the road. According to the OPW Flood Hazard Mapping information, this was an unusual occurrence with an estimated AEP of 5% to 10%.

At the road junction between the R462 and L7026, the lack of capacity of the culvert under the R462 apparently caused water to overflow across the R462 north of Sixmilebridge. The road was flooded but passable.

At Broadford Road, northeast of Sixmilebridge, the road and surrounding land was flooded in January 2005. The flooding was reportedly due to the sheer volume of water and inadequate drainage due to the low lying nature of the area with no stream or drain in this area. According to the OPW Flood Hazard Mapping information, this was an exceptional event and has only occurred once.

Flooding also occurred at Rossmanagher where the culvert under the railway bridge outfalls to the River Ratty just to the south of Sixmilebridge. The culvert was reportedly unable to cope with the volume of water. The road was impassable. According to the OPW Flood Hazard Mapping information, this AEP of this occurrence was 10% to 20%.

**February 2002**

The land at Moyhill near **Bunratty** was flooded apparently due to a high tide coupled with sluice failure. The sluice has subsequently been replaced.

**February 1997**

During the February 1997 event, a dwelling at Moyhill near **Bunratty** was threatened by the high tide. Most of the flood water entered this small subcatchment via the openings in the parapet surrounding the Village Stores. A stretch of wall to the north of the premises was washed away.

**January 1995**

***Bunratty***

The flooding event was apparently caused by the high tide and extremely low barometric pressure at the Shannon Estuary. The design crest level of the embankments on the Owenogarney River is 6.7mOD (Poolbeg). A tide level of 6.6mOD (Poolbeg) was recorded at the Ferrybridge gauge which is situated on the tidal stretch of the Maigue which joins the Shannon almost directly opposite the mouth of the Owenogarney. Although no data was available to compare the tidal surge in the Owenogarney to the tidal levels recorded in the Maigue, it is apparent that even small waves would have caused a problem at tides of such magnitude (OPW Report to Regional Engineers, February 1995). The overtopping of the embankment on this occasion lasted for only a very short duration but the lower levels in **Bunratty** Castle were flooded.

***Sixmilebridge***

The January 1995 flooding lasted for two weeks and caused substantial damage to 14 houses, threatened a number of other properties and inundated the sewage treatment plant on the left bank of the Owenogarney River. This caused the backing up in the sewer pipe and manhole system and sewage flowed into the gardens of all 14 houses, outbuildings, and some of the houses, and threatened others. Six houses were rendered uninhabitable for several weeks.

During this flood event, surface water runoff in the town was backed up and flowed out into the street. Part of the square in the centre of the town was also flooded. The water caused erosion and undermined the railway bridge stability and caused damage to the river walls.

The flood level experienced at the houses affected ranged between 7.46 to 8.01mOD (Poolbeg) (24.46 to 26.26ftOD (Poolbeg)) according to the survey information of the OPW (see Note 1 in Table 8-E above). Aerial photographs (ref. opd_re_tg_0000000507) showed the extent of flooding during this flood event.

Subsequent to this flood event, a study was carried out in December 1995 to investigate options of alleviating the flooding problem. The study investigated various options and recommended profiling the river channel along with building an embankment on the left bank of the Owenogarney River and a small tributary river to the east of the town as the preferred option. Detailed information on the study was documented in the Environmental Impact Statement for the Proposed Flood Relief Works on the River Owenogarney, Sixmilebridge, Clare County Report (December 1995).

**January 1965**

Flooding also occurred in January 1965 in **Bunratty**. However, no details of flooding were available.

**Other Flooding Events**

Other flooding events are known to have occurred in Sixmilebridge, as noted in Table 8-F in 1994, 1991, December 1959, and January/February 1946. However, little or no information on the extent of flooding is recorded.

**Recurrent Flooding**

The low point on the road in the Deerpark Housing Estate, **Bunratty**, appears to be flooded to a maximum depth of about 100mm once every two years. The flooding is apparently caused by the soak pits from the road gully drainage being unable to cope with the heavy rainfall. The road however is passable during the flood.

## 8.5 Other (Tidal) Catchment

There are four CARs and three IRRs located within the Other (Tidal) catchment. This is located within the southern area of UoM 27. The locations of all the CARs or IRRs and their associated flow and level gauges within the catchment used in this study are shown in Figure 4.

The mechanism of flooding for CARs and IRRs considered in the Other (Tidal) Catchment is shown in Table 8-G below.

| CAR/IRR | County | River | Mechanism of Flooding |
|---|---|---|---|
| CAR 33 Kilkee | Clare | Victoria Stream | Tidal & fluvial |
| CAR 36 Kilrush | Clare | Cooraclare | Tidal & fluvial – surface water network unable to cope with runoff |
| CAR 38 Lissan West | Clare | - | Tidal? (No data available) |
| CAR 53 Shannon | Clare | - | Tidal – surface water network unable to cope with runoff |
| IRR 06 Shannon International Airport | Clare | - | Tidal – surface water network unable to cope with runoff |
| IRR 07 Radar Station for Shannon Airport | Clare | - | Tidal? (No data available) |
| IRR 08 Moneypoint Power Station | Clare | - | Tidal? (No data available) |

***Table 8-G Flooding mechanism in the Other (Tidal) Catchment***

### 8.5.1 Records of Historical Flood Risk

#### (a) CAR 33 Kilkee

| Event | Peak Flow ($m^3/s$) | Maximum flood depth | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| February 1990 | - | - | - | County Clare experienced serious flooding with about 200 houses and many roads affected. Kilkee was one of the most seriously affected areas. Roads damaged in County Clare from Galway Bay to Loop Head and up to Carrigaholt in the Shannon Estuary. | - |
| 16-17 January 1965 | - | 610mm (house flooding) | - | The town was in complete darkness Promenade wall collapsed causing flooding to houses along the front of the wall. Widespread damage from Loop Heap to Black Head. | - |
| 22 October 1961 | - | - | - | A golf pavilion was blown away in Kilkee. Windows on the seafront and a number of shop windows were smashed by flying slates. No flooding details available. | - |
| 8 December 1954 | - | - | - | Large tract of land and low lying roads at Kilkee and other parts of West Clare flooded. | - |
| 18 October 1954 | - | - | - | Low lying roads and lands flooded. | - |
| 24 October 1949 | - | - | - | No flooding details available. | - |
| 12 August 1946 | - | - | - | No flooding details available. | - |
| Recurring | - | - | - | Church Street and Well Road car park flooded. Road impassable and car park closed. 4 to 5 houses flooded. | - |

***Table 8-H Summary of historical flood events in CAR 33 Kilkee***

The mechanism of flooding in Kilkee appears to be typically high tides and strong winds. Flooding is also apparently caused by out of bank flows from the Victoria Stream at Carrigholt Road.

There is no representative gauging station for the area and therefore no AEP for the historical flood events were derived.

### (b) CAR 36 Kilrush

| Event | Peak Flow ($m^3/s$) | Maximum flood depth | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 7 January 2005 | - | 500mm (road flooding) | - | Land and R483 road flooded. Road impassable. | - |
| 25 August 1986 | - | - | - | No flooding details available. | - |
| 19-20 January 1969 | - | - | - | No flooding details available. | - |
| 24-26 December 1968 | - | - | - | No flooding details available. | - |
| 09-10 January 1965 | - | - | - | No flooding details available. | - |
| 22 October 1961 | - | - | - | An individual was surrounded by water up waist level at a mudflat near Moyasta. | - |
| 24 October 1949 | - | - | - | No flooding details available. | - |
| 12 December 1924 | - | - | - | No flooding details available. | - |
| 14 October 1886 | - | - | - | No flooding details available. | - |
| Recurring | - | 1200mm (R473 road flooding) | - | R483 on Kilrush Road flooded but passable. R473 on Cappagh side of the Creek Lodge Hotel flooded and impassable. | - |

***Table 8-I Summary of historical flood events in CAR 36 Kilrush***

The mechanism of flooding in Kilrush appears to be high tides, and this may also be exacerbated by the operation of the Marina lock gates which may have the effect of prolonging high water. The flooding was also apparently caused by the backing up from the Cooraclare River and inadequacy of the surface water drainage in the low lying area.

No flood frequency estimates were derived due to the absence of annual maximum flow data from the Kilrush (27013) gauging station.

### (c) CAR 38 Lissan West

There were no recorded flooding incidents for Lissan West.

### (d) CAR 53 Shannon

| Event | Peak Flow ($m^3/s$) | Maximum flood depth | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| January 2005 | - | - | - | Road L3169 flooded (from surface water runoff). Water flowed around a house but not flooded. | - |
| Recurring circa 2000 | - | - | - | L7174 flooded (tidal). | - |

***Table 8-J Summary of historical flood events in CAR 53 Shannon***

The mechanism of flooding in Shannon appears to be due to high tide backing up from the estuary. The flooding was also apparently caused by the inadequacy of the surface water drainage at Ballycally.

There is no representative gauging station for the area and therefore no AEP for the historical flood events were derived.

### (e) IRR 06 Shannon International Airport

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Malin) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| January 2005 | - | - | - | Road L3169 flooded (from surface water runoff). Water flowed around a house but not flooded. | - |
| 25 December 1999 | - | 3.7[1] (Clarecastle Bridge) | - | Two houses flooded (tidal). | - |
| Recurring circa 2000 | - | - | - | L7174 flooded (tidal). | - |

Note:
(1) Observed tide level at Clarecastle Bridge from the previous OPW Report to Regional Engineers (September 2000).

***Table 8-K Summary of historical flood events In IRR 06 Shannon International Airport***

The mechanism of flooding in Shannon International Airport has been reported as high tide overtopping the embankment. The flooding was also apparently caused by the inadequacy of the surface water drainage at Ballycally.

There is no representative gauging station for the area and therefore no AEP for the historical flood events were derived.

### (f) IRR 07 Radar Station for Shannon International Airport

There were no recorded flooding incidents for the Radar Station for Shannon International Airport.

#### (g) IRR 08 Moneypoint Power Station

There were no recorded flooding incidents for Moneypoint Power Station.

### 8.5.2 Discussion

Several flooding events are known to have occurred in the Other (Tidal) Catchments within UoM 27. Major flood events include January 2005, December 1999, January 1995 and January 1965 and these and others are discussed below. For the CARs and IRRs considered under this Unit of Management, there are no flooding event details for Lissan West, the Radar Station for Shannon Airport or Moneypoint Power Station.

**January 2005**

In **Kilrush**, the low lying land, cut away bog at each side of the R483, was flooded. The road was flooded to a maximum depth of 500mm and impassable. The flooding was reportedly due to the very poor drainage which was unable to cope with the runoff. This has apparently happened twice a year.

In January 2005, the flooding at Ballycally (just west of **Shannon International Airport)** was apparently due to surface water runoff from land to south of the L3169 road. Water flowed around one dwelling house but the house was not flooded. According to the OPW Flood Hazard Mapping information, this was a rare event.

**December 1999**

In December 1999, two houses at Carrigerry, west of **Shannon International Airport** were flooded. This tidal flooding is reported to have been due to overtopping of the embankment and houses being below the embankment crest and tide levels. The crest level of the embankment in the vicinity was 6.3mOD (Poolbeg) (3.6mOD (Malin)). A tide level of about 6.4mOD (Poolbeg) (3.7mOD (Malin)) was observed at Clarecastle Bridge during this flood event.

**February 1990**

During the February 1990 event, County Clare experienced serious tidal flooding with approximately 200 houses and many roads affected. **Kilkee** was one of the most seriously affected areas. Roads were also damaged in County Clare from Galway Bay to Loop Head and up to Carrigaholt in the Shannon Estuary with damage estimated at approximately £1M.

**January 1965**

At **Kilkee**, the flooding event was apparently caused by a high tide and strong winds. It was reported that the seas were breaking over the cliffs and sending spray inland for a distance of one mile. The town itself was in complete darkness because of a power failure and portions of the promenade wall were severely damaged. A collapse of the wall resulted in flooding to the houses along the front to a depth of 610mm. The reported hurricane force winds lashed Killkee and the Clare coast for 24 hours and widespread damage was caused from Loop Head to Black Head.

**October 1961**

The flooding was apparently caused by a storm which hit the coast of Clare following a day of torrential rain. Damage was reported to buildings along the seafront in **Kilkee**.

**December 1954**

In **Kilkee** and other parts of West Clare, there was a light fall of snow in the morning but this was quickly followed by heavy rain which resulted in flooding to large tracts of land and low lying roads. The flooding situation was worsened by showers of sleet and a severe storm and large waves in the late evening.

**October 1954**

During the October 1954 flood event, the heavy rainfall resulted in flooding to low lying roads and land in **Kilkee**.

**Other flooding events**

Other flooding events of lesser magnitude have also occurred in **Kilkee** in October 1949 and August 1946. In **Kilrush**, other flooding events occurred in August 1986, January 1969, December 1968, October 1965, October 1949, December 1924 and October 1886. However, no details of the flooding are available.

**Recurrent Flooding**

In **Kilkee**, Church Street on the Carrigaholt Road in front of St Patrick's Terrace and Well Road car park were flooded when the Victoria Stream which flowed in an easterly direction just north of the R487 road overflowed its banks over a length of 200 to 300m. The road was impassable and the car park was closed due to runoff. Four to five houses were affected by the flooding. This apparently happens approximately once every year and the flooding situation is apparently exacerbated by tides and wind. It has been reported that the development in the Victoria Stream floodplain also worsened the situation by reducing the flood storage and increasing the runoff.

The R483 **Kilrush** Road is reported as being flooded on average once a year. The road remains passable and there are no houses affected. The flooding is apparently caused by the backing up of the Cooraclare River. According to the OPW Flood Hazard Mapping information, the river used to be cleaned and maintained by local landowners up to the late 1950's. The Cappagh Road (R473) was also flooded on the Cappagh side of the Creek Lodge Hotel to a maximum depth of 1.2m. The flooding caused the road to be impassable. The cause of flooding was reported as tidal but may be exacerbated by the operation of Marina lock gates which may have the effect of prolonging high water levels according to the OPW Flood Hazard Mapping information. This has apparently occurred on average once every two or three years.

The L7174 road was flooded circa 2000 apparently due to tidal back up from the estuary. Since the event, a flap valve has been installed at Ballycally and the problem has not recurred since (west of **Shannon** and **Shannon International Airport**).

# 9 Proposed Methodologies for Future Work

## 9.1 Introduction

Within the scope of works for the Inception report, the OPW requested that a detailed method statement be provided which sets out the datasets to be used and the approaches to be followed for the hydrometric gauging station rating reviews and in the derivation of design flows. These are provided below.

## 9.2 Hydrometric Gauging Station Rating Reviews

The OPW have identified two stations (ref. Table 3-G), located within the Shannon Estuary North, for which rating reviews are required. For each of these gauging stations an assessment of the quality and limitations of the flood flow data will be made and where necessary the rating adjusted to reduce the uncertainty associated with it. The ratings will be extrapolated to beyond the highest recorded levels and if possible to the highest design flow (0.1% AEP). The methods used are likely to vary between sites depending on the availability of gaugings, survey data and local controls. Section 9.2.2 describes the techniques to be used. For all gauging stations for which a rating review is required, a 1D hydraulic model will be developed. Where the floodplain is too complex to be characterised in 1D a 2D representation will be used based on topographic survey and 5m SAR data. The reach modelled will extend sufficiently downstream such that any backwater effects within the channel are accounted for, and upstream to take account of approach conditions that could influence the rating.

### 9.2.1 Data Required

All available data and information made available will be used to assess the quality and uncertainty associated with the high flow ratings. The analysis will build on the work undertaken by Hydro-Logic in 2007 using the information listed below:

- Check flow gaugings;
- Rating equations (historical and current) and associated dates;
- Cross sectional survey data.

### 9.2.2 Methodology

For the gauging stations, the upper range of the stage –discharge rating will be reviewed. A range of techniques will be employed to understand the quality and limitations of the high flow rating as detailed below:

A. An assessment of the quality of the spot flow gaugings, the range in levels over which they have been taken and the frequency of gaugings. This will determine the quality of the underlying data on which the rating is based.
B. Consideration of the limitations imposed by the gauging site i.e the cross section profile, stability, the presence of bypassing, backwater effects etc.
C. Goodness of fit of the rating (as measured by the standard error)
D. Identification of the upper limit in which reasonable confidence can be placed.
E. Identification of any recommendations made in previous review not yet completed.

The findings will be tabulated for each site and an overall classification given on a simple scale according to the confidence that can be placed in the high flow rating.

**Extension of Ratings**
For the two sites identified in the Brief, hydraulic modelling will be undertaken to extrapolate the stage discharge relationship to approximately 3 times the Qmed. Preliminary investigations of design flows suggest that the extended rating will include and exceed the 0.1% AEP design peak flow. At each target gauging station, extended cross sectional data will be input to the hydraulic modelling software to develop a representative hydraulic model of the reach and floodplain. The hydraulic model will be calibrated against the higher flow check gaugings and then used to develop one or more high flow rating equations.

## 9.3 Design Events

This section describes the data required, the methodology and the outputs from the proposed work to define the hydrological design flows. The design flows will be used in the hydraulic models, developed later in the project, to estimate extreme flood water levels. The method by which the design flows are used in the hydraulic models is also detailed.

### 9.3.1 Data Required

The following data will be required to complete the design flood estimates in accordance with the methodology set out below:

The following data will be required to complete the design flood estimates in accordance with the methodology set out below:

- Gauging station surveys for the rating reviews (from Survey Contractors);
- Hydraulic models of the gauging stations for rating review (2 gauges in UoM 27) (by Jacobs);
- Rating equations and spot flow gaugings for all gauges requiring rating review (from OPW);
- Hydrological and Hydrogeological volumes from the Ennis Main Drainage Report and Flooding Study (from Clare County Council);
- High flow rating reviews (by Jacobs);
- Agreement on the way forward with each of the catchment area boundary anomalies highlighted in this report (Jacobs/OPW);
- Hydrological Estimation Point definitions (by Jacobs).

### 9.3.2 Methodology

The dearth of sub-daily rainfall records for the catchment severely limits the application and accuracy of traditional rainfall runoff techniques. Rainfall runoff modelling has therefore been discounted. 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.

The method to be employed will draw upon the techniques set out in the Flood Studies Update (FSU) reports making best use of the gauged data to improve upon the estimates of Qmed, growth curves and the hydrograph shape.

The Hydrological Estimation Points (HEPs) will be determined in accordance with Jacobs Technical Note 10 and the lessons learnt from the trial areas (see Section 4).

The data from the gauging stations detailed in Table 9 of the Stage II Tender Brief will be subjected to high flow rating reviews and on the basis of the review deemed suitable or otherwise for Qmed estimation, derivation of a flood frequency growth curve and dimensionless hydrograph. Cognisance will be given to the gauges used in the FSU to develop the Qmed equation (4 in UoM 27, 1 of which will also be subject to rating review in this project) together with others assessed as being of sufficient quality and or others which become so after annual maximum flow series are reworked during the rating review.

The reaches of watercourse to be modelled in the two main catchments in UoM 27, the Fergus and Owenogarney (Ratty), are both served by flow gauges which ultimately, following the rating review, will be able to supply useful data to estimate Qmed and the dimensionless hydrograph shapes. The annual maximum flow series for the gauges are detailed on the summary sheets in Appendix H. Also detailed on these summary sheets are the preliminary estimates of Qmed and the dimensionless hydrographs for the highest recorded flows, prior to the rating review.

However, other watercourses to be modelled in the vicinity of Kilkee, Kilrush and Shannon do not have flow records and hence flood estimates in these watercourses will be prone to more uncertainty. Additionally, at each of these locations tidal influences also need to be taken into account.

Specific details of the methodology proposed for each of the main items of the design hydrology are presented below:

**Qmed**
The objective is to define Qmed at each HEP, in a manner that it is consistent with reliable gauged Qmed data. The method should ensure that the Qmed estimate increases with increasing catchment area unless there is good hydrological justification for this not being the case.

The use of pivotal gauges to refine catchment descriptor Qmed estimates at ungauged sites is, where appropriate, one of the best ways of improving design flow hydrology and is a critical part of the flood frequency estimation process.

The Qmed equation from FSU will be employed to estimate Qmed at each HEP. At gauging stations where we have confidence in the Qmed estimate at the site, following the rating review, this will be compared to the synthetic FSU Qmed estimate and correction factors established for all such gauges. These correction factors will then be applied across the catchment, in the manner described in FSU Report Work Package 2.3 *Flood Estimation in Ungauged Catchments* but importantly employing hydrological knowledge to better judge how to make these adjustments.

Urban adjustments in Ireland will generally be very small in comparison with rural runoff from the catchments discharging to the modelled reaches. A standard approach to taking account of urbanisation is included within the equations for estimating Qmed. With regard to land use change over long time horizons, for large rural catchments the impact of increased urbanisation will generally be extremely small, and will therefore generally be ignored in the derivation of flood discharges for future scenarios. Where catchment areas are small and urbanisation is likely to be

significant, urban adjustment to take account of future land use changes will be considered, and applied as necessary.

**Growth Curves**

The objective is to define a growth curve for each HEP, that is representative of growth curves derived from reliably gauged data, such that the extreme flood discharges increase with increasing catchment area unless there is a good hydrological justification for it not so doing.

Growth curves for Ireland are generally flat and consistent between areas, this reflects the wet nature of the catchments prior to large floods, which tend to be caused by the sequential passage of frontal rainfall systems over the catchments. The Flood Studies Report recommended a single growth curve for the whole of Ireland.

In UoM 27 the Gumbel (EV1) distribution fitted to the annual maximum series suggest growth factors to 1% AEP(Q100/Q2) of 1.6 to 2.2 for the area compared to that implied from the Flood Studies Report (FSR) of 2.06 (Q100/Q2). A growth factor of approximately 2 is very similar to that for the FSU rainfall estimates shown in Appendix D.

Two main approaches are considered to estimate suitable growth curves:

- Gauged annual maximum series fitted to a distribution which can then provide a growth curve for use in the catchment.
- A pooling group approach.

In a subsequent phase of this CFRAM study, Jacobs will decide on the most appropriate statistical distribution for design flood estimation for the unit of management (see Section 7.5). Based on FSU Work Package 2.2 the most likely candidates are the EV1 and lognormal distributions. We feel a consistent growth curve should be a priority for the area, as otherwise anomalies may arise in the magnitude of flood discharges for the more extreme floods as you move down the catchment. Such growth curve data would be examined on a catchment and sub-catchment wide basis to determine whether patterns exist to better inform the selection of an appropriate growth curve.

The procedures set out in FSU Work Package 2.2 will be followed for the pooling group approach. Following liaison with OPW it was decided that these pooling groups should typically contain approximately 500 years of AMAX data, based on the following two considerations:

1. the focus of the design hydrology should normally be on the 100-year design event (as specified by OPW on the National Technical Coordination Group Meeting of 19 June 2012); and
2. FSU Work Package 2.2 recommends that the number of years should be 5 times the design event return period.

Both methods will be trialled for the gauges in the first sub-catchment area to be considered in UoM 24. Based on the trial a decision will then be made as to which option to apply on the project in the remaining sub-catchment areas.

Growth Curves will be developed to allow the peak flows for design events to be estimated at each HEP for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% Annual Exceedance Probabilities (AEP).

**Hydrograph Shape/Volume**
The objective will be to use a hydrograph shape which is a reasonable representation of the gauged hydrograph shapes and volumes realised in the catchment. This will then be scaled to match the design flow for a given frequency, estimated as detailed above.

The options are to use a dimensionless hydrograph typical of the largest gauged floods, a non-parametric approach, or to employ a synthetic hydrograph shape where regression-based expressions are used to estimate the values of relevant hydrograph descriptors, following a parametric approach. Both methods are defined FSU in Report Work Package 3.1, Hydrograph Width Analysis.

Where gauged data exists, on the basis that it is better to use gauged data than synthetic data, the former approach will be employed. However, the prescriptive methods outlined in FSU for defining the typical hydrograph shape are rather involved and, given the uncertainties involved in the changing hydrograph shape throughout the catchment, a more subjective method of defining hydrograph shape is considered more appropriate.

On the Fergus and Owenogarney (Ratty) catchment modelled watercourses, there should be sufficient gauged data to allow gauged dimensionless hydrographs to be employed. A dimensionless hydrograph shape will be derived for each gauge following the rating review. The typical hydrograph shape broadly being the mean hydrograph shape from a number of the largest floods recorded at the site (similar to those shown on the gauging station summary sheets (see Appendix H).

For smaller ungauged catchments the FSU synthetic hydrograph methodology will be considered but our preference would be to use a suitable transfer of hydrograph shape from gauged hydrographs from catchments with similar catchment descriptors (using FSU descriptors) where possible, as that way gauged data is used to its full potential.

### 9.3.3 Output

The outputs from the design flood hydrology will be peak flow estimates at each HEP for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% Annual Exceedance Probabilities (AEPs) together with a defined typical flood hydrograph shape for each HEP.

### 9.3.4 Application to Hydraulic Models

The objective will be to produce a hydraulic model that reproduces the flood hydrographs estimated at each HEP within a reasonable degree of accuracy.

FSU Work Package 3.4, Guidance for River Basin Modelling, describes a method of estimating tributary inflows so as to preserve the flood frequency in the main watercourse when applying FSU techniques to a hydraulic model. However, this method, whilst no doubt appropriate for smaller scale models of a limited extent, will unavoidably lead to errors which will accumulate as different tributary flows contribute throughout a larger system.

We therefore propose an alternative method to preserve the flood frequency along the main watercourse to match the design hydrographs estimated at each HEP. This alternative method is described below and illustrated in Figure 16.

The reaches to be hydraulically modelled will be considered between tributary junctions or, where the space between these results in a difference in catchment area of more than 10%, at intermediate hydrological model nodes. These locations will be coincident with HEPs. Flood hydrograph estimates for the main watercourse immediately upstream of the tributary (Hydrograph B in Figure 16) and upstream of the next tributary/model node (Hydrograph D in Figure 16) will be established as described above (for Qmed, growth curve and hydrograph shape). The difference between the two hydrograph estimates, derived by subtracting the upstream flow estimate from the downstream flow estimate for each hydrograph ordinate, will form the inflow from the tributary/location (i.e. Hydrograph D minus Hydrograph B gives Hydrograph E in Figure 16). The hydraulic model is run with the tributary inflow (Hydrograph E) and inflow at the upstream node (Hydrograph A). The resulting hydrograph from the model (Hydrograph D') is then compared to the hydrograph originally estimated at the downstream nodel (Hydrograph D in Figure 16). The timing of the tributary inflow hydrograph (Hydrograph E in Figure 16) has to be adjusted by trial and error in running the hydraulic model to account for the travel time in the modelled reach. The target is that the peak flow differences are less than approximately 5% (Hydrograph D' compared to Hydrograph D) and that the timing is representative. Additional nodes can be inserted and lateral inflows added (with flows derived using the same method as described here for tributary inflows) to reduce the error between nodes where appropriate. In this manner the design hydrograph peak and shape are preserved within a reasonable degree of accuracy throughout the model. The system is then repeated for any other tributaries requiring inflows to be modelled.

The approach has been successfully applied to the Lower River Thames for the Thames Region of the Environment Agency in the UK.

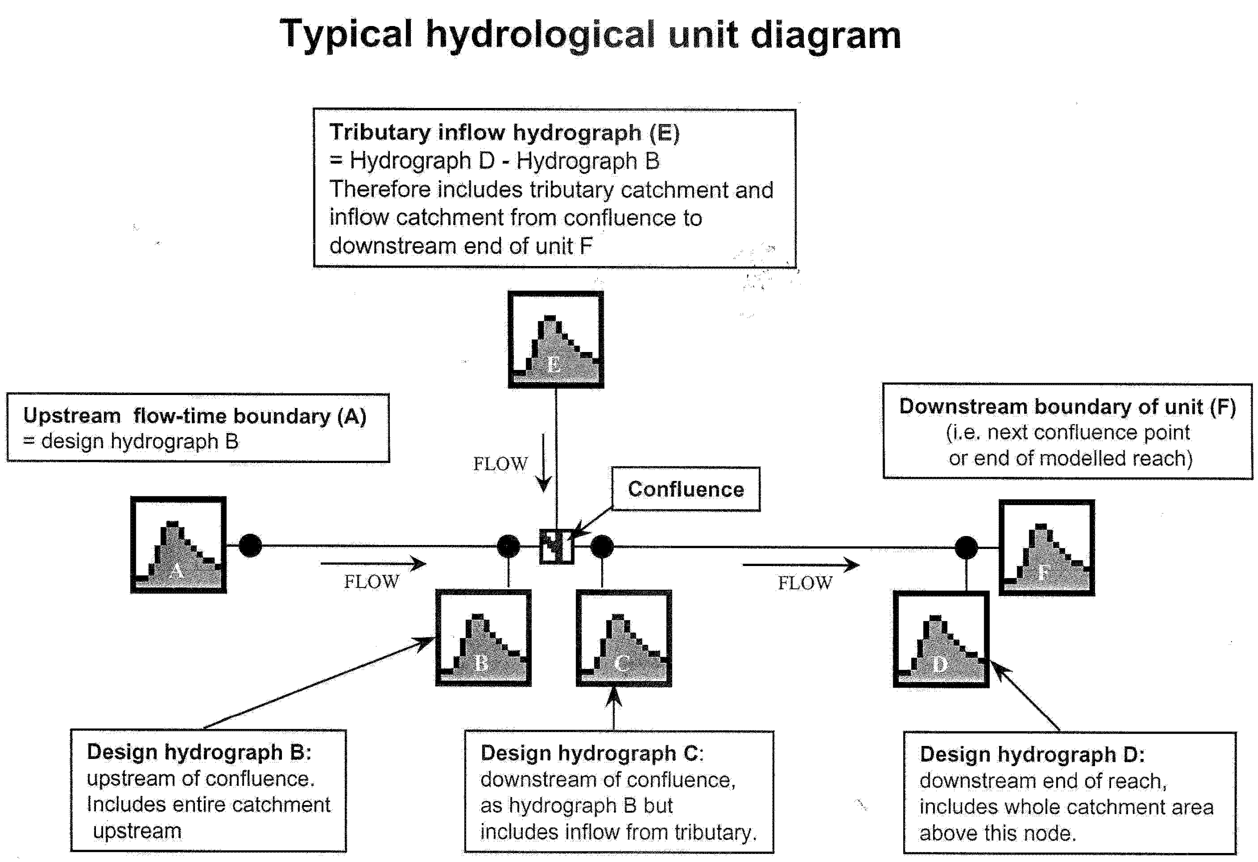



*Figure 16 Typical Model Hydrograph Method*

## 9.4 Joint Probability

Section 6.5.6 of the Brief requires a joint probability analysis. However, Section 7.5.2.1 requires mapping to indicate fluvially dominated extents and tidally dominated extents, and a merged map showing both.

Joint Probability is a complex issue that would benefit from the pooling of ideas and concepts from all members of the NTC Group. We therefore suggest that the most appropriate methodology is discussed and agreed through the NTC Group forum. This will ensure a consistent approach is adopted. However, the Group is not yet fully developed and functioning. There remains a need to resolve the combinations of flows and sea levels to be run, as we have commenced modelling and require the information in order to proceed with the study.

Jacobs will therefore make use of the results of the Joint Probability Analysis carried out by Halcrow for the Lee Catchment study. Halcrow followed the Defra/EA guidance on joint probabilities and adopted a conservative approach, assuming a high level of dependence between surge and fluvial levels. The study resulted in a joint probability table, which gives design scenarios (in the form of pairs of fluvial and tidal exceedance probabilities) for each joint probability. For each joint probability two design scenarios are given, representing the fluvially dominated and the tidally dominated conditions. All tidally affected hydraulic models will be run with both design scenarios for each joint probability, and the highest water level will be adopted as the design level.

## 9.5 Hydraulic Model Calibration

A proposed approach to hydraulic model calibration was set out in Section 7.4.2 of the Jacobs Stage 1 Tender Response. We propose to follow this methodology.

The limited amount of short duration rainfall data available in the region indicates that rainfall-runoff modelling will not provide the required confidence in the temporal distribution of rainfall and hence flows. We shall therefore make best use of any reliable observed data to calibrate the hydraulic models, where this exists.

The hydraulic models will provide design flood flow and level frequency estimates that can be compared with gauged and observed data, and/or implied flood frequency, as a check on the modelled estimates. These comparisons are a vital reality check on the model, particularly where flood data is sparse.

## 9.6 Coastal Flood Modelling

### 9.6.1 Tide and Surge

OPW have provided the results from the Irish Coastal Protection Strategy Study (ICPSS). This gives extreme tidal peak levels for the following annual probabilities: 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.1% for the south western coast and the Shannon Estuary.

Tidal curves will be generated using mean spring tidal cycles obtained at Carrigaholt, Foynes and Limerick from the Shannon Foynes Port Company and the Admiralty Report. To develop the extreme tide/surge hydrographs, a surge event of 30 hrs will be assumed. Then ICPSS extreme peak levels together with the

assumed surge event profile and the mean spring tide levels will be used to create the tide/surge hydrographs associated with each annual probability event. This process is illustrated on Figure 17. The Mean High Water Springs (MHWS) tide levels will be chosen according to the geographic position of the sites under consideration relatively to the three tidal record locations mentioned above.

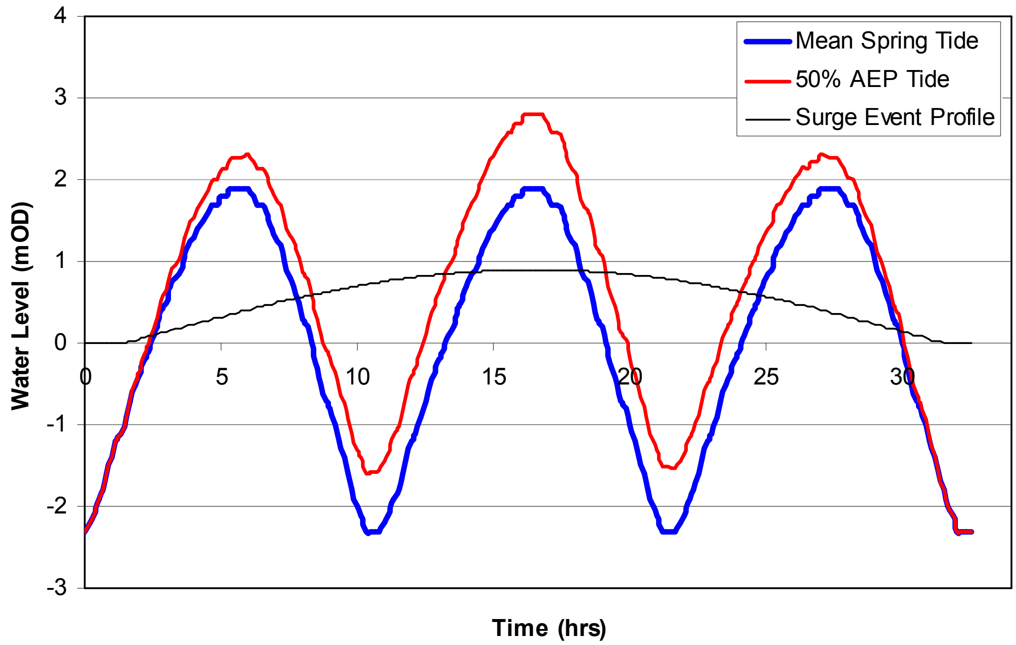



***Figure 17 Tide/Surge Hydrograph***

For model sections where both tidal levels and fluvial flows affect the risk of flooding, a joint probability approach will be needed. This is discussed in Section 9.4.

### 9.6.2 Wave Overtopping

Wave overtopping will be considered separately from tidal overtopping for tide/surge events where the tide+surge levels for the design events under consideration do not cause overtopping of the coastal defences, but the additional wave action would cause a flow across the defences that has the potential to cause flooding.

OPW has provided results from the ICWWS (Irish Coastal Wave & Water Level Modelling Study) screening analysis which highlight coastal locations potentially vulnerable to wave overtopping for the south western coast and the Shannon estuary.

For these locations, detailed wave and still water level model outputs are available in the form of shoreline prediction points and their associated predicted water level and wave climate (wave height $H_{mo}$, period $T_p$ and mean direction) combinations for a range of annual probabilities (50%, 20%,10%, 5%, 2%, 1%, 0.5% and 0.1%). These outputs include both the current condition and two future scenarios (Mid Range Future Scenario [MRFS] and High End Future Scenario [HEFS]).

ICWWS data will be used in the coastal flooding models developed for this study to simulate flooding from wave overtopping of coastal defences for the design flood events.

The following paragraphs detail the proposed methodology to simulate flooding from wave overtopping using the coastal flooding models developed for this study.

**Site selection**
OPW has supplied eight locations which are potentially vulnerable to wave overtopping, and where modelling has been requested to simulate flooding arising from wave overtopping of coastal defences. These sites are:

- AFAs: Limerick, Shannon, Kilrush, Kilkee, Foynes and Tralee
- IRRs: Shannon Airport and Tarbert Power Station

For those sites for which appropriate data ia provided, in agreement with OPW, we will undertake wave overtopping modelling. At each site, coastal defences are likely to vary in height, type and orientation relative to the mean direction of the incident waves. We will divide the coastal defences prone to wave overtopping in discrete reaches of similar characteristics and allocate a wave prediction point according to its geographic proximity and the mean direction of the incident waves.

**Wave characteristics selection for the selected reaches of coastal defence**
For each flood event annual probability, ICWWS data consists of six combinations of extreme coastal water levels with predicted significant wave heights ($H_{mo}$), peak wave period ($T_p$) and mean wave direction. We will choose one combination for which the extreme water level is the closest to the average elevation of the stretch of defence identified whilst remaining below it. We will then calculate the mean overtopping discharge (in $m^3$/s per m of coastal defence length) associated with the wave characteristics and the type of flood defence (sea dikes, embankments, vertical wall) involved. This calculation will be undertaken using the online tool available from the Overtopping Manual (EurOtop, 2007).

**Generating a wave overtopping discharge hydrograph for the selected reaches of coastal defences**
As quoted from the overtopping manual, "*in reality there is no constant discharge over the crest of a defence during overtopping. The process of wave overtopping is very random in time and volume*". A simplified approach is proposed here to generate a wave overtopping discharge hydrograph (flow vs. time) that will be input in the coastal flooding model at the landward side of the structure.

As illustrated in Figure 18 below, a wave overtopping discharge hydrograph will be generated assuming a 30-hour storm surge duration. Overtopping will occur when the selected wave height superimposed on the tide level exceeds the average elevation of the defence. During these overtopping periods, half of the mean overtopping discharge calculated above will be applied. This is because the wave height is at a maximum at the peak of the tide, but reduces to zero either side of the peak. On average, half the overtopping flow computed at peak tide can be assumed to flow over the defence, between the time of initial overtopping (some time prior to the peak tide) to the time overtopping ceases (some time after the peak tide). The time over which overtopping occurs is dependent on the tidal level and wave height selected.

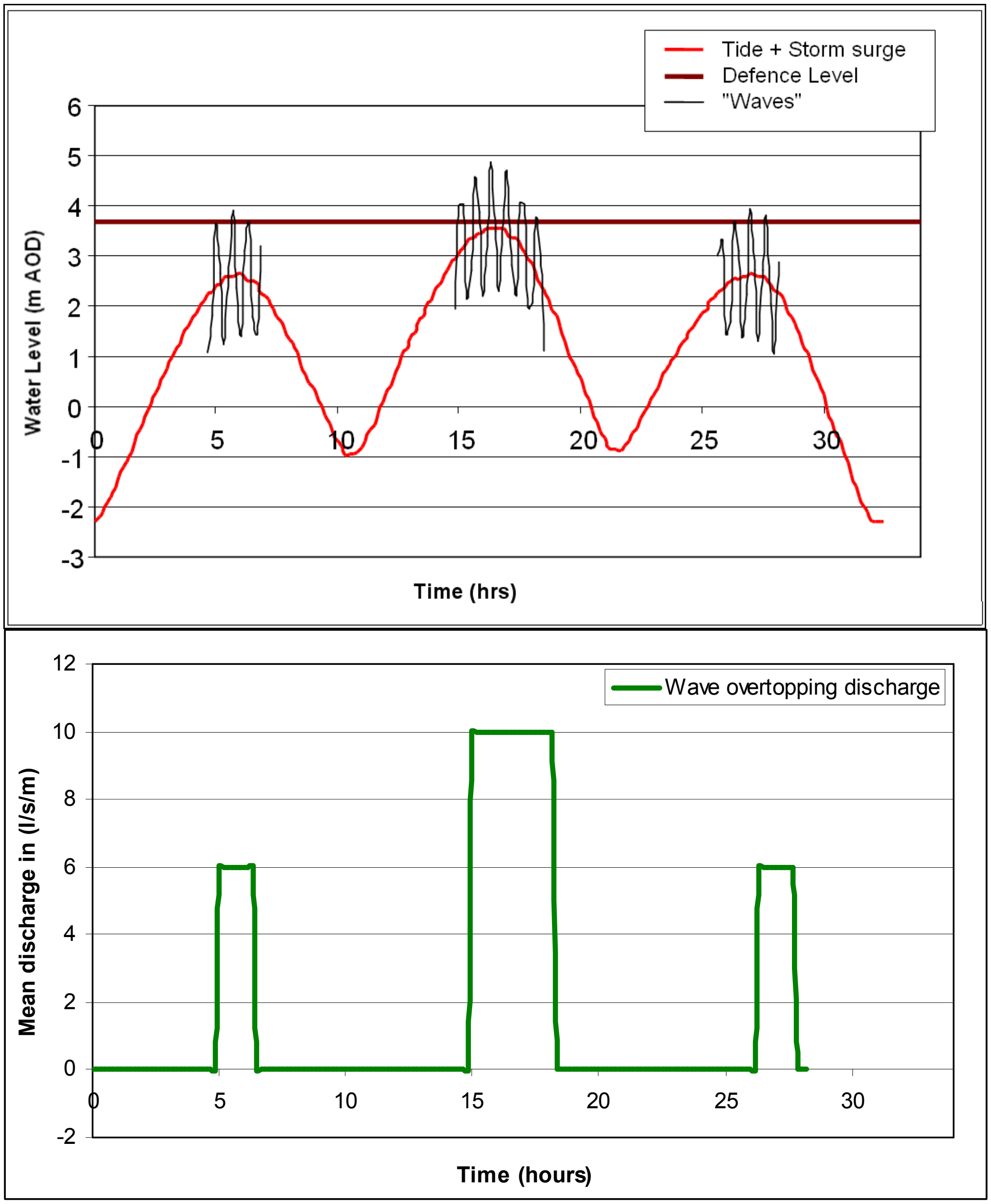



***Figure 18 (a and b) Wave overtopping hydrograph***

It should be noted that if, for a given annual probability event, the tidal levels for all six wave - water level combinations (as described above) exceed the average elevation of the coastal defence reach, no simulation of flooding arising from wave overtopping will be carried out for this event. This is because the results will be represented by the separate tidal inundation modelling.

# 10 Constraints, Data Problems and Other Issues

A complete list of gauging stations for which data is available can be found in Appendix A.

As outlined in Section 3.2 data collation at this stage has focused on the key hydrometric stations, but where data has not been provided for other stations, this may still be requested at a later stage in the project. A single daily and instantaneous flow and level series for the key hydrometric stations identified in Section 3.2 has not yet been received (Table 10-A). Confirmation of whether the relevant data series exists is requested in the first instance.

Although there is unlikely to be any cost implication associated with the lack of provision of the data below, any lack of data may have an impact on the uncertainty and quality of the derived flood flow estimates and hydraulic model calibration all of which are programmed to be undertaken in the next phases of the project.

| Station number | Data holder | Daily mean flows outstanding | Instantaneous flow data outstanding | Staff gauge readings outstanding | Check gaugings outstanding | Rating equations outstanding |
|---|---|---|---|---|---|---|
| 27001 | OPW | | | | | |
| 27002 | OPW | | | | | |
| 27003 | OPW | | | | | |
| 27011 | OPW | | | | | |
| 27013 | EPA | | | Yes | | |
| 27023 | OPW | | | | | |
| 27024 | OPW | | | | | |
| 27025 | OPW | | | | | |
| 27026 | OPW | | | | | |
| 27028 | OPW | | | | | |
| 27060 | OPW | | | | | |
| 27066 | OPW | Yes | Yes | | | |
| 27092 | OPW | | | | | |

***Table 10-A Outstanding hydrometric data for Shannon Estuary North (UoM 27)***

In the process of reviewing the available daily mean flow and level series, trends in the data series (Section 7.3) were identified at two out of the four stations, 27001 and 27002. These trends may be indicative of external factors or reflect actual trends in the flow and/or level series. In addition, step changes were identified in the other two stations, 27003 and 27011. Any feedback on these issues from the data managers the OPW would be useful to ensure maximum confidence in using the associated flows in future work.

The lack of sub daily rainfall data for the Unit of Management precludes the use of rainfall-runoff modelling. Alternative methods are proposed, as set out in Section 9 of this report. These may give rise to difficulties in future use to examine the potential impacts of land use change, although sensitivity analysis could be used to overcome these difficulties.

# 11 Conclusions

A significant proportion of the Shannon Estuary North Unit of Management is underlain by limestone. The Burren, with its characteristic karst landscape features and the virtual absence of any surface water features is known to extend over the northern portion of the unit of management. A dominant baseflow regime, typically associated with highly permeable landscapes is often exhibited by a slow responding and attenuated peak flow.

In order to avoid abortive work the definition of Hydrological Estimation Points (HEPs) has been postponed until the Flood Risk Review has been completed and the final list of Areas of Potential Significant Risk agreed with OPW. However, the results of a trial application of the proposed method to define HEP are presented herein together with lessons learned.

Catchment areas, defined using a range of datasets, have been compared and the comparison reported where catchment areas to gauging stations, Communities at Risk and Individual Risk Receptors exceed 10%. The discrepancies identified have been documented herein such that the way forward can be agreed with OPW before the design hydrology commences.

A review of rainfall and flow gauges in the catchment has been undertaken and specific flood events studied to better understand the data and provide a hydrological understanding of the data for use in subsequent phases of the project.

Seven Met Éireann daily storage raingauges have been identified within the Shannon Estuary North Unit of Management. Sub-daily rainfall data was available at one location, Shannon Airport.

Two rainfall events across the unit of management have been studied; December 1999 and November 2009.

Rainfall depths calculated for a range of durations 1 hour, 2 hour, 6 hour, 12 hour (at Shannon Airport only) and 1-day (or 24 hour at Shannon Airport), 2-day, 4-day (or 96-hour at Shannon Airport) and 10-day, suggest that both events were the result of winter depressions, characterised by a moderately intense rainfall event preceded by prolonged rainfall.

Annual exceedance probabilities for the 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 96 hour were estimated at Shannon Airport and for 1 day and 4 day durations estimated at the three daily raingauges, based on probability plots developed from annual maxima series derived from the rainfall record. The analysis indicates that the majority of rainfall events were typically around the annual or median (once every two years) events with an AEP of around 50% or greater. The lowest annual exceedance probability estimated was 1% for a 4 day rainfall depth at station 1218 during the December 2009 event. AEPs estimated for the daily and sub-daily rainfall durations at Shannon Airport indicate that the rainfall totals recorded during the December 1999 or November 2009 were relatively frequent events and that it was the longer 96-hour rainfall totals which were more infrequent.

Annual exceedance probabilities estimated from actual data for the 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 96 hour durations at Shannon Airport and 1 day and 4 day durations at the remaining three daily raingauges. These AEPs were compared

to theoretical AEPs for the corresponding 1 hour, 2 hour, 6 hour, 12 hour, 24 hour and 4 day durations created for the Flood Studies Update. FSU AEPs were higher for the 1 day and identical for the 4-day rainfall depths at station 1218 and lower at 2018 and 5311. At Shannon Airport the estimated AEPs and FSU AEPs were greater than 50% for all durations with the exception of 96 hours (or 4 days), where for both events the estimated AEP and the FSU AEP were the same or very close. Any differences in AEP estimates may reflect the fit of the EV1 distribution selected here compared to the log logistic growth curve assumed in the FSU.

Fluvial data has been analysed for the Shannon Estuary North Unit of Management. Initially, daily mean flows, where available for four hydrometric gauging stations, were reviewed for long term errors or trends. Trends in water level and/or flow were observed at 27001 between 1972 and 1991 and over the entire period of record at 27002. A step change in 1984 is evident in the flow series at 27003. At station 27011 the flow series post-2007 appears to higher following an extended period of missing data.

Instantaneous flow data was provided for four gauging stations. Two flood events were selected across the unit of management to analyse the series in detail. Event selected were:

- 24 - 28 December 1999;
- 19 - 24 November 2009;

Hydrographs from 27001 indicate a highly responsive catchment as demonstrated by the steep rising limbs and recessions. Flows gauged at 27002, 27003 and 27011 indicate the presence of attenuating factors, likely to be both groundwater and on-line storage, such that the hydrograph at 27002 typically has no flashy component to it at all. This can largely be attributed to the influence of the karstic landscape and the dominance of baseflow on the flow regime in the upper reaches of the Fergus catchment.

The highest peak flow in the three events was 80.6 $m^3/s$ recorded on the 24th November 2009 at Ballycorey on the River Fergus (27002).

Runoff within the Shannon Estuary North Unit of Management was highest at station 27003 located within the headwaters of the River Fergus.

Annual exceedance probabilities estimated for each event suggested a range of values across the catchment. Based on the annual maxima series, as advised by the OPW, the lowest AEP estimated was 0.5% for the River Fergus at Ballycorey for peak flows recorded during the November 2009 event. However, this is based on an annual maxima series of 37 years. The AEP estimated at 27001 (on a tributary to the Fergus) was 8%.

Methodologies for the hydrometric gauging station rating reviews procedure will be applied to two gauges in the catchment and for the design flow estimation methods have been proposed together with the design event hydrological methodology to be adopted for the study. A traditional rainfall-runoff modelling approach is not considered practical due to the lack of short duration rainfall data within the catchment.

Historic flood event information was collated as part of the inception study. The majority of the information was gathered from the “Floodmaps” database. The

information available was summarised in this report and will be available for later stages of the CFRAM study.

Consideration of the tidal issues has concluded that Joint Probability is a complex issue that would benefit from the pooling of ideas and concepts from all members of the NTC Group. We therefore suggest that the most appropriate methodology is discussed and agreed through the NTC Group forum. This will ensure a consistent approach is adopted.

JACOBS

# 12 References


Compass Informatics (2009), *Preparation of Digital Catchment Descriptors*, Flood Studies Update, Work Package 5.3, January 2009

Dunsmore, S.J. (2007), River Thames Flood Hydrology Design Curves. Water and Environment Journal. Vol. 11 (1), pp 67-71

EPA (2011), *Register of Hydrometric Stations in Ireland*,
Website: http://www.epa.ie/downloads/pubs/water/flows/name,12745,en.html
(Accessed March 2011)

EPA *Hydronet* Website
Website: http://hydronet.epa.ie/introduction.htm (Accessed March - June 2011)

Hydro-Logic Ltd (2006), *Review of flood flow ratings for Flood Studies Review*, Work Package 2.1, Flood Studies Update

Jacobs (2011), Preliminary Hydrological Assessment and Method Statement, Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study, Unit of Management Shannon Estuary South (UoM 24).

JBA Consulting (2009), *IBIDEM (Interactive Bridge Invoking the Design Event Method)*, Flood Studies Update, Work Package 3.5, July 2009

JBA Consulting (2010), *Guidance for River Basin Modelling* (Revised Final Report), Flood Studies Update, Work Package 3.4, June 2010

Kiely, G., Leahy, P., Fenton, M., Donovan, J. (2008), *Flood event analysis,* Flood Studies Update, Work Package 3.2, University College Cork, Hydromet Research Group, Centre for Hydrology, Micrometeorology and Climate Change

Met Éireann (2007), *Estimation of point rainfall frequencies*, Flood Studies Update, Work Package 1.2

Murphy, C. (2009), *Flood Estimation in Ungauged Catchments*, Flood Studies Update, Work Package 2.3, Irish Climate Analysis and Research Units (ICARUS), Department of Geography

National University of Ireland (2009), *Frequency analysis*, Flood Studies Update, Work Package 2.2, Department of Engineering Hydrology and The Environmental Change Institute, Galway

Office of Public Works (2009), *Base Flow Index derived from soils* (Draft Final Report), Flood Studies Update, Work Package 5.2, August 2009

Office of Public Works *Floodmaps* Website
Website: http://www.floodmaps.ie/ (Accessed March to July 2011)

Office of Public Works *Hydro- Data* Website
Website: http://www.opw.ie/hydro/ (Accessed March to July 2011)

O'Connor, K.,  Goswami, M. (2009), *Hydrograph Width Analysis*, Flood Studies Update, Work Package 3.1, National University of Ireland (2009), Department of Engineering Hydrology Environmental Change Institute

Ragneborn-Tough, L., Pybus, M.J. & Pybus, C. (1999) A Hydrographic Study of Lough Bunny, Co. Clare. *Biology and Environment: Proceedings of the Royal Irish Academy*, 99B, 3, pp/ 191-196. Royal Irish Academy, URL. (Accessed via http://www.jstor.org/stable/20500066)
Reed, D.W. (2007), *PROPWET for Ireland: a dimensionless index of typical catchment wetness*, Flood Studies Update, Work Package 5.4, May 2007

University College Dublin (2006), *Scoping Study of Urban Flooding Issues*, Flood Studies Update, Work Package 4.1, Centre for Water Resources Research, October 2006

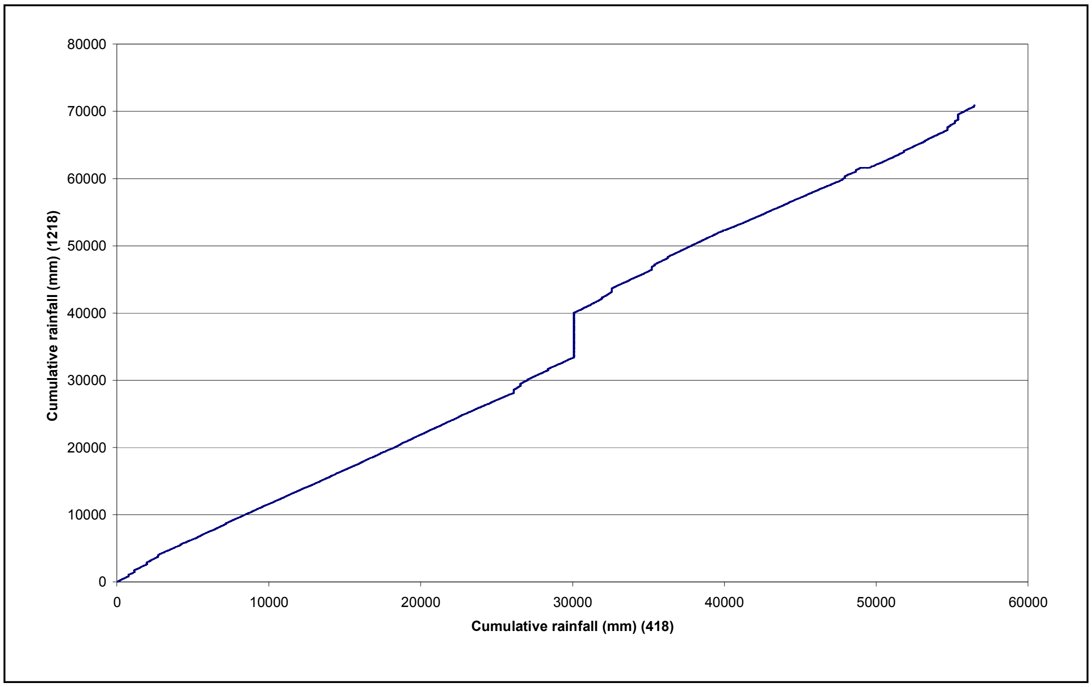
# Appendix A - All Hydrometric Stations listed in EPA Register

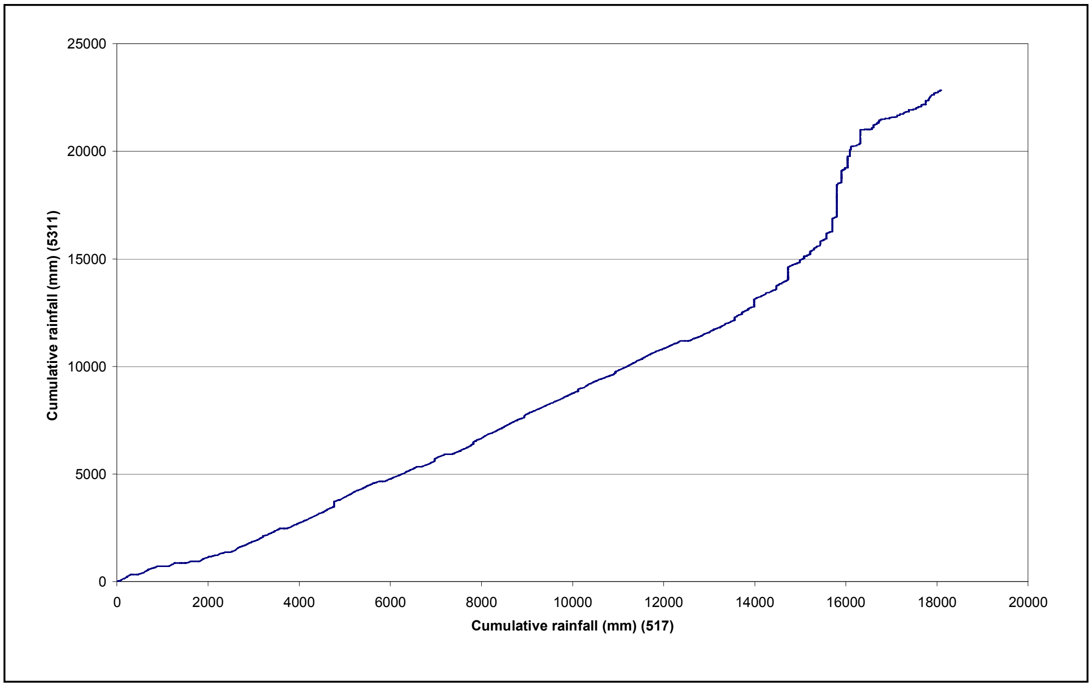
| Station Number | Station Name | Waterbody | Catchment Area ($km^2$) | Station Status | Station Type | Data Available | BDS | Easting | Northing | Type | Record Start | Record End | Telemetry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27001 | Inch Br. | Claureen | 46.7 | Active | Recorder | Water Level and Flow | Office of Public Works | 130159 | 175321 | River | 01-Jul-57 | | Yes |
| 27002 | Ballycorey | Fergus | 511.4 | Active | Recorder | Water Level and Flow | Office of Public Works | 134431 | 180323 | River | 01-Apr-54 | | Yes |
| 27003 | Corrofin | Fergus | 166.4 | Active | Recorder | Water Level and Flow | Office of Public Works | 128653 | 188589 | River | 01-Oct-57 | | No |
| 27004 | Carnelly | Manus | 15.8 | Active | Recorder | Water Level and Flow | Office of Public Works | 136813 | 173481 | River | 01-Jan-79 | | Yes |
| 27005 | Cratloemoyle | Cratloe Creek | 6.6 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 151950 | 159862 | River | 12-Sep-80 | 25-Oct-94 | No |
| 27006 | Carrowniska | Crompaun | 35.6 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 110767 | 156554 | River | 18-Feb-82 | 24-Jan-91 | No |
| 27007 | Ballyvohane | Stream | 11.7 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 124106 | 158774 | River | 06-Dec-80 | 31-Jul-92 | No |
| 27008 | Clondagad | Ballycorick | 47.7 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 127204 | 166000 | River | 19-Mar-81 | 25-Oct-91 | No |
| 27009 | Poplar Br | Fergus | 138.3 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 127127 | 191118 | River | 27-Aug-76 | 12-Aug-82 | No |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | 161.8 | Active | Recorder | Water Level and Flow | Office of Public Works | 147964 | 164870 | River | 03-Nov-94 | | Yes |
| 27013 | Kilrush | Wood | 17.9 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 99668 | 154886 | River | 28-Jun-84 | 28-Sep-95 | No |
| 27021 | Ardsolus | Quin | 113.4 | Inactive | Staff Gauge Only | Flow Measurements | Office of Public Works | 140128 | 172201 | River | | | No |

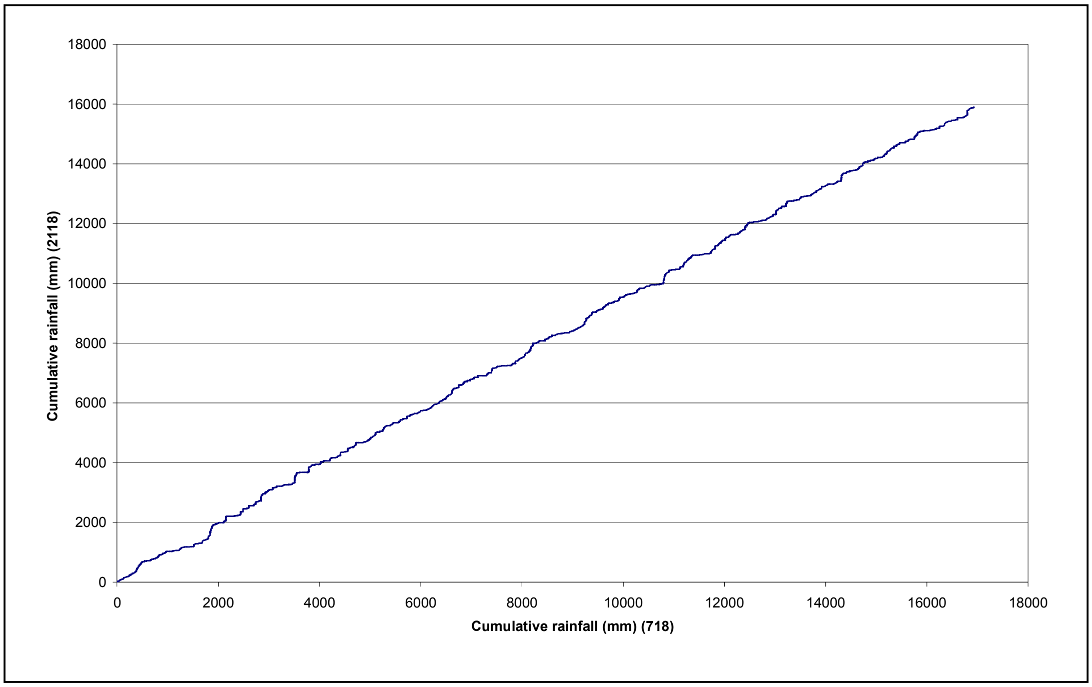
| Station Number | Station Name | Waterbody | Catchment Area ($km^2$) | Station Status | Station Type | Data Available | BDS | Easting | Northing | Type | Record Start | Record End | Telemetry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27022 | Cullaun Br | O/L L. Cullaun | 14.2 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 147818 | 175307 | River | 18-Aug-80 | 09-Jul-92 | No |
| 27023 | Victoria Bridge | Fergus | | Active | Recorder | Water Level Only | Office of Public Works | 133293 | 177935 | River | 19-Jun-02 | | No |
| 27024 | Mill Bridge | Fergus | | Active | Recorder | Water Level Only | Office of Public Works | 133410 | 177739 | River | 19-Jun-02 | | No |
| 27025 | Knoxs Bridge | Fergus | | Active | Recorder | Water Level Only | Office of Public Works | 134527 | 177876 | River | 17-Jun-02 | | No |
| 27026 | Tulla Road Bridge | Fergus | | Active | Recorder | Water Level Only | Office of Public Works | 134645 | 178517 | River | 17-Jun-02 | | No |
| 27028 | Gaurus Bridge | Gaurus | | Active | Recorder | Water Level Only | Office of Public Works | 136018 | 178282 | River | 18-Jun-02 | | No |
| 27060 | Doora Br | Fergus | 608.2 | Active | Recorder | Water Level Only | Office of Public Works | 134873 | 176825 | Tidal | 17-Jun-02 | | No |
| 27061 | Crows Br. | Fergus Esty | | Inactive | Staff Gauge Only | Flow Measurements | Office of Public Works | 135855 | 176844 | Tidal | | | No |
| 27062 | Carrigaholt | Shannon Esty. | | Active | Recorder | | LHC | 84950 | 151278 | Tidal | | | No |
| 27064 | Clarecastle u/s | Fergus Esty | | Active | Recorder | Water Level Only | Office of Public Works | 135139 | 174425 | Tidal | 01-Sep-47 | 01-Dec-90 | Yes |
| 27065 | Clarecastle d/s | Fergus Esty | 625.5 | Active | Recorder | Water Level Only | Office of Public Works | 135133 | 174414 | Tidal | 01-Sep-50 | 01-Dec-90 | No |
| 27066 | Ennis Br. | Fergus Esty | 58.3 | Active | Recorder | Water Level and Flow | Office of Public Works | 133910 | 177721 | Tidal | 01-Aug-80 | | Yes |
| 27068 | Clarecastle Bridge | Fergus | | Active | Recorder | Water Level Only | Office of Public Works | 135218 | 174218 | Tidal | 18-Jun-02 | | No |

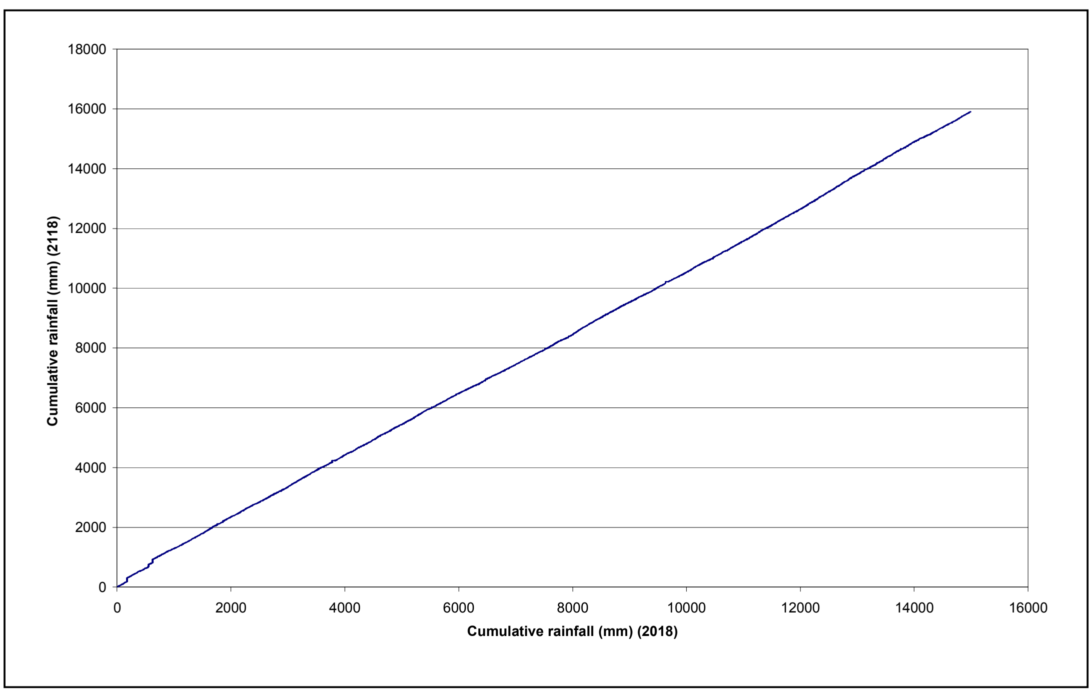
| Station Number | Station Name | Waterbody | Catchment Area (km$^2$) | Station Status | Station Type | Data Available | BDS | Easting | Northing | Type | Record Start | Record End | Telemetry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27070 | Baunkyle | L. Inchiquin | 143.6 | Active | Recorder | Water Level Only | Clare County Council | 127224 | 189375 | Lake | 11-Nov-76 | | No |
| 27071 | Cullaun | Cullaun L. | 22.9 | Inactive | Recorder | Water Level Only | Clare County Council | 147626 | 174682 | Lake | 31-Oct-81 | 22-Dec-86 | No |
| 27072 | Blean | Gortglass L. | 2.2 | Inactive | Staff Gauge Only | Flow Measurements | Clare County Council | 122623 | 159978 | Lake | 06-Dec-80 | 18-Aug-82 | No |
| 27073 | Inchicronan Lough | Inchicronan Lough | 28.6 | Active | Recorder | Water Level Only | Clare County Council | 139874 | 186620 | Lake | 17-Dec-09 | | No |
| 27090 | Cappahard | Gaurus Flood plain | 27.7 | Inactive | Recorder | No Data Recorded | Clare County Council | 134966 | 177143 | River | | | No |
| 27092 | Gaurus Landfill | Drain | | Active | Recorder | Water Level Only | Office of Public Works | 135425 | 177422 | Drain | 18-Jun-02 | | No |

# Appendix B - Double Mass Rainfall Plots

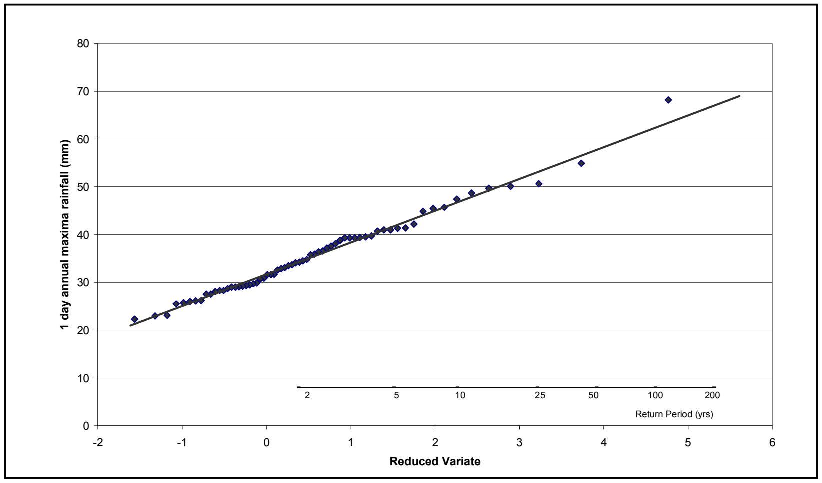


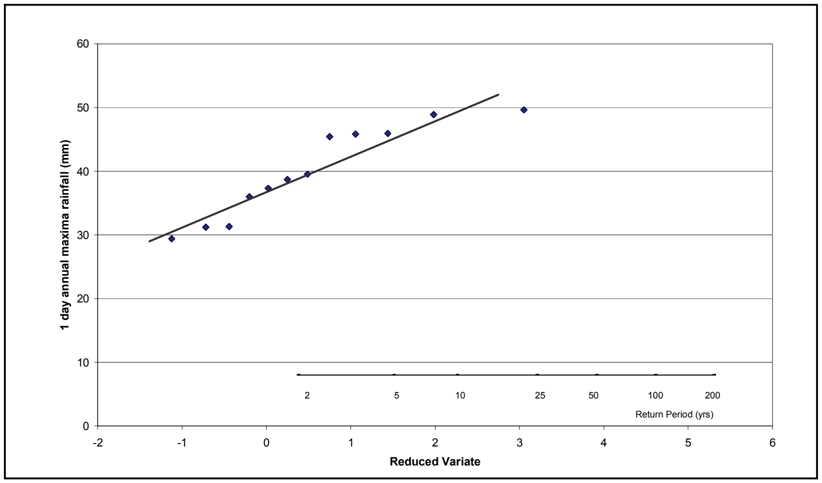

Cumulative rainfall (mm) (2118)
Cumulative rainfall (mm) (718)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000


Cumulative rainfall (mm) (2118)
Cumulative rainfall (mm) (2018)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000

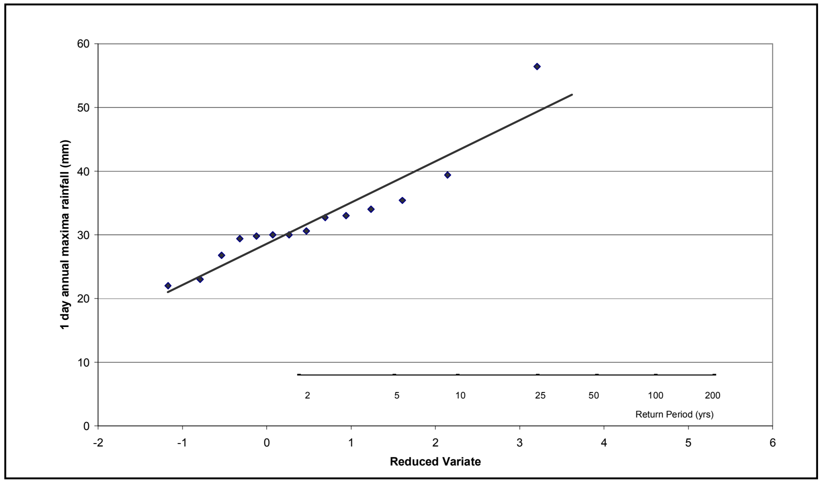
# Appendix C - 1-day and 4-day Rainfall Probability Plots



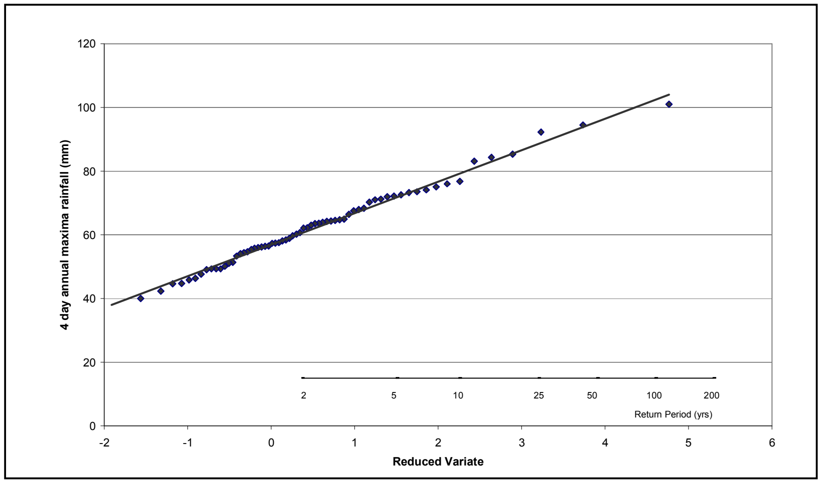

a) Raingauge 1218 – Tulla – 1 day duration



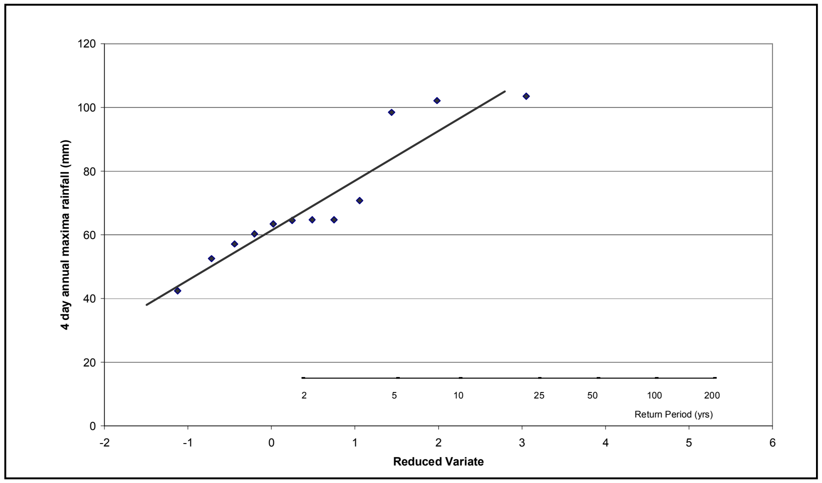

b) Raingauge 2018 – Carheeny Beg - 1 day duration



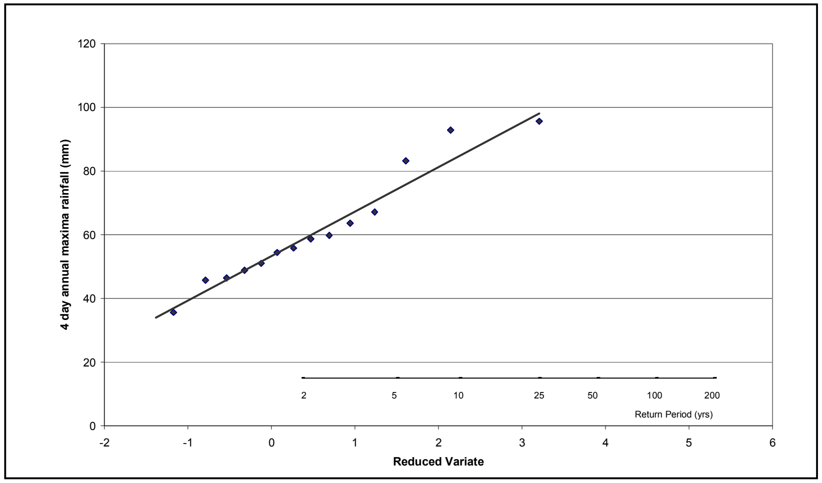

c) Raingauge 5311 – Moneypoint E.S.B - 1 day duration



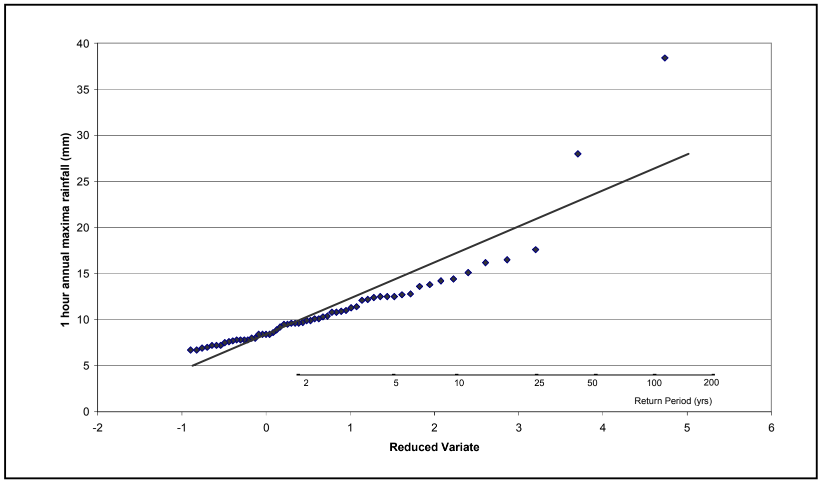

d) Raingauge 1218 – Tulla – 4 day duration



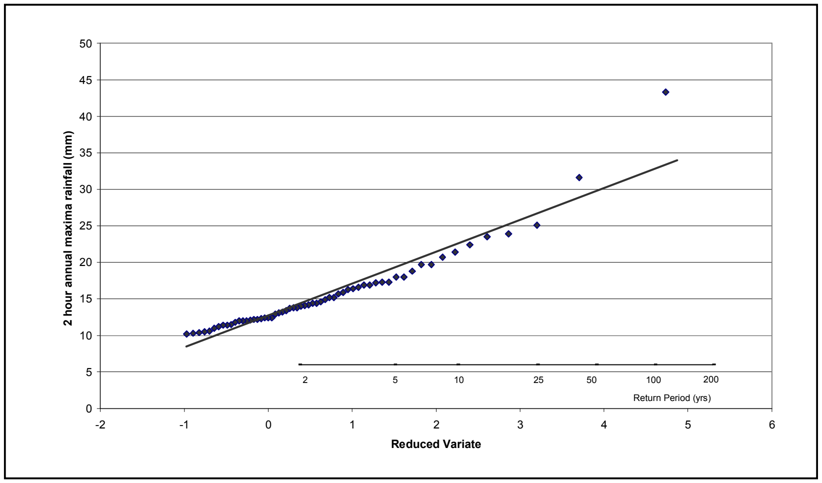

e) Raingauge 2018 – Carheeny Beg – 4 day duration



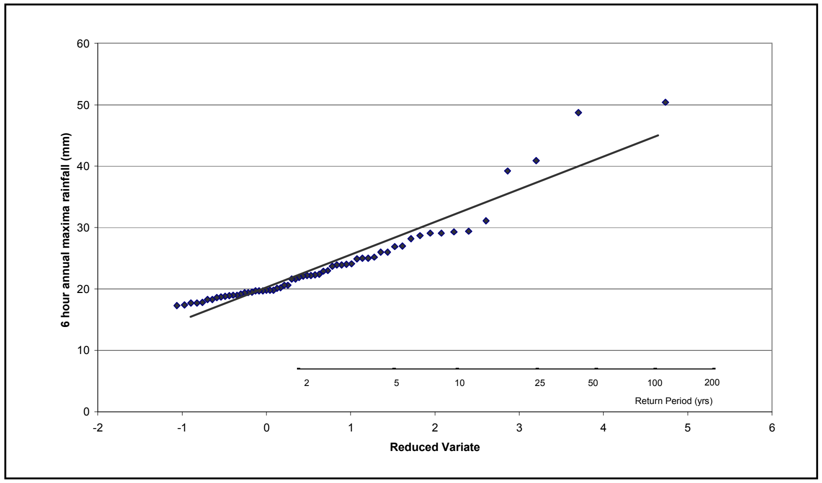

f) Raingauge 5311 – Moneypoint E.S.B – 4 day duration



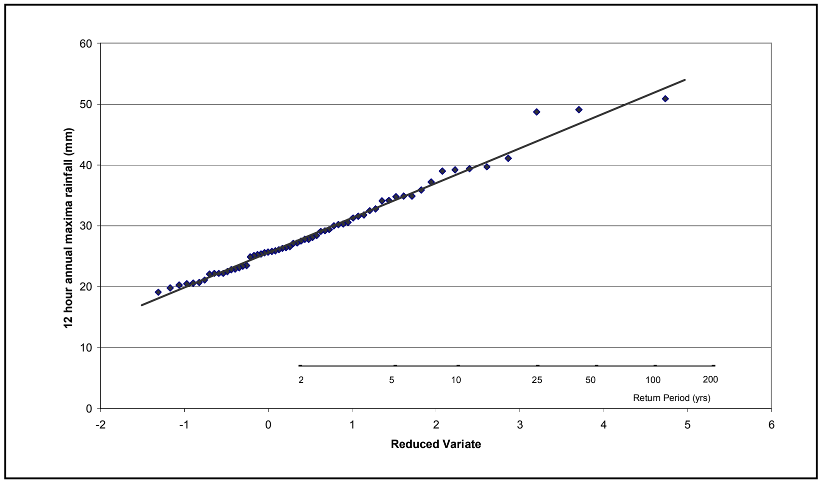

g) Raingauge Shannon Airport – 1 hour duration



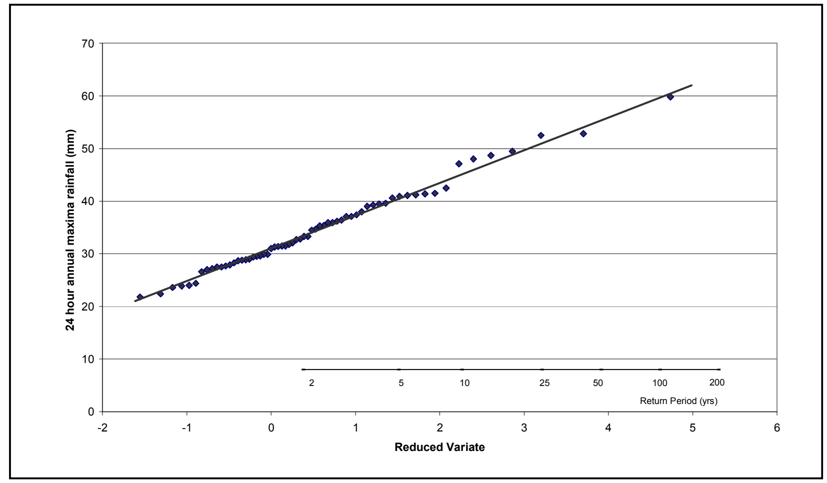

h) Raingauge Shannon Airport – 2 hour duration



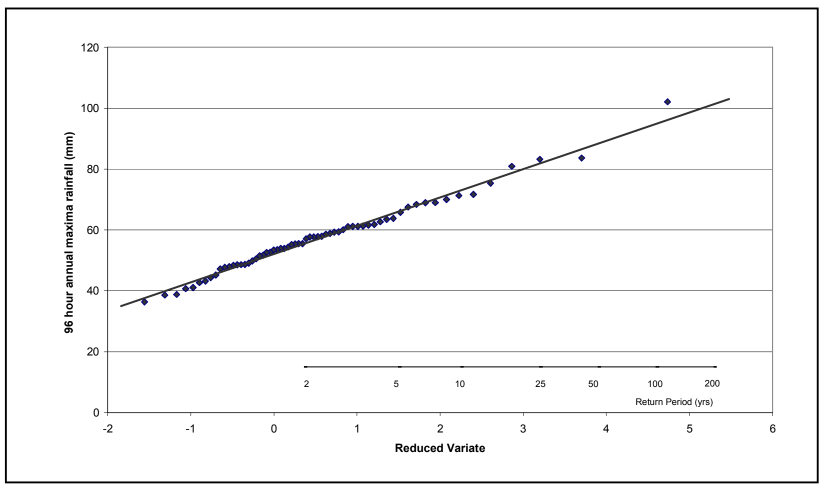

i) Raingauge Shannon Airport – 6 hour duration




j) Raingauge Shannon Airport – 12 hour duration



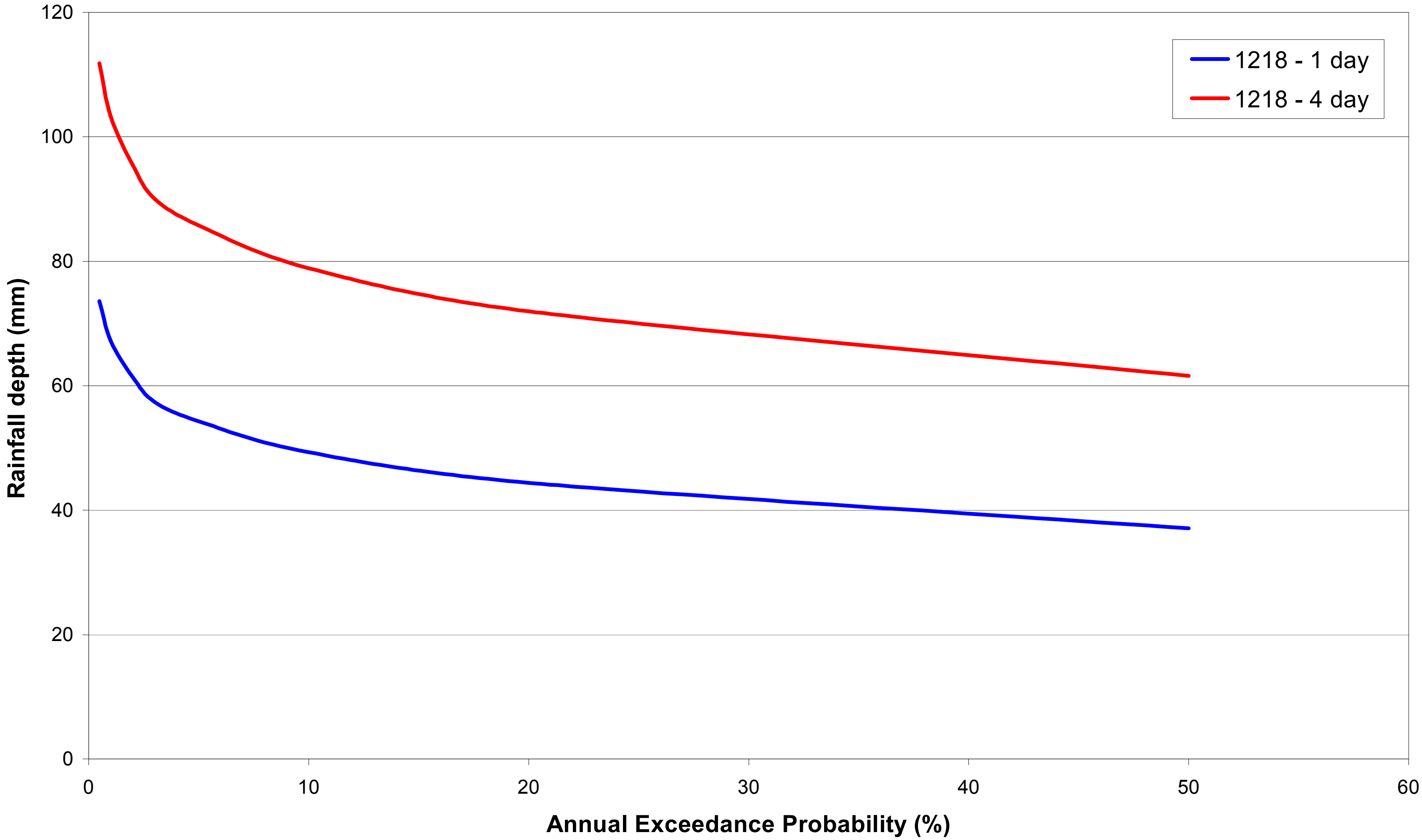

k) Raingauge Shannon Airport – 24 hour duration



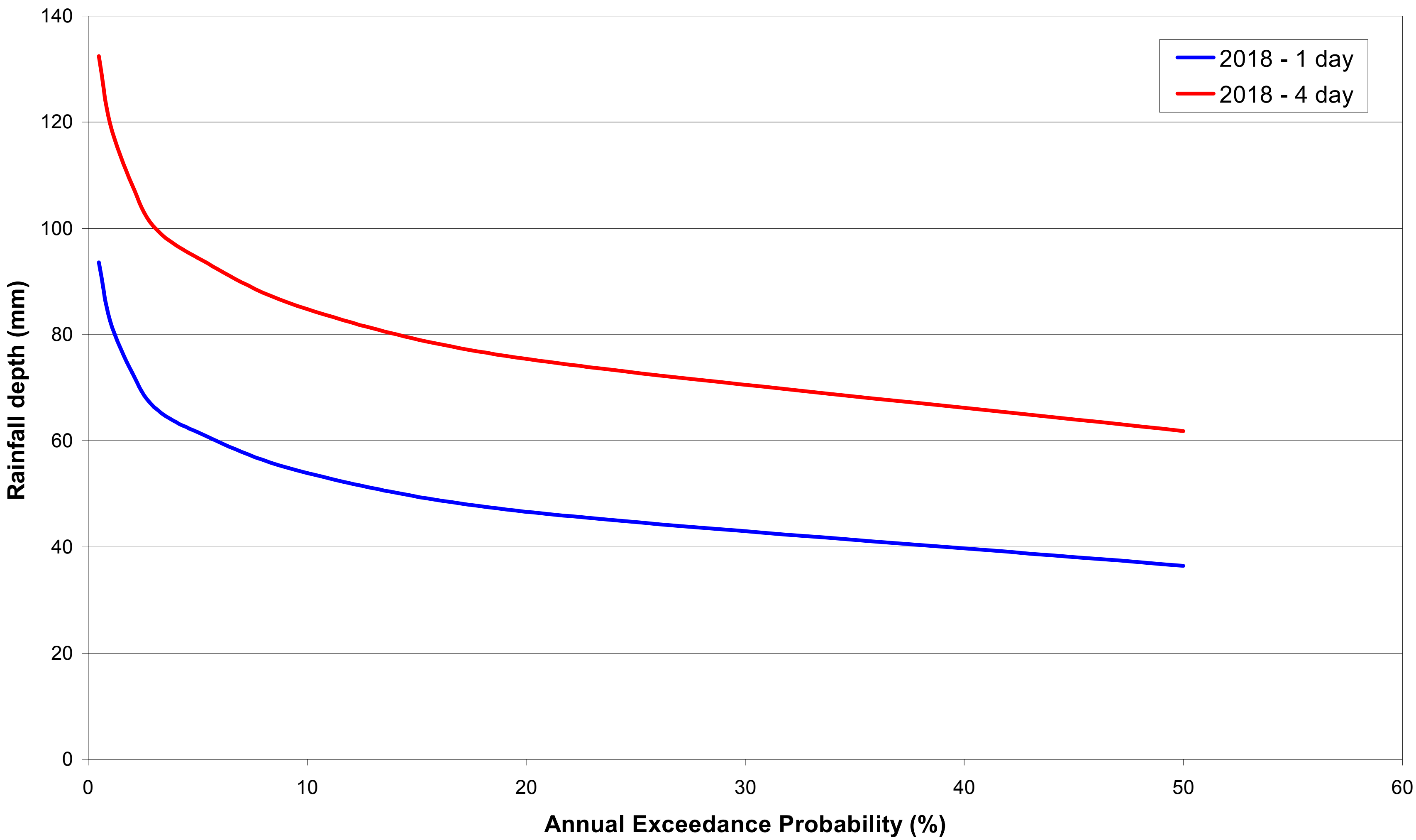

l) Raingauge Shannon Airport – 96 hour duration

# Appendix D - FSU Depth Duration Frequency Plots

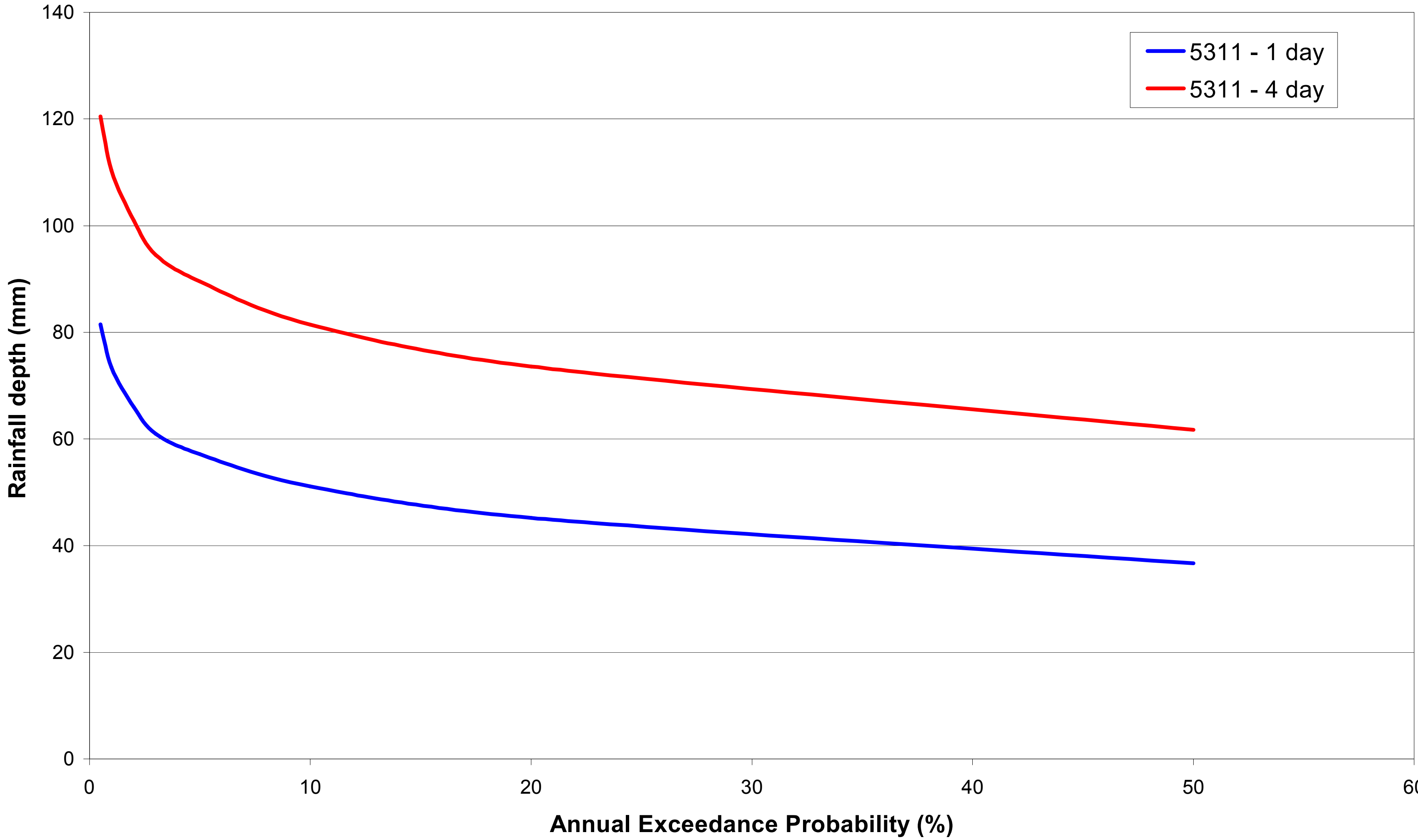
Depth Duration Frequency Curves for raingauge 1218 (based on data from FSU Workpackage 2.2)



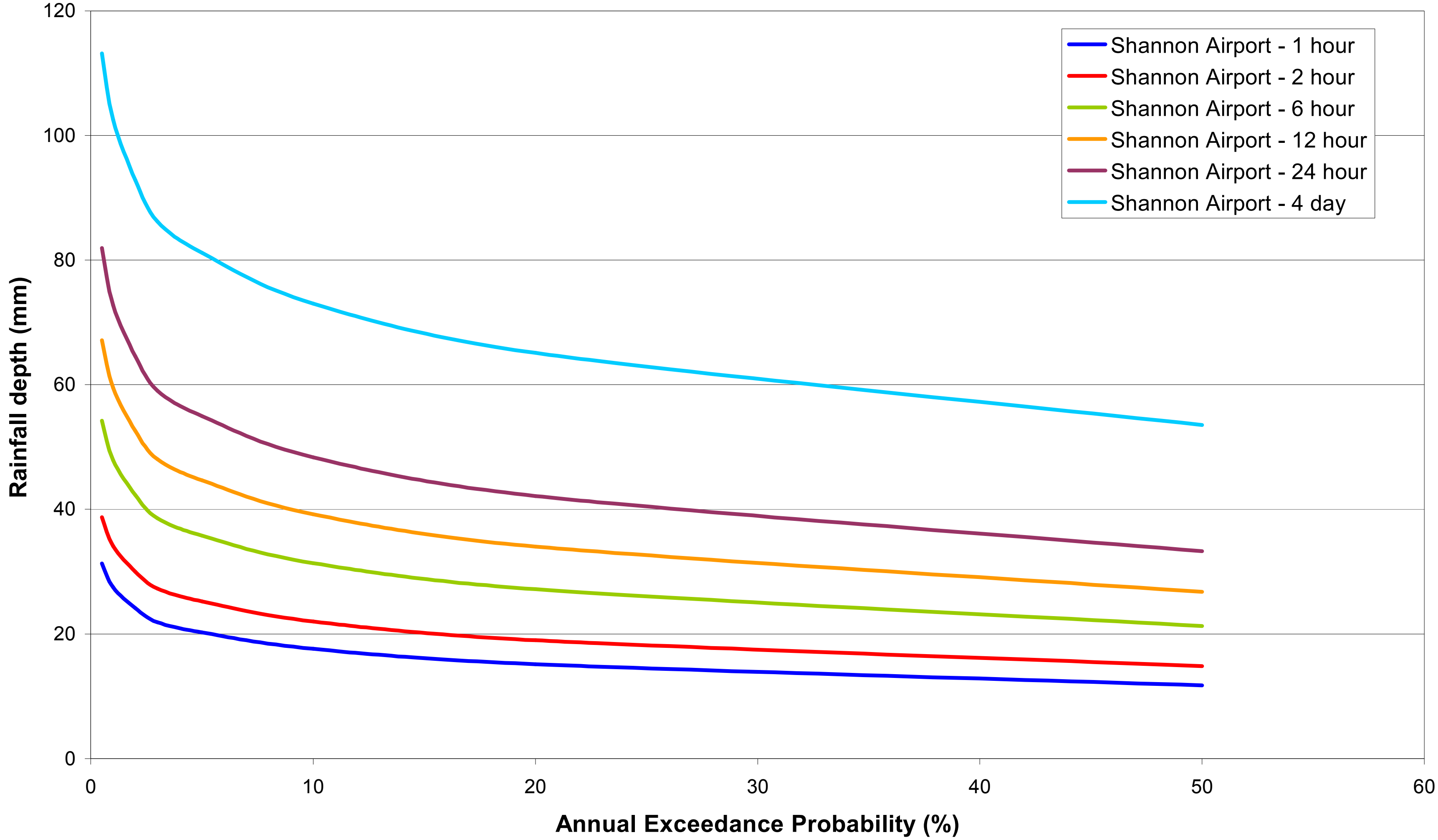
Depth Duration Frequency Curves for raingauge 2018 (based on data from FSU Workpackage 2.2)



Depth Duration Frequency Curves for raingauge 5311 (based on data from FSU Workpackage 2.2)



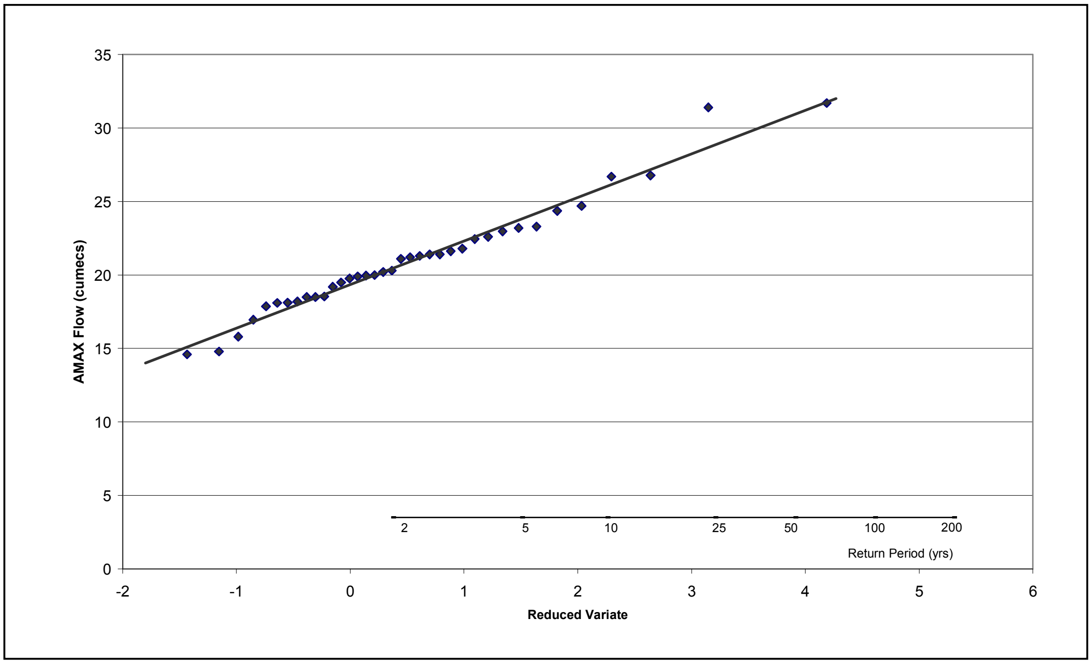
Depth Duration Frequency Curves for raingauge Shannon Airport (based on data from FSU Workpackage 2.2)



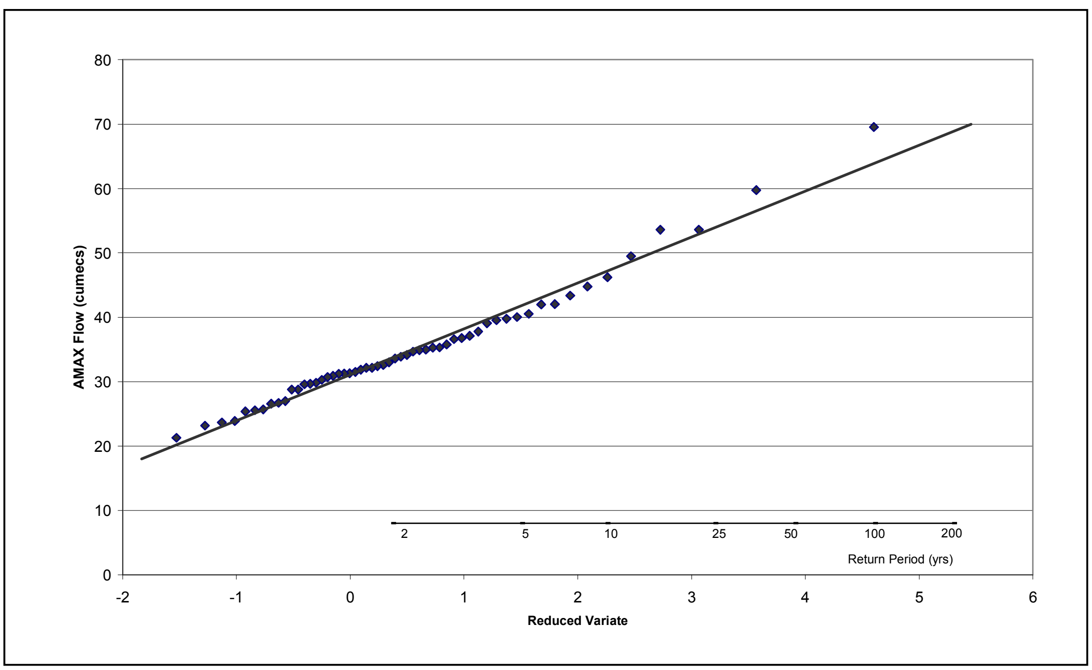
# Appendix E - Daily Mean Flow Review

| Station number | Station name | River | Daily mean flow start | Daily mean flow end | Daily mean level start | Daily mean level end | Daily Flow data only: No. of good days | No. of fair days | No. of poor days | No. of beyond limit days | No. of unchecked days | No. of cautionary days | No. of missing days | Quality code not known | Total no. of days | Daily Level data only: No. of good days | No. of beyond limit days | No. of unchecked days | No. of cautionary days | No. of missing days | Quality code not known | Total no. of days | Comment on visual inspection of record |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27001 | Inch Br. | Claureen | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 | 4176 | 492 | 3975 | 0 | 0 | 54 | 1165 | 3997 | 13859 | 12938 | 0 | 54 | 0 | 867 | 0 | 13859 | Trend of rising water levels 1972 to 1991. Step down change in water level 1993. Possible reduction in high flows from 1991 onwards. |
| 27002 | Ballycorey | Fergus | 01/01/1956 | 12/01/2010 | 01/06/1954 | 12/01/2010 | 19343 | 0 | 0 | 0 | 0 | 3 | 342 | 48 | 19736 | 19922 | 0 | 48 | 3 | 342 | 0 | 20315 | Gradual trend of rising levels and flows along entire period of record (1954 to 2010). Suspicious level value (27/3/01) |
| 27003 | Corrofin | Fergus | 01/10/1972 | 31/12/1999 | 01/10/1972 | 27/02/2005 | 3406 | 2035 | 952 | 0 | 0 | 0 | 3560 | 0 | 9953 | 10477 | 0 | 204 | 0 | 1157 | 0 | 11838 | Obvious step change in flow series in 1984 (not reflected in level series - rating?). Flow series post-1984 frequently missing data. |
| 27011 | Owenogarney (Rly) Br. | Owenogarney | 03/02/1997 | 11/01/2003 | 03/02/1997 | 09/09/2010 | 0 | 770 | 0 | 15 | 0 | 979 | 405 | 0 | 2169 | 366 | 15 | 2466 | 0 | 2117 | 3 | 4967 | Potentially post 2007 discontinuity |

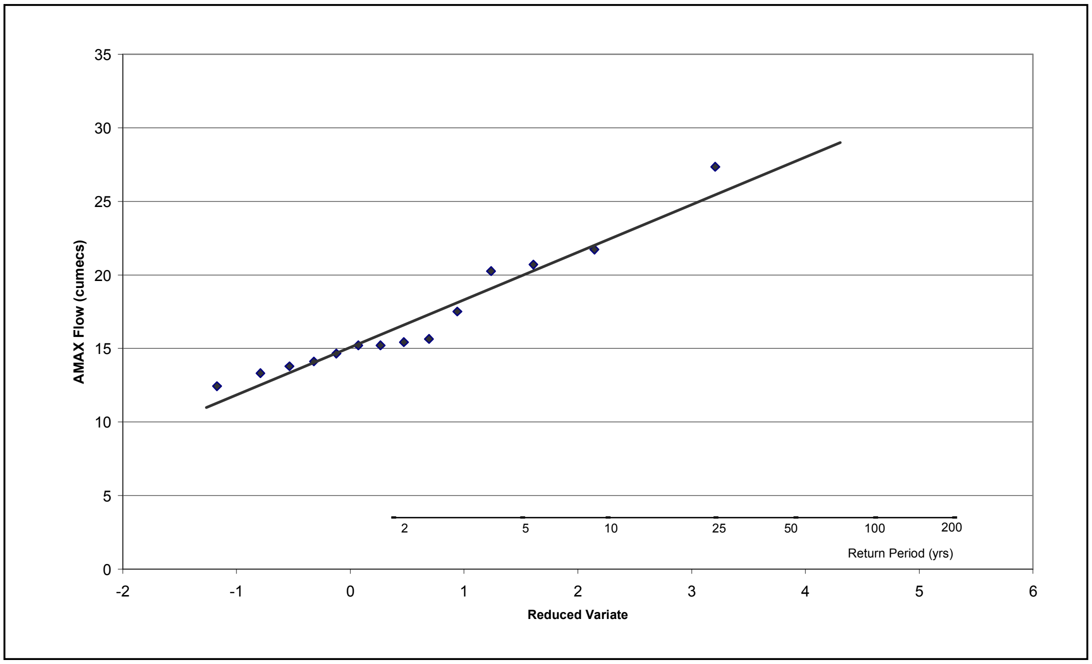
## Appendix F - Flood Frequency Probability Plots




Hydrometric station 27001




Hydrometric station 27002




Hydrometric station 27011

JACOBS

# Appendix G - Catchment Boundary Discrepancies

The data used to assess the catchment boundary discrepancies is provided to OPW using the Sharepoint file sharing system.

# Appendix H - Gauging Station Summary Sheets

# 27001 – CLAUREEN AT INCH BR.

**Annual Maxima Series** (Source: OPW)

| Hydrological Year | 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 | 21.2 | 12/11/1972 |
| 1973 | 26.7 | 29/11/1973 |
| 1974 | 19.9 | 22/01/1975 |
| 1975 | 21.4 | 09/01/1976 |
| 1976 | 15.8 | 12/10/1976 |
| 1977 | 21.4 | 21/04/1978 |
| 1978 | 23.2 | 15/11/1978 |
| 1979 | 21.8 | 04/09/1980 |
| 1980 | 18.5 | 14/11/1980 |
| 1981 | 22.6 | 18/06/1982 |
| 1982 | 20.3 | 14/12/1982 |
| 1983 | 20.2 | 09/12/1983 |
| 1984 | 24.7 | 14/08/1985 |
| 1985 | 31.4 | 06/08/1986 |
| 1986 | 21.3 | 18/11/1986 |
| 1987 | 18.1 | 14/08/1988 |
| 1988 | 19.2 | 11/04/1989 |
| 1989 | 19.5 | 23/01/1990 |
| 1990 | 14.6 | 24/02/1991 |
| **1991** | **31.7** | **05/01/1992** |
| 1992 | 14.8 | 21/11/1992 |
| 1993 | | |
| 1994 | 23.3 | 27/01/1995 |
| 1995 | 21.1 | 26/10/1995 |
| 1996 | 20.0 | 04/08/1997 |
| 1997 | 18.5 | 06/03/1998 |
| 1998 | 18.2 | 21/10/1998 |
| 1999 | 19.8 | 24/12/1999 |
| 2000 | 18.5 | 26/10/2000 |
| 2001 | 17.0 | 19/02/2002 |
| 2002 | 17.9 | 29/10/2002 |
| 2003 | 18.1 | 15/01/2004 |
| 2004 | 23.0 | 07/01/2005 |
| 2005 | 22.4 | 21/09/2006 |
| 2006 | 21.6 | 26/10/2006 |
| 2007 | 20.0 | 06/12/2007 |
| 2008 | 24.4 | 23/08/2009 |
| 2009 | 26.8 | 19/11/2009 |

**Length of AMAX series:** 37 years

1993 - channel works undertaken

**Gauging Authority:** Office of Public Works

| | |
|---|---|
| **Easting:** 130159 | **Northing:** 175321 |
| **Catchment:** Fergus | **Telemetry:** Yes |
| **Station Type:** Recorder | **Catchment Area:** 46.70 $km^2$ |

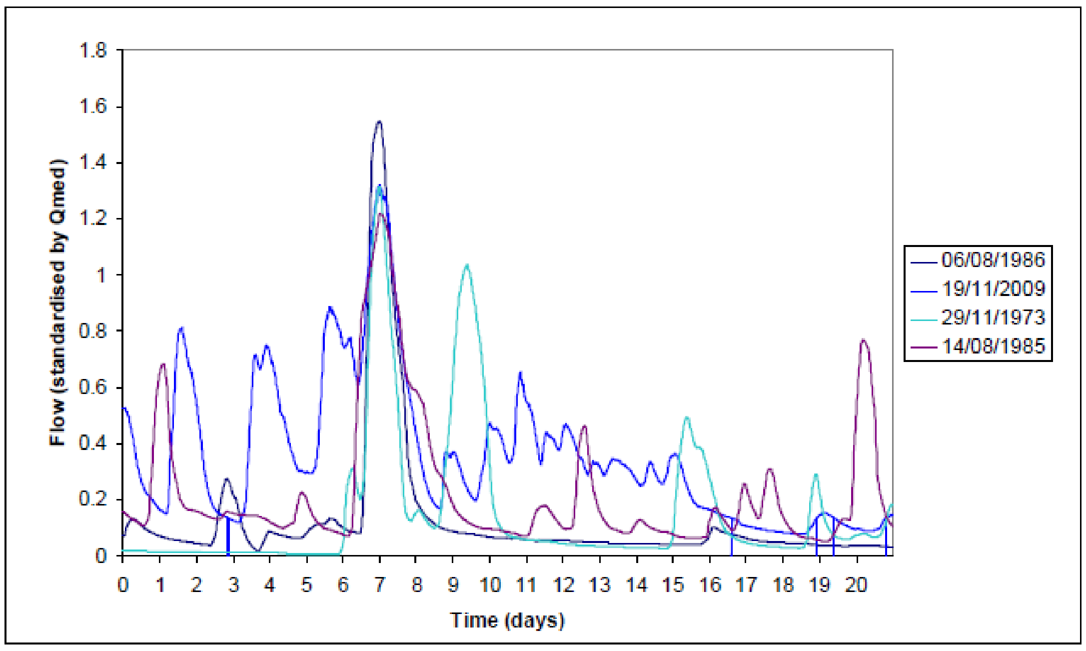
| | |
|---|---|
| **QMED (gauged):** 20.30 $m^3/s$ | **AREA (FSU):** 46.70 $km^2$ |
| **QMED (FSU):** 18.50 $m^3/s$ | **SAAR (FSU):** 1476.89 |
| **QMED (predicted):** 27.92 $m^3/s$ | **FARL (FSU):** 0.99 |
| **BFIsoils (FSU):** 0.33 | **S1085:** 4.45 |
| **URBEXT:** N/A | **ARTDRAIN2:** 8.00 |
| **DRAIND:** 1.79 | |

**Comments:** Automated velocity-area station installed in 1939 and automated in 1957. Unstable gravel bed. Natural channel control.

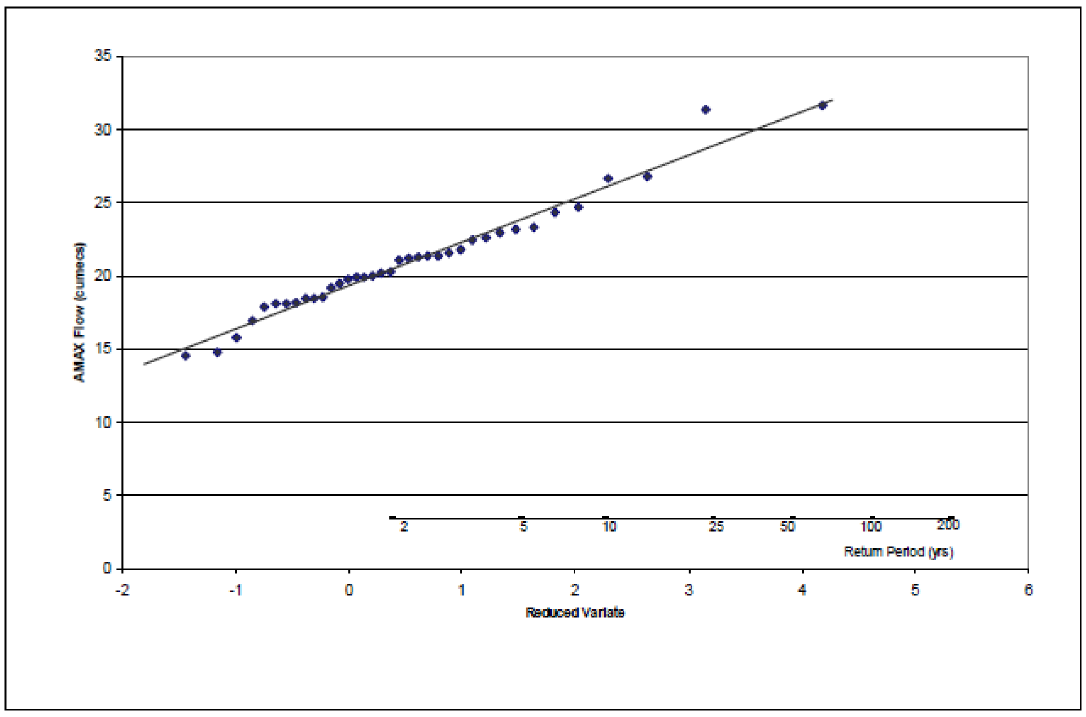
**Nearby APSRs**: To be confirmed

| | |
|---|---|
| **Jacobs Rating Review required:** Yes | **OPW Station Classification:** A2 |

Normalised Hydrographs




Flood Frequency (EV1 with Gringorten plotting positions)




Last Updated: May 2011

# 27002 – FERGUS AT BALLYCOREY

**Annual Maxima Series** (Source: OPW)

| Hydrological Year | Flow ($m^3/s$) | Date |
|---|---|---|
| 1946 | | |
| 1947 | | |
| 1948 | | |
| 1949 | | |
| 1950 | | |
| 1951 | | |
| 1952 | | |
| 1953 | | |
| 1954 | 39.6 | 12/12/1954 |
| 1955 | 23.6 | 30/01/1956 |
| 1956 | 33.6 | 05/01/1957 |
| 1957 | 31.8 | 04/11/1957 |
| 1958 | 21.3 | 07/01/1959 |
| 1959 | 59.8 | 30/12/1959 |
| 1960 | 39.1 | 08/02/1961 |
| 1961 | 32.4 | 13/12/1961 |
| 1962 | 23.9 | 16/12/1962 |
| 1963 | 31.3 | 28/11/1963 |
| 1964 | 40.0 | 16/12/1964 |
| 1965 | 32.1 | 18/12/1965 |
| 1966 | 28.8 | 01/03/1967 |
| 1967 | 33.0 | 24/10/1967 |
| 1968 | 40.5 | 27/12/1968 |
| 1969 | 30.7 | 25/12/1969 |
| 1970 | 29.6 | 19/11/1970 |
| 1971 | 25.6 | 28/01/1972 |
| 1972 | 34.1 | 14/12/1972 |
| 1973 | 34.9 | 15/09/1974 |
| 1974 | 42.1 | 29/01/1975 |
| 1975 | 31.3 | 06/12/1975 |
| 1976 | 25.4 | 11/02/1977 |
| 1977 | 35.0 | 14/11/1977 |
| 1978 | 27.0 | 17/12/1978 |
| 1979 | 36.8 | 18/12/1979 |
| 1980 | 30.3 | 22/12/1980 |
| 1981 | 29.8 | 17/03/1982 |
| 1982 | 34.7 | 21/12/1982 |
| 1983 | 37.8 | 09/02/1984 |
| 1984 | 26.7 | 20/08/1985 |
| 1985 | 29.7 | 26/01/1986 |
| 1986 | 35.3 | 20/12/1986 |
| 1987 | 33.9 | 06/02/1988 |
| 1988 | 25.7 | 25/03/1989 |
| 1989 | 43.4 | 12/02/1990 |
| 1990 | 39.8 | 05/01/1991 |
| 1991 | 32.6 | 11/01/1992 |
| 1992 | 31.5 | 08/12/1992 |
| 1993 | 46.2 | 23/12/1993 |
| 1994 | 53.6 | 01/02/1995 |
| 1995 | 23.2 | 31/10/1995 |
| 1996 | 30.9 | 26/02/1997 |
| 1997 | 37.1 | 09/01/1998 |
| 1998 | 36.6 | 05/01/1999 |
| 1999 | 53.6 | 27/12/1999 |
| 2000 | 35.8 | 02/11/2000 |
| 2001 | 42.0 | 11/02/2002 |
| 2002 | 31.2 | 14/11/2002 |
| 2003 | 28.8 | 17/01/2004 |
| 2004 | 32.1 | 13/01/2005 |
| 2005 | 26.6 | 27/09/2006 |
| 2006 | 44.8 | 22/12/2006 |
| 2007 | 49.5 | 23/01/2008 |
| 2008 | 35.3 | 26/01/2009 |
| **2009** | **69.6** | **24/11/2009** |

**Length of AMAX series:** years

2001- peak flows could be higher - missing.

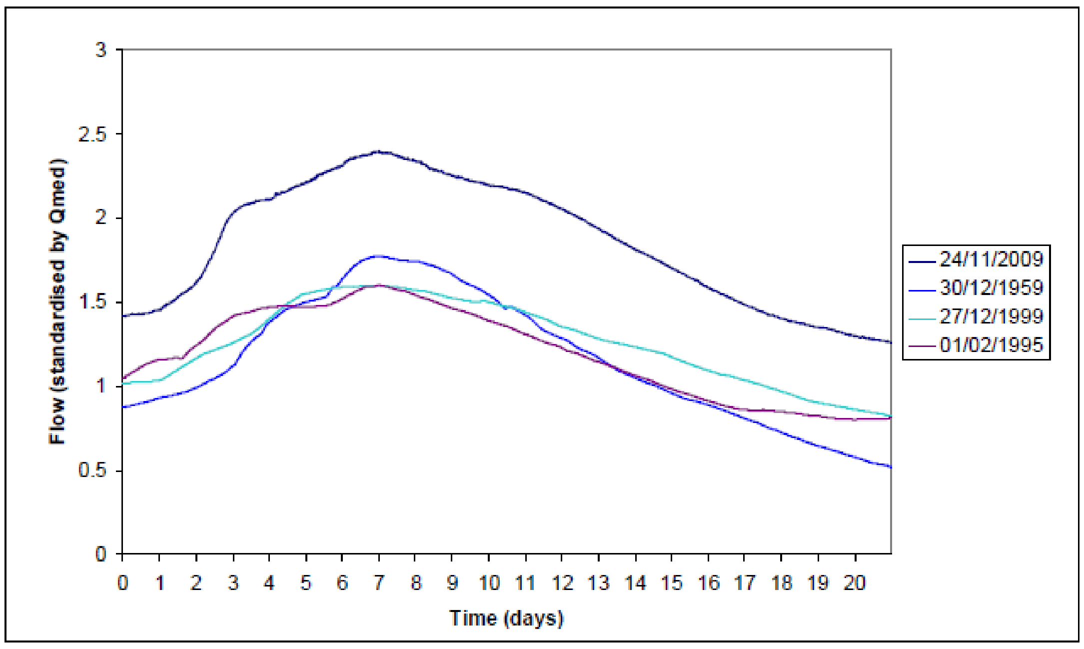
| | |
|---|---|
| **Gauging Authority:** Office of Public Works | |
| **Easting:** 134431 | **Northing:** 180323 |
| **Catchment:** Fergus | **Telemetry:** Yes |
| **Station Type:** Recorder | **Catchment Area:** 511.40 $km^2$ |
| **QMED (gauged):** 33.29 $m^3/s$ | **AREA (FSU):** 564.27 $km^2$ |
| **QMED (FSU):** 32.60 $m^3/s$ | **SAAR (FSU):** 1336.35 |
| **QMED (predicted):** 47.22 $m^3/s$ | **FARL (FSU):** 0.84 |
| **BFIsoils (FSU):** 0.65 | **S1085:** 1.22 |
| **URBEXT:** 0.08 | **ARTDRAIN2:** N/A |
| **DRAIND:** 0.54 | |

**Comments:** Velocity-area station installed in 1940 and automated in 1954. Flat V crump weir acts as control. Stable bed, negligible weed growth.

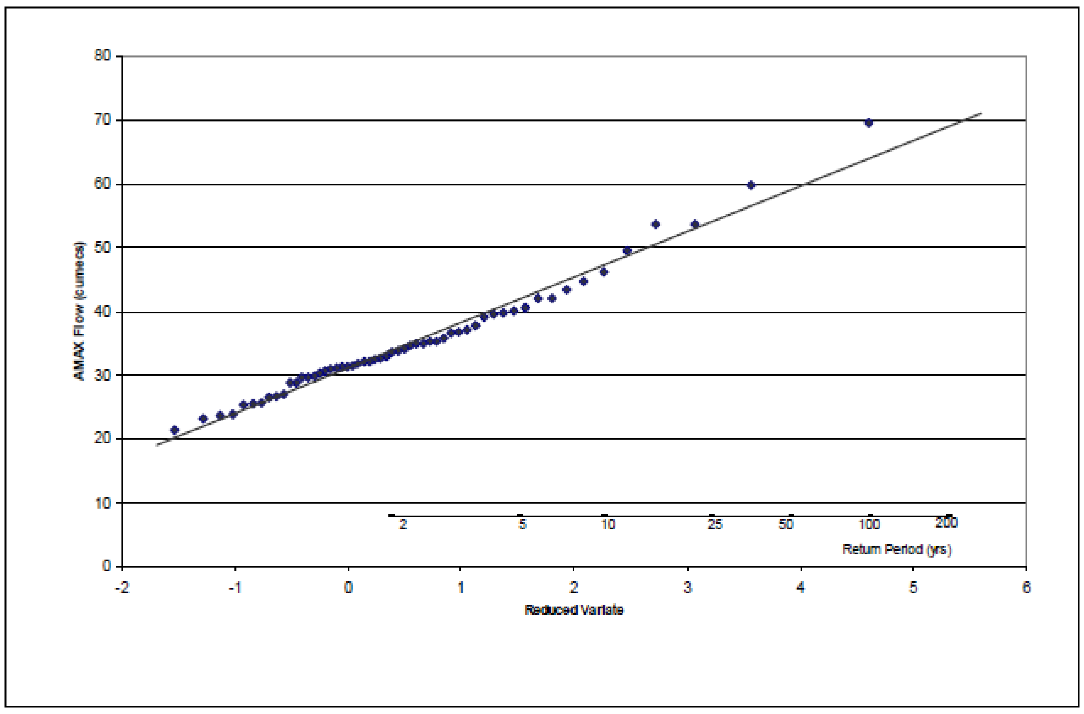
**Nearby APSRs**: To be confirmed

| | |
|---|---|
| **Jacobs Rating Review required:** No | **OPW Station Classification:** A1 |

Normalised Hydrographs




Flood Frequency (EV1 with Gringorten plotting positions)




Last Updated: May 2011

# 27003 – FERGUS AT CORROFIN

**Annual Maxima Series** (Source: OPW)

| Hydrological Year | Level (mOD) | Date |
|---|---|---|
| 1946 | | |
| 1947 | | |
| 1948 | | |
| 1949 | | |
| 1950 | | |
| 1951 | | |
| 1952 | | |
| 1953 | | |
| 1954 | | |
| 1955 | | |
| 1956 | | |
| 1957 | 20.25 | 30/10/1957 |
| 1958 | 19.88 | 14/10/1958 |
| 1959 | 20.37 | 30/12/1959 |
| 1960 | 20.29 | 03/12/1960 |
| 1961 | 20.09 | 10/12/1961 |
| 1962 | 19.98 | 11/12/1962 |
| 1963 | 20.21 | 12/05/1964 |
| 1964 | 20.36 | 08/10/1964 |
| 1965 | 20.08 | 09/12/1965 |
| 1966 | 20.11 | 28/02/1967 |
| 1967 | 20.23 | 10/10/1967 |
| 1968 | 20.50 | 25/12/1968 |
| 1969 | 20.16 | 22/02/1970 |
| 1970 | 20.17 | 30/10/1970 |
| 1971 | 20.12 | 21/11/1971 |
| 1972 | 20.15 | 13/11/1972 |
| 1973 | 20.28 | 01/12/1973 |
| 1974 | 20.24 | 23/01/1975 |
| 1975 | 20.16 | 02/12/1975 |
| 1976 | 19.85 | 08/02/1977 |
| 1977 | 20.26 | 10/11/1977 |
| 1978 | 20.26 | 15/12/1978 |
| 1979 | 20.24 | 15/12/1978 |
| 1980 | 20.24 | 20/09/1981 |
| 1981 | 20.17 | 19/06/1982 |
| 1982 | 20.24 | 24/11/1982 |
| 1983 | 20.36 | 10/10/1983 |
| 1984 | 20.28 | 16/12/1985 |
| 1985 | 20.18 | 07/08/1986 |
| 1986 | 20.19 | 16/12/1986 |
| 1987 | 20.20 | 04/02/1988 |
| 1988 | 20.07 | 13/01/1989 |
| 1989 | 20.33 | 30/10/1989 |
| 1990 | 20.23 | 12/02/1991 |
| 1991 | 20.21 | 08/01/1992 |
| 1992 | 20.13 | 02/12/1992 |
| 1993 | 20.36 | 23/12/1993 |
| 1994 | 20.54 | 01/02/1995 |
| 1995 | 20.04 | 27/10/1995 |
| 1996 | 20.22 | 06/08/1997 |
| 1997 | 20.16 | 09/01/1998 |
| 1998 | 20.24 | 25/09/1999 |
| 1999 | 20.47 | 26/12/1999 |
| 2000 | 20.21 | 01/11/2000 |
| 2001 | 20.31 | 04/02/2002 |
| 2002 | 20.23 | 11/11/2002 |
| 2003 | 20.16 | 16/01/2004 |
| 2004 | 20.25 | 09/01/2005 |
| 2005 | 20.40 | 22/09/2006 |
| 2006 | 20.31 | 12/12/2006 |
| 2007 | 20.36 | 17/08/2008 |
| 2008 | 20.33 | 03/09/2009 |
| 2009 | 20.86 | 26/11/2009 |

**Length of AMAX series:** 53 years

| | |
|---|---|
| **Gauging Authority:** Office of Public Works | |
| **Easting:** 128653 | **Northing:** 188589 |
| **Catchment:** Fergus | **Telemetry:** No |
| **Station Type:** Recorder | **Catchment Area:** 166.40 km$^2$ |
| **QMED (gauged):** 22.75 m$^3$/s | **AREA (FSU):** 166.42 km$^2$ |
| **QMED (FSU):** 22.92 m$^3$/s | **SAAR (FSU):** 1567.43 |
| **QMED (predicted):** 28.64 m$^3$/s | **FARL (FSU):** 0.92 |
| **BFIsoils (FSU):** 0.64 | **S1085:** 4.15 |
| **URBEXT:** 0.15 | **ARTDRAIN2:** N/A |
| **DRAIND:** 0.49 | |

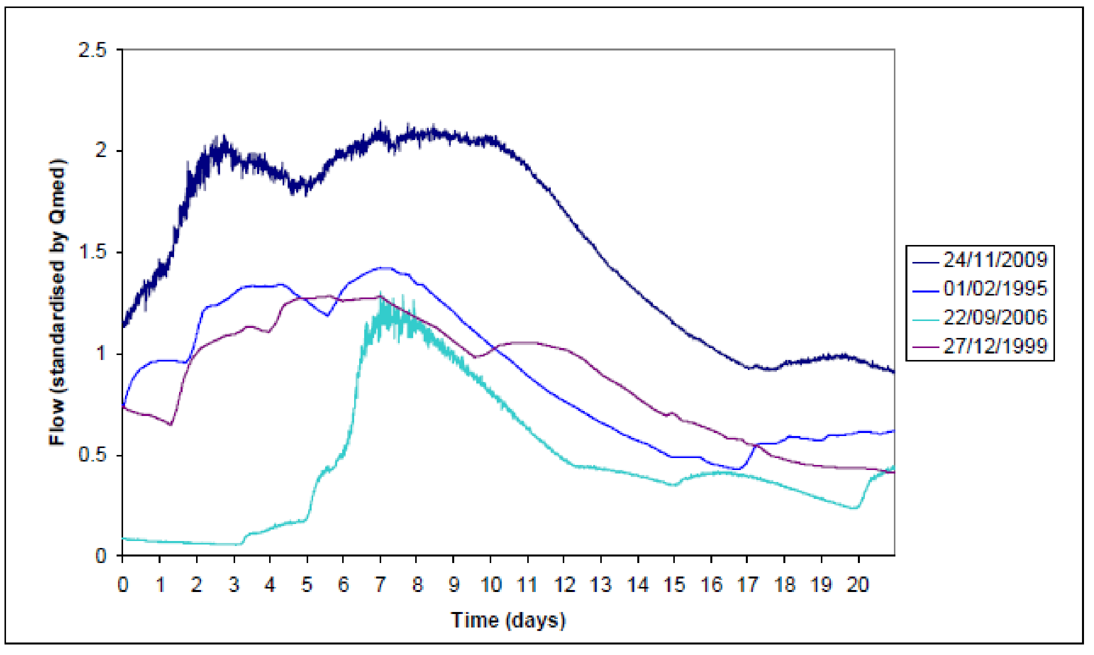
**Comments:** Velocity area station installed in 1940 and automated in 1957. Unstable rock bed. Seasonal weed growth. Bridge location.

**Nearby APSRs**: To be confirmed

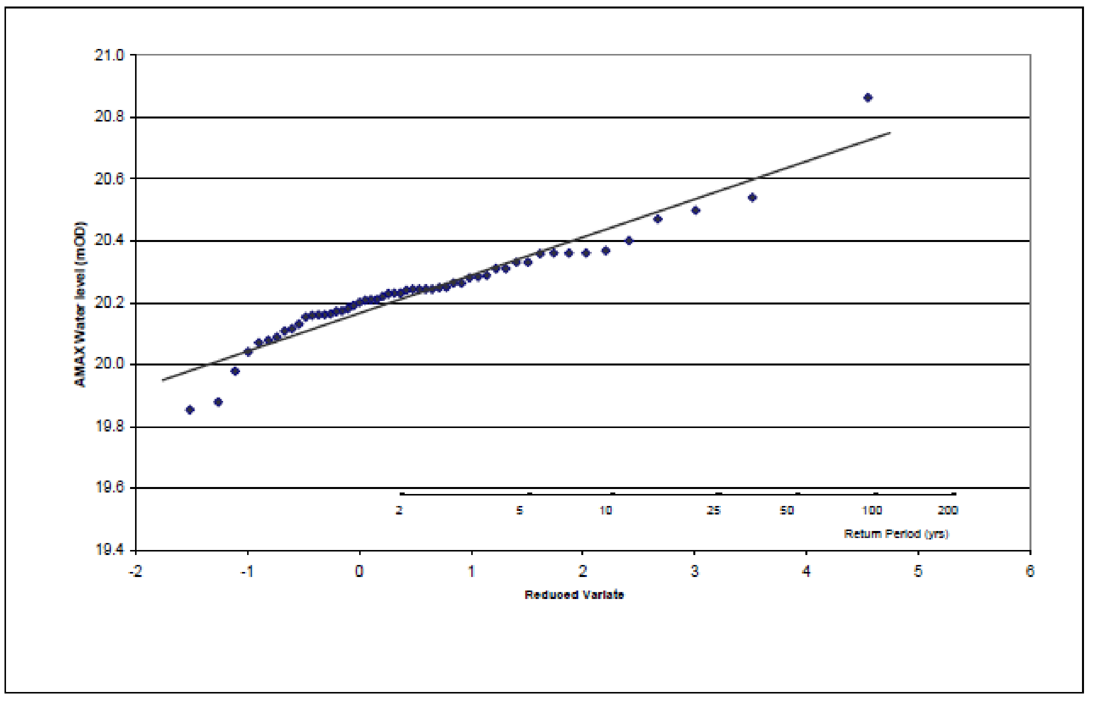
**Jacobs Rating Review required:** No

**OPW Station Classification:** A2

Normalised Hydrographs




Flood Frequency (EV1 with Gringorten plotting positions)



Shannon Catchment Flood Risk Assessment and Management (CFRAM) Study
Gauging Station Information Sheet

JACOBS OPW

# 27004 – MANUS AT CARNELLY

**Annual Maxima Series** (Source: OPW)

| Hydrological Year | Level (mOD) | 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 | 3.8 | 11/03/1979 |
| 1979 | 4.0 | 15/12/1979 |
| 1980 | 4.0 | 20/12/1980 |
| 1981 | 3.9 | 13/03/1982 |
| 1982 | 4.2 | 23/11/1982 |
| 1983 | 4.3 | 13/01/1984 |
| 1984 | 4.4 | 21/11/1984 |
| 1985 | 3.9 | 08/08/1986 |
| 1986 | 4.2 | 17/12/1986 |
| 1987 | 4.4 | 05/02/1988 |
| 1988 | 4.1 | 13/01/1989 |
| 1989 | 4.4 | 09/02/1990 |
| 1990 | 4.0 | 25/12/1990 |
| 1991 | 4.3 | 29/12/1991 |
| 1992 | 4.1 | 07/12/1992 |
| 1993 | 4.4 | 18/12/1993 |
| 1994 | 4.5 | 31/01/1995 |
| 1995 | 4.0 | 13/02/1996 |
| 1996 | 4.1 | 16/07/1997 |
| 1997 | 4.3 | 08/01/1998 |
| 1998 | 4.3 | 05/01/1999 |
| 1999 | 4.6 | 26/12/1999 |
| 2000 | 4.1 | 27/10/2000 |
| 2001 | 4.2 | 27/01/2002 |
| 2002 | 4.0 | 03/11/2002 |
| 2003 | 4.1 | 15/01/2004 |
| 2004 | 4.3 | 08/01/2005 |
| 2005 | 4.0 | 11/11/2005 |
| 2006 | 4.2 | 10/12/2006 |
| 2007 | 4.2 | 14/12/2007 |
| 2008 | 4.3 | 25/01/2009 |
| **009** | **4.7** | **22/11/2009** |

**Length of AMAX series:** 32 years

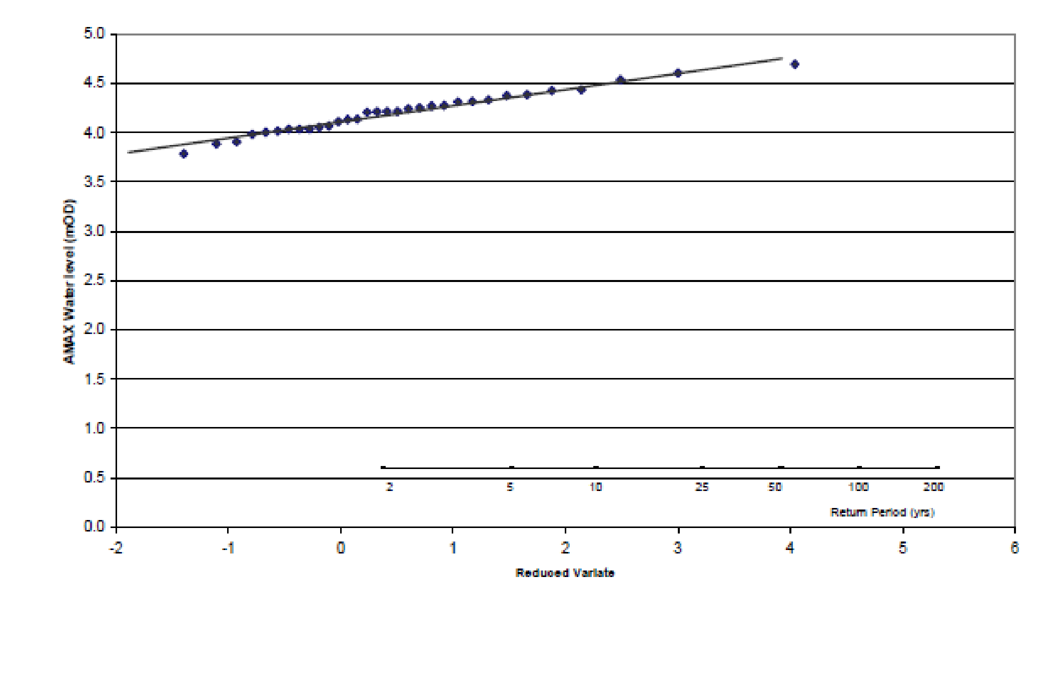
1990 - recorder malfunctioned

| | |
|---|---|
| **Gauging Authority:** Office of Public Works | |
| **Easting:** 136813 | **Northing:** 173481 |
| **Catchment:** Fergus | **Telemetry:** Yes |
| **Station Type:** Recorder | **Catchment Area:** 15.80 $km^2$ |
| **QMED (gauged):** N/A $m^3/s$ | **AREA (FSU):** N/A $km^2$ |
| **QMED (FSU):** N/A $m^3/s$ | **SAAR (FSU):** N/A |
| **QMED (predicted):** N/A $m^3/s$ | **FARL (FSU):** N/A |
| **BFIsoils (FSU):** N/A | **S1085:** N/A |
| **URBEXT:** N/A | **ARTDRAIN2:** N/A |
| **DRAIND:** N/A | |
| **Comments:** | |
| **Nearby APSRs**: To be confirmed | |
| **Jacobs Rating Review required:** No | **OPW Station Classification:** None |

Normalised Hydrographs

Chart not available

Flood Frequency (EV1 with Gringorten plotting positions)




Last Updated: May 2011

Shannon Catchment Flood Risk Assessment and Management (CFRAM) Study
Gauging Station Information Sheet

JACOBS OPW

# 27011 – OWENOGARNEY AT OWENOGARNEY (RLY) BR.

**Annual Maxima Series** (Source: OPW)

| Hydrological Year | 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 | | |
| 1981 | | |
| 1982 | | |
| 1983 | | |
| 1984 | | |
| 1985 | | |
| 1986 | | |
| 1987 | | |
| 1988 | | |
| 1989 | | |
| 1990 | | |
| 1991 | | |
| 1992 | | |
| 1993 | | |
| 1994 | | |
| 1995 | | |
| 1996 | 13.1 | 05/08/1997 |
| 1997 | 15.0 | 08/01/1998 |
| 1998 | 13.3 | 17/01/1999 |
| **1999** | **20.6** | **24/12/1999** |
| 2000 | 14.4 | 01/11/2000 |
| 2001 | 15.4 | 11/02/2002 |
| 2002 | 10.5 | 01/01/2003 |
| 2003 | | |
| 2004 | | |
| 2005 | | |
| 2006 | | |
| 2007 | | |
| 2008 | | |
| 2009 | | |

**Length of AMAX series:** 14 years

Fluvial peaks are estimated from semi-tidal hydrograph

**Gauging Authority:** Office of Public Works

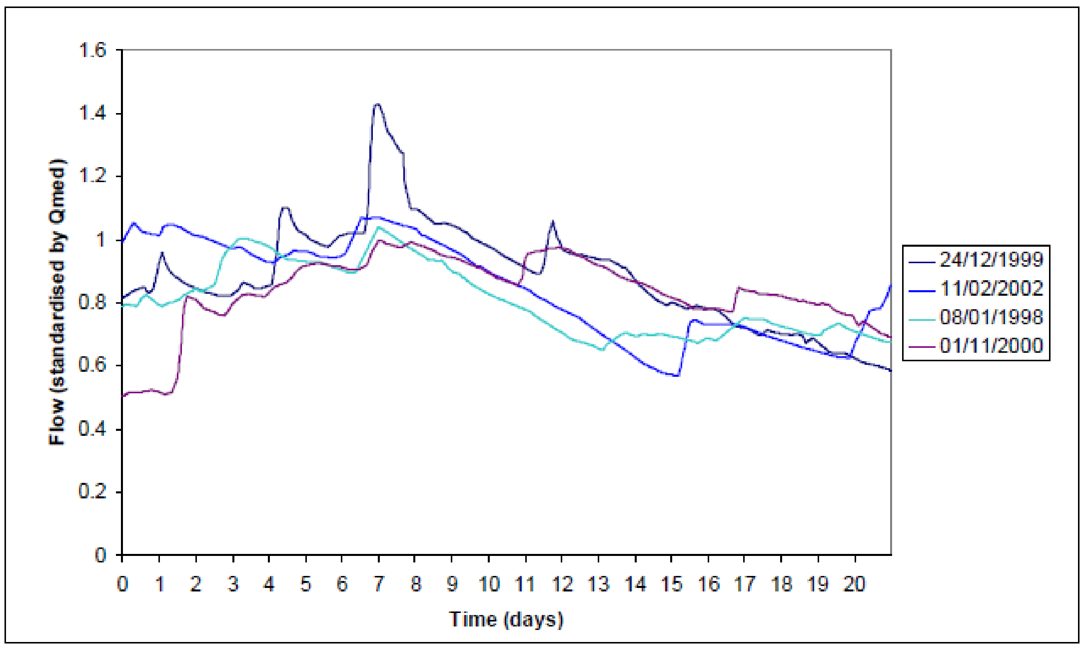
| | |
|---|---|
| **Easting:** 147964 | **Northing:** 164870 |
| **Catchment:** Owenogarney | **Telemetry:** Yes |
| **Station Type:** Recorder | **Catchment Area:** 161.80 $km^2$ |
| **QMED (gauged):** 14.40 $m^3/s$ | **AREA (FSU):** N/A $km^2$ |
| **QMED (FSU):** N/A $m^3/s$ | **SAAR (FSU):** N/A |
| **QMED (predicted):** N/A $m^3/s$ | **FARL (FSU):** N/A |
| **BFIsoils (FSU):** N/A | **S1085:** N/A |
| **URBEXT:** N/A | **ARTDRAIN2:** N/A |
| **DRAIND:** N/A | |

**Comments:**

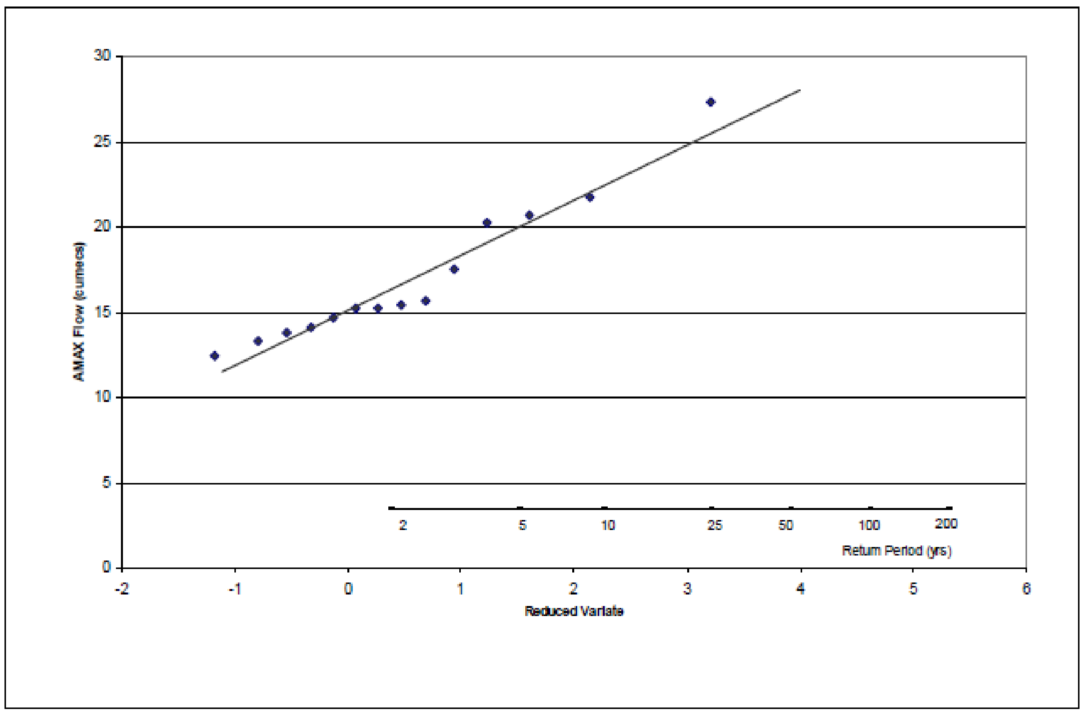
**Nearby APSRs**: To be confirmed

| | |
|---|---|
| **Jacobs Rating Review required:** Yes | **OPW Station Classification:** None |

Normalised Hydrographs




Flood Frequency (EV1 with Gringorten plotting positions)




Last Updated: May 2011

# 27025 – FERGUS AT KNOXS BRIDGE

**Annual Maxima Series** (Source: OPW)

| Hydrological Year | Level (mOD) | 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 | | |
| 1981 | | |
| 1982 | | |
| 1983 | | |
| 1984 | | |
| 1985 | | |
| 1986 | | |
| 1987 | | |
| 1988 | | |
| 1989 | | |
| 1990 | | |
| 1991 | | |
| 1992 | | |
| 1993 | | |
| 1994 | | |
| 1995 | | |
| 1996 | | |
| 1997 | | |
| 1998 | | |
| 1999 | | |
| 2000 | | |
| 2001 | | |
| 2002 | 2.6 | 03/11/2002 |
| 2003 | | |
| 2004 | | |
| 2005 | 2.5 | 22/09/2006 |
| 2006 | 2.8 | 07/12/2006 |
| 2007 | 2.8 | 23/01/2008 |
| 2008 | 2.6 | 25/01/2009 |
| **2009** | **3.0** | **20/11/2009** |

**Length of AMAX series:** 6 years

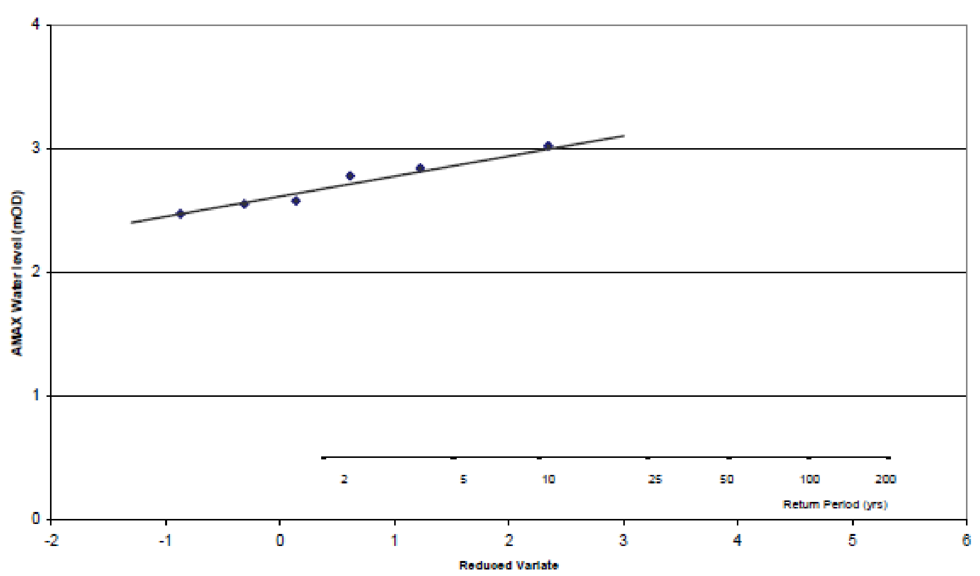
2001, 2003, 2004 logger malfunction

| | |
|---|---|
| **Gauging Authority:** Office of Public Works | |
| **Easting:** 134527 | **Northing:** 177876 |
| **Catchment:** Fergus | **Telemetry:** No |
| **Station Type:** Recorder | **Catchment Area:** 0.00 $km^2$ |
| **QMED (gauged):** N/A $m^3/s$ | **AREA (FSU):** N/A $km^2$ |
| **QMED (FSU):** N/A $m^3/s$ | **SAAR (FSU):** N/A |
| **QMED (predicted):** N/A $m^3/s$ | **FARL (FSU):** N/A |
| **BFIsoils (FSU):** N/A | **S1085:** N/A |
| **URBEXT:** N/A | **ARTDRAIN2:** N/A |
| **DRAIND:** N/A | |
| **Comments:** | |
| **Nearby APSRs**: To be confirmed | |
| **Jacobs Rating Review required:** No | **OPW Station Classification:** None |

Normalised Hydrographs

Chart not available

Flood Frequency (EV1 with Gringorten plotting positions)




Last Updated: May 2011

# 27026 – FERGUS AT TULLA ROAD BRIDGE

**Annual Maxima Series** (Source: OPW)

| Hydrological Year | Level (mOD) | 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 | | |
| 1981 | | |
| 1982 | | |
| 1983 | | |
| 1984 | | |
| 1985 | | |
| 1986 | | |
| 1987 | | |
| 1988 | | |
| 1989 | | |
| 1990 | | |
| 1991 | | |
| 1992 | | |
| 1993 | | |
| 1994 | | |
| 1995 | | |
| 1996 | | |
| 1997 | | |
| 1998 | | |
| 1999 | | |
| 2000 | | |
| 2001 | | |
| 2002 | | |
| 2003 | | |
| 2004 | 2.7 | 08/01/2005 |
| 2005 | 2.4 | 22/09/2006 |
| 2006 | 2.8 | 07/12/2006 |
| 2007 | 2.7 | 23/01/2008 |
| 2008 | 2.5 | 25/01/2009 |
| **2009** | **2.9** | **20/11/2009** |

**Length of AMAX series:** 6 years

| | |
|---|---|
| **Gauging Authority:** Office of Public Works | |
| **Easting:** 134645 | **Northing:** 178517 |
| **Catchment:** Fergus | **Telemetry:** No |
| **Station Type:** Recorder | **Catchment Area:** 0.00 km$^2$ |
| **QMED (gauged):** N/A m$^3$/s | **AREA (FSU):** N/A km$^2$ |
| **QMED (FSU):** N/A m$^3$/s | **SAAR (FSU):** N/A |
| **QMED (predicted):** N/A m$^3$/s | **FARL (FSU):** N/A |
| **BFIsoils (FSU):** N/A | **S1085:** N/A |
| **URBEXT:** N/A | **ARTDRAIN2:** N/A |
| **DRAIND:** N/A | |

**Comments:**

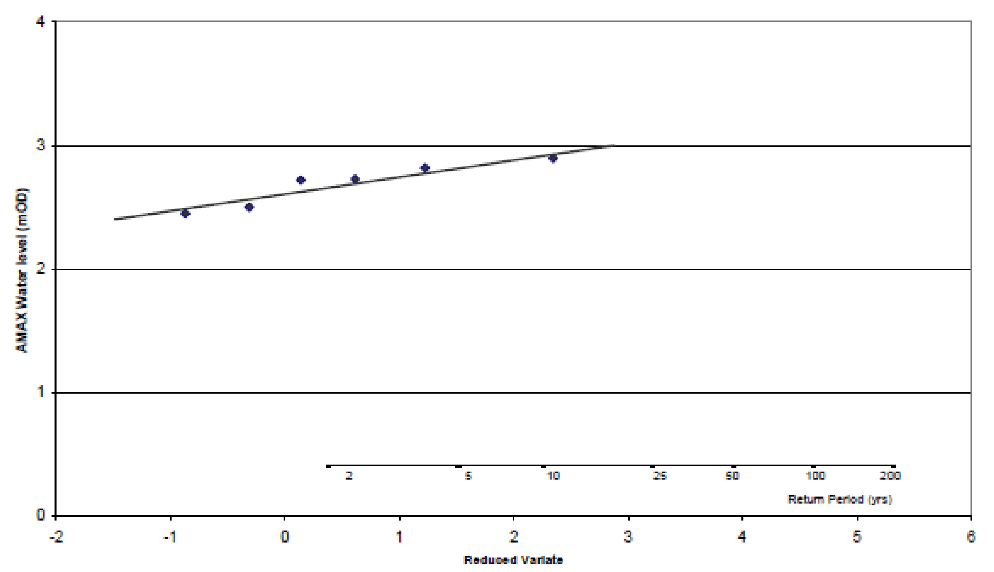
**Nearby APSRs**: To be confirmed

| | |
|---|---|
| **Jacobs Rating Review required:** No | **OPW Station Classification:** None |

Normalised Hydrographs

Chart not available

Flood Frequency (EV1 with Gringorten plotting positions)




Last Updated: May 2011

# 27070 – L. INCHIQUIN AT BAUNKYLE

**Annual Maxima Series** (Source: FSU)

| Hydrological Year | 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 | 11.8 | 07/02/1977 |
| 1977 | 14.6 | 08/11/1977 |
| 1978 | 22.1 | 15/12/1978 |
| 1979 | 28.4 | 27/11/1979 |
| **1980** | **31.9** | **20/09/1981** |
| 1981 | 29.0 | 15/12/1981 |
| 1982 | 28.2 | 15/12/1982 |
| 1983 | 27.4 | 06/10/1983 |
| 1984 | 27.8 | 15/08/1985 |
| 1985 | 22.5 | 07/08/1986 |
| 1986 | 15.4 | 19/11/1986 |
| 1987 | 15.0 | 02/01/1988 |
| 1988 | 13.6 | 28/01/1989 |
| 1989 | 15.8 | 08/02/1990 |
| 1990 | 16.2 | 24/12/1990 |
| 1991 | 16.7 | 29/12/1991 |
| 1992 | 15.6 | 23/11/1992 |
| 1993 | 15.6 | 22/12/1993 |
| 1994 | 19.4 | 27/12/1994 |
| 1995 | 14.3 | 27/10/1995 |
| 1996 | 17.2 | 06/08/1997 |
| 1997 | 15.7 | 10/09/1998 |
| 1998 | 16.8 | 22/09/1999 |
| 1999 | 17.1 | 29/11/1999 |
| 2000 | 15.2 | 06/11/2000 |
| 2001 | 16.3 | 30/11/2001 |
| 2002 | 16.3 | 10/11/2002 |
| 2003 | 16.0 | 16/01/2004 |
| 2004 | 24.9 | 12/01/2005 |
| 2005 | | |
| 2006 | | |
| 2007 | | |
| 2008 | | |
| 2009 | | |

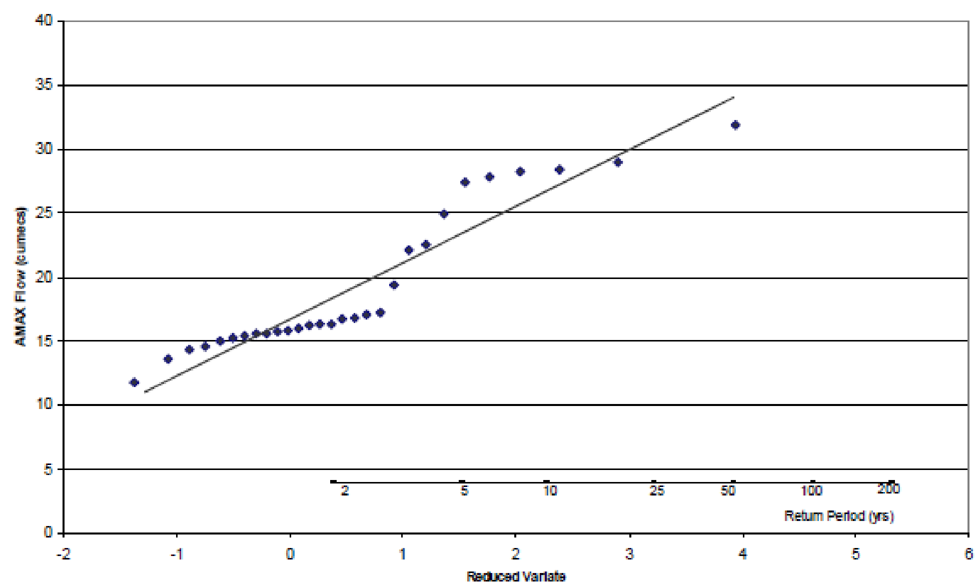
**Length of AMAX series:** 29 years

| | |
|---|---|
| **Gauging Authority:** Clare County Council | |
| **Easting:** 127224 | **Northing:** 189375 |
| **Catchment:** Fergus | **Telemetry:** No |
| **Station Type:** Recorder | **Catchment Area:** 143.60 $km^2$ |
| **QMED (gauged):** 16.30 $m^3/s$ | **AREA (FSU):** 143.58 $km^2$ |
| **QMED (FSU):** 16.30 $m^3/s$ | **SAAR (FSU):** 1592.48 |
| **QMED (predicted):** 22.11 $m^3/s$ | **FARL (FSU):** 0.91 |
| **BFIsoils (FSU):** 0.64 | **S1085:** 4.65 |
| **URBEXT:** N/A | **ARTDRAIN2:** N/A |
| **DRAIND:** 0.33 | |
| **Comments:** | |
| **Nearby APSRs**: To be confirmed | |
| **Jacobs Rating Review required:** No | **OPW Station Classification:** None |

Normalised Hydrographs

Chart not available

Flood Frequency (EV1 with Gringorten plotting positions)



# Appendix I - Historical Flood Risk Review Details

**JACOBS**

# COMMUNITIES AT RISK

| LEGEND: | |
|---|---|
| TEXT | Same data from the other CARs/IRRs |
| TEXT | No data attached, no relevant data to the associated CAR/IRR or unable to read the text |
| TEXT | Data obtained from other CARs/IRRs which is not included in the "floodmaps" for the relevant CAR/IRR |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
| CAR 14 BUNRATTY | | | | | | | | | | | | | | | | | | | | | |
| 14-1a | Coastal (Bunratty) | Owenogarney | Bunratty | Bunratty | R 452 608 | 1995 | Jan | | Design crest level of the embankments on the Owenagarney River = 22 ft OD (Poolbeg). Tide level = 6.6mOD (21.65 ft) (@ Ferrybridge) | | | Castle | Overtopping embankment. High tide due to low barometric pressure. | The lowest level in Bunratty Castle was flooded. | - | | Report to Regional Engineers | flood maps | 09/02/1995 | | 3 |
| 14-2a, 4a, 5a, 6a | Coastal (Bunratty) | Owenogarney | Bunratty | L3040 to Bunratty | R 453 615 | 2005 | Jan | | 400mm deep | | | Road & castle | Surface runoff from land at both sides of road drains onto road & stream and drains to the east of the road overflow. High tide combined with winds. | Bunratty - low lying area. Road was flooded and impassable. L3040 adjacent to Bunratty Castle - flooded over a localised area. | - | 10-20% (1:5/10 years) | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |
| 14-2a, 4a, 5a, 6a | Coastal (Bunratty) | Owenogarney | Bunratty | Deerpark Housing Estate | R 448 637 | | Recurring (Every 2 years) | | 100mm (max depth on the road) | | | Road | Heavy rainfall & soak pits unable to cope | There is a low point on road in this housing estate. The road floods but is passable. The drainage from road gullies in this estate drains into soak pits. These soak pits are not able to cope with heavy rainfall. Frequency is one in two years. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |
| 14-3a | Coastal (Bunratty) | Owenogarney | Bunratty | Moyhill | R 459 601 | 2002 | Febr | 1/2 | | | | Land | Tidal & sluice failure (replaced) | Land flooded. | - | | OPW memo | flood maps | 15/02/2002 | | 3 |
| 14-3b | Coastal (Bunratty) | Owenogarney | Bunratty | Moyhill | R 459 601 | 1997 | Febr | 10 | | | | Property | High tide. Flood water entered through the openings in the parapet surrounding Village Stores. | A dwelling was threatened with flooding. A stretch of wall to the north of a premise was washed away. | - | | OPW memo | flood maps | 10/02/1997 | | 3 |
| 14-3c | NO DATA ATTACHED | | | | | 1965 | Jan | 16-17 | | | | | | | - | | Clare Champion | flood maps | 23/01/1965 | | - |
| | | | | | | | | | | | | | | | | | | | | | |
| **CAR 28 ENNIS** | | | | | | | | | | | | | | | | | | | | | |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | | | | | | | |
| 28-1a | Fergus | Fergus, Claureen | Ennis | Other areas in Ennis Environs & surrounding | R 338 775 | 2009 | Nov – Dec | 18-02 | | | | Appendix B - List of affected properties | Prolonged rainfall with high river levels stopping the discharge of storm drains, backflow through open drains/shores from the river, inability of sewers to discharge, overflow from low level river embankments/walls & groundwater movement due to high river levels. | Appendix B: 12 houses flooded at Ennis Environs. | 1, 1 (T) | | Flood Incidents Report | flood maps | 01/2010 | | 3 |
| 28-1a | Fergus | Fergus, Claureen | Ennis | Ennis | R 338 775 | 1995 | | | | | | | | | 3 (T) | | Flood Incidents Report | flood maps | 01/2010 | | 3 |
| 28-1a | Fergus | Fergus, Claureen | Ennis | Ennis | R 338 775 | 1998 | | | | | | | | | 6 (T) | | Flood Incidents Report | flood maps | 01/2010 | | 3 |
| 28-1b | Fergus | Fergus, Claureen | Ennis | Ennis – Gort Rd including industrial estate. Kidysert Rd, Oakwood Drive, Fior Uisce, Harmony Row, Colaiste Mhuire, Newbridge Rd & College Rd, Abbey St & Francis St, Quin Rd Industrial Estate, Fergus Park, Castlelawn, Clonroad/ Francis St, Ard Aoibhinn, Clonroadmore, Tobartascain, Abbeyville, White Park, Tulla Rd | R 338 775 | 2009 | Nov | 19-21 | | | | Photographs showing extent of flooding (location) | High tides & prolonged rainfall over the preceding weeks & months. | Extensive flooding in Ennis. *Ennis Certified Drainage (Upper) was substantially completely but not finalised, performed well & met the design standards. Parnell St car park Rd however was prevented from flooding. Several properties & road were flooded at Gort Rd including industrial estate, Kildysert Rd Cross, Oakwood Drive, Fior Uisce, Harmony Row, including County Library, Sports field at Colaistre Mhuire, Newbridge Rd & College Rd, Abbey St car park, Abbey St & Francis St, Ard Aoibhinn, Clonroadmore, Tabartascain, White Park & Tulla Rd. At Quin Rd Industrial Estate, Fergus Park, Castlelawn & Abbeyville, serious flooding was prevented using pumping. Clonroad/Francis St junction and Tesco car park was flooded also. | 1, 1 (T) | | OPW report | flood maps | 22/02/2009 | | 3 |
| 28-1c | Fergus | Fergus, Claureen | Ennis | Ennis | R 338 775 | 2009 | Nov | | | | | Aerial photographs showing extent of flooding. | Prolonged period of very intensive rainfall & high tides in the Fergus Estuary | Extensive flooding in Ennis. | 1, 1 (T) | | OPW Mungret | flood maps | 19/01/2010 | | 3 |
| 28-1d | Fergus | Fergus, Claureen | Ennis | Co Clare | | 2009 | Nov | | | | | Roads | | *Map showing roads flooded in the Co of Clare. Ennis is out of the map. | 1, 1 (T) | | Clare CC | flood maps | 26/01/2009 | | 4 |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | | | | | | | |
| 28-2a, 4a, 5a, 9a, 10a | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1999 | Dec | | 2.85mOD Malin (@Doora bridge), 2.7mOD (@Gaurus floodplain), 4.02mOD (@ Mill Bridge), 3.75mOD (@ Clarecastle), 2.48mOD (lands at Knocknoura & Cappaghard), 3.85mOD (@ Parnell St), 5.7mOD (in the vicinity of Auburn Lodge), 5.2mOD (@ Victoria Bridge (Cusack Rd)), 5.9 to 6.1mOD (@ Clogleagh). | | 72m3 /s (25/12/1999) | Properties, roads & lands | Intensive prolonged rainfall combined with high tide (low pressure & winds also). Fergus Park also suffered from ingress of water through the walls by seepage and/or backwater flow through storm runoff pipes & other openings (surface water flooding). Overtopping of walls @ Woodquay. | *Embankment @ Fergus Park did not overtop. Failure of surface water drainage sewer to discharge to the River Fergus during floods. A number of houses on Drumcliffe Rd experience flooding in their gardens & driveways. Drumcliffe Rd flooded and the road running northwest from the cross roads to the Ennistimon Rd became impassable. Lands at Knocknoura & Cappaghard were flooded. Town centre - Woodquay, Parnell St, Mill Rd, Carmody St, Cornmarket St, R474 Rd @ Ennistimon roundabout, Mill Rd @ Vacational School, College Rd, Lifford, new Bridge Rd, Fergus Park, Castlelawn, Roverdle, Tulla Rd, Knockanoura & Cappaghard, Gort Rd/Lough Girroga, Drumcarronmore, Lough Vell, Spellissy's turlough, St Flannan's College, St Flanna's Drive, vicinity of Ballybeg Lough, N18 - R473 junction, Clonroadmore (nr Toberteastaun), land btw Clare Marts Ltd & River Fergus, NW of Doora Bridge, land btw Clonroadmore Business Park & River Fergus, Quin Rd, land east of River Fergus & south of Quin Rd @ Bunnow, Roslevan/Hillerest were affected by flooding. See end of Appendix I for further details. | 2 (T) | | Consultants Report | flood maps | 06/2001 | | 1 |
| 28-2a, 4a, 5a, 9a, 10a | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1995 | Feb | | 400mm to 600mm (houses flooded in Fergus Park), 1.46mOD (lands at Knocknoura & Cappaghard) | | | Properties & lands | Water overflowed the bank | Houses in Fergus Park flooded. *Embankment constructed @ Fergus Park following the flooding event. | 3 (T) | | Consultants Report | flood maps | 06/2001 | | 1 |
| 28-2a, 4a, 5a, 9a, 10a | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1993 | | | | | | | | Serious flooding in Ennis. | 8 (T) | | Consultants Report | flood maps | 06/2001 | | 1 |
| 28-2a, 4a, 5a, 9a, 10a | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1989 /90 | | | | | | | | Serious flooding in Ennis. | 7 (T) | | Consultants Report | flood maps | 06/2001 | | 1 |

JACOBS

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | | | | | | | |
| 28-2a, 4a, 5a, 9a, 10a | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | Pre 1954 | | | >4.3mOD Malin (in the vicinity of Corravorrin Bridge) | | | Properties | | A local resident & landowner reported that the water reached the top of the fourth step of the stairs in his family house. | - | | Consultants Report | flood maps | 06/2001 | | 1 |
| 28-2b, 4b, 5b | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1999 | Dec | | 3.82mOD, 100mm (@ both sides of Mill Rd), 18" (Parnell Car Park & Mill Rd), 1 to 12" (Premises in Woodquay). | 35mm (24 hrs), 70mm (48 hrs), 196mm (5 days); average 15mm/ day | | Properties, roads | Intensive prolonged rainfall combined with high tide & south westerly wind | A small premises in Mill Rd was affected by flooding. Mill Rd, Woodquay Car Park, Parnell St etc were closed to traffic. Woodquay, Considine Terrace, Clonroadmore Industrial Estate, lands @ south of Doors Bridge, Circular Rd, riverside amenity park @ Knox's Bridge, St Flannan's College & Tobartaoscain & adjacent to vocational school were flooded. No houses in Fergus Park were flooded. | 2 (T) | | Clare CC memo | flood maps | 05/01/2000 | | 1 |
| 28-2b, 4b, 5b | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1995 | Jan/ Feb | | 3.80mOD | 74mm (3 days), 125mm (5") (11 days); average 11.5mm/ day | | Town centre | Intensive prolonged rainfall combined with high tide & south westerly wind | Severe flooding in the town centre & Fergus Park. "Worst flooding in almost 30 years". *Remedial work: (1) Embankment constructed btw Fergus Park & the River Fergus, (2) New sump in Woodquay car park to facilitate pumps | 3 (T) | | Clare CC memo | flood maps | 05/01/2000 | | 1 |
| 28-2c | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1995 | Feb | | 23.12mOD (Western Garages), 21.39mOD (Harys Lawn Moner), 23.75mOD (Mill Road?) | | | Map with copy of level survey book | | | 3 (T) | | OPW Mungret | flood maps | 15/02/1995 | | 2 |
| 28-2d, 4d, 5d | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1999 | Dec | | 2.8mOD (Doora bridge) | | 60 $m^3/s$ | Map showing extent of flooding | | Various locations - Mill Bridge, Woodquay, Parnell Car Park, Lifford & Fergus Park were flooded. (*Table showing the water level at these locations are not included in the report) | 2 (T) | 14% (1 in 7 yrs) | Consultants Report | flood maps | 02/2004 | | 3 |
| 28-2d, 4d, 5d | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1995 | | | | | | Map showing extent of flooding | | | 3 (T) | | Consultants Report | flood maps | 02/2004 | | 3 |
| 28-2e, 5e | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774, R312 784 | - | | | | | | | | Severe flooding in Ennis. | - | | OPW note | flood maps | - | | - |
| 28-2f | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | - | | | | Rainfall in Jan is double its normal level | | Town centre & road | Heavy rain - River Fergus overflowed @ Claracastle. | Heavy flooding in and around Ennis. Main Rd from Quin to Ennis was impassable. | - | | Irish Times | flood maps | 01/02/1995 | | - |

JACOBS

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | | | | | | | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | Rank | Estimated AEP | Source | | Date | Authenticity | |
| 28-3a, 6a | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 1999 | Dec | | | | | | | | 2 (T) | | OPW memo | flood maps | 15/02/2002 | | 3 |
| 28-3a, 6a | Fergus | Fergus, Claureen | Ennis | Ennis | R 335 774 | 2002 | Feb | 01/02 | circa 150mm | | | Properties & road | Combined tidal & fluvial & pluvial? | Road and 2 properties affected. | 4 (T) | 50% (1 in 2 yrs) | OPW memo | flood maps | 15/02/2002 | | 3 |
| 28-4c | NO DATA ATTACHED | | | | | 1999 | Decr | | | | | | | | 2 (T) | | OPW Dublin | flood maps | - | | 2 |
| 28-4e | Fergus | Fergus, Claureen | Ennis | Ennis - Parnell St, Mill Road, Castlelawn & Claureen, the main Limerick-Galway Rd | R 357 795 | 1999 | Dec | 23-24 | 2ft of water (@ Parnell St) | | | Properties & roads | Snow, rain & high winds | "Worst flooding in the town in recent memory - worse than in 1995)". Parnell St & many business premises were flooded. Properties also flooded in Mill Road, Castlelawn & Claureen. A stretch of the main Limerick - Galway Rd was impassable. One house adjacent to River Fergus was reported flooded. | 2 (T) | | Irish Times | flood maps | 27/12/1999 | | - |
| 28-4f | Fergus | Fergus, Claureen | Ennis | Ennis, main road to Galway | R 357 795 | 1999 | Dec | 25-26? | | | | Town centre, road | Torrential rain | Town's main shopping streets were flooded. Part of the main road to Galway was impassable. | 2 (T) | | Irish Independent | flood maps | 27/12/1999 | | - |
| 28-4g | Fergus | Fergus, Claureen | Ennis | Ennis - Parnell St, Limerick-Galway Rd | R 357 795 | 1999 | Dec | 24-25 | Water was up to the 1st floor of one resident's house nr River Fergus. | | | Properties & roads | Heavy winds & rain | "Worst flooding in the town in 60 years - worse than in 1995)". Parnell St & properties were flooded. The main Limerick-Galway Rd was impassable. One house adjacent to River Fergus was reported flooded. | 2 (T) | | Examiner (Cork) | flood maps | 27/12/1999 | | - |
| 28-5c | NO DATA ATTACHED | | | | | 1995 | Jan | | | | | | | | 3 (T) | | OPW Dublin | flood maps | - | | 2 |
| 28-6a, 8a | Fergus | Fergus, Claureen | Ennis | Ennis & surrounding areas - Parnell St, Cornmarket St, Mill Rd, Clarecastle, St Flannan/s College, Ennis?-Gort Rd | R335 774, R 338 790 | 1959 | Dec | | 18.9'mOD (Ennis Bridge), 17.3'mOD (u/s of barrage), 19.5'mOD (tide d/s of barrage), 2" (houses, stores & business premises - half a dozen had water to a depth of 1'), 6" (a no of laneways? From Parnell St to the river wall & small residences in those laneways), 1'0" (Parnell St & Commarket St), 1'6" (Mill Rd), *Gauge | | | Properties, roads & land | Exceptional heavy rainfall, high tide & gale force south westerly winds | Flooding in Ennis & surrounding areas - vast area of land under water (stretched the 2 miles from Clarecastle to Ennis), 100 houses, stores & business premises were flooded. Area btw Parnell St & the river was worst affected. Houses at Mill Road were flooded. Road flooding btw Ennis-Gort Rd. Ground and adjacent main road at St Flannan's College were also flooded. | - | | OPW Report | flood maps | 06/01/1959 | | 2 |

JACOBS

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | | | | | | | |
| | | | | | | | | | reading at Ennis is documented in the report. | | | | | | | | | | | | |
| 28-6b, 9b, 10b | Fergus | Fergus, Claureen | Ennis | | R335 774 | 1959 | Dec | | | | | Properties | Heavy rainfall, high tides & strong south westerly winds | Houses flooded & some people were forced out at their houses for 3 to 5 weeks. | - | | Report on Deputation | flood maps | 03/02/1961 | | 3 |
| 28-6b, 9b, 10b | Fergus | Fergus, Claureen | Ennis | | R335 774 | 1955 | | | | | | Properties | Heavy rainfall, high tides & strong south westerly winds | Houses in many principal streets were flooded. | - | | Report on Deputation | flood maps | 03/02/1961 | | 3 |
| 28-6b, 9b, 10b | Fergus | Fergus, Claureen | Ennis | | R335 774 | 1947 | | | | | | Properties | Heavy rainfall, high tides & strong south westerly winds | Same degree of flooding as 1959 event. | - | | Report on Deputation | flood maps | 03/02/1961 | | 3 |
| 28-7b | Fergus | Fergus, Claureen | Ennis | Keelty area west of Ennis | R323 775 | 2002 | Feb | | | | | Aerial photograph showing extent of flooding | | | 4 (T) | | National Roads Authority | flood maps | 02/2002 | | 2 |
| 28-7c | Fergus | Fergus, Claureen | Ennis | Keelty area west of Ennis | R323 775 | 2002 | Feb | | | | | Aerial photograph showing extent of flooding | | | 4 (T) | | National Roads Authority | flood maps | 02/2002 | | 2 |
| 28-7d | Fergus | Fergus, Claureen | Ennis | Keelty area west of Ennis | R323 775 | 2002 | Feb | | | | | Aerial photograph showing extent of flooding | | | 4 (T) | | National Roads Authority | flood maps | 02/2002 | | 2 |
| 28-7e | Fergus | Fergus, Claureen | Ennis | Keelty area west of Ennis | R323 775 | 2002 | Feb | | | | | Aerial photograph showing extent of flooding | | | 4 (T) | | National Roads Authority | flood maps | 02/2002 | | 2 |
| 28-11a | NO DATA ATTACHED | | | | - | 2006 | Dec | | | | | Map showing extent of flooding | | | 2, 5 (T) | | OPW Mungret | flood maps | 16/12/2006 | | 2 |
| 28-11b | Fergus | Fergus, Claureen | Ennis | Ennis (looking north east) | R354 759 | 2006 | Dec | | | | | Aerial photograph showing extent of flooding | | | 2, 5 (T) | | Clare CC | flood maps | 16/12/2006 | | 2 |
| 28-11c | Fergus | Fergus, Claureen | Ennis | Ennis (looking north) | R354 759 | 2006 | Decr | | | | | Aerial photograph showing extent of flooding | | | 2, 5 (T) | | Clare CC | flood maps | 16/12/2006 | | 2 |

| Ref | Where? River Basin | Tributary | CAR | Location | Grid Ref | When? Year | Month | Day | Magnitude? Peak level | Rainfall | Flow | Flood Extent | Flooding mechanism | Impact? Any damage caused | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28-12a, 13a | Fergus | Fergus, Claureen | Ennis | Mill Road | R333 776 | | Recurring | | | | | Road | | *Mill Road is a serious flooding black spot in Ennis town. It was decided that the details of this problem & other problem areas in Ennis town would be sourced in 'Ennis Main Drainage & Flooding Study'. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 09/03/2006 | | 4 |
| 28-12a, 13a | Fergus | Fergus, Claureen | Ennis | Gaurus River @ Doora North | R355 780 | | Recurring | | | | | Land | Rainfall/runoff and exacerbated by tidal influences, especially the closing of the gates on the River Fergus at Clarecastle to alleviate flooding on the Fergus. | *Noora North Newpark is a large floodplain that acts as a flood storage basin & has been designed as such. The area floods several times per year. No roads or houses are affected. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 09/03/2006 | | 4 |
| 28-12b | NO DATA ATTACHED | | | | - | - | | | | | | | | | | | Irish Independent | flood maps | 02/02/1995 | | - |
| 28-12c | NO DATA ATTACHED | | | | - | 1968 | Dec | 24-26 | | | | | | | - | | Clare Champion | flood maps | 04/01/1969 | | - |
| | | | | | | | | | | | | | | | | | | | | | |
| **CAR 33 KILKEE** | | | | | | | | | | | | | | | | | | | | | |
| 33-1a | Other? | Victoria Stream | Kilkee | Church St on Carrigaholt Rd in front of St Patrick's Terrace | Q 884 597 | | | | | | | Properties & roads | Heavy rainfall/runoff exacerbated by tides/wind. The Victoria Stream overflows its banks over a length of 200-300m. | Church St and Well Rd Car Park are flooded. Road is not passable and the car park is closed. 4 to 5 houses are flooded. Frequency is about once per yr. The problem is being worsened by development in the Victoria Stream floodplain which is reducing flood storage & increasing runoff. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 26/02/2006 | | 4 |
| 33-1b, 1c | Other | Tidal | Kilkee | Co Clare, Kilkee | | 1990 | Feb | | | | | Properties & roads | Storm, heavy seas | Co Clare experienced serious flooding with about 200 houses & many roads affected. Kilkee was one of the most seriously affected area. Roads also damaged in Co Clare - Galway Bay to Loop Head & on up to Carrigaholt in the Shannon Estuary. | - | | Irish Times | flood maps | 14/02/1990 | | - |
| 33-1d | NO DATA ATTACHED | | | | | - | | | | | | | | | - | | Irish Times | flood maps | 18/12/1968 | | - |
| 33-1e | Other | Tidal | Kilkee | Kilkee | | 1961 | Oct | 22 | 10ft of water (@ mudflat nr Moyasta) | | | Land | Storm & gales | Breaches in the River Shannon causing thousands of acres of lands flooded & 2 factories inundated (on the Ennis Road, Limerick nr the Gaelie Grounds). A golf pavilion was blown away in Kilkee. Windows on the seafront & a | - | | Cork Examiner | flood maps | 24/10/1961 | | - |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
| | | | | | | | | | | | | | | number of shop windows were smashed by flying slates. | | | | | | | |
| 33-1f | NO DATA ATTACHED | | | | | 1961 | Oct | 22-24 | | | | | | | - | | Clare Champion | flood maps | 28/10/1961 | | - |
| 33-1g | Other | Tidal | Kilkee | Kilkee | | 1954 | Dec | 8 | | | | Land & roads | Heavy rain & severe storm | Kilkee & other parts of West Clare - flooding to large tracts of land & low lying roads. | - | | Cork Examiner | flood maps | 09/12/1954 | | - |
| 33-1h | NO DATA ATTACHED | | | | | 1949 | Oct | 24 | | | | | | | - | | Clare Champion | flood maps | 29/10/1949 | | - |
| 33-1i | NO RELEVANT INFO FOUND | | Kilkee | | | 1946 | Aug | 12 | | | | | | | - | | Irish Independent | flood maps | 13/08/1946 | | - |
| 33-1j | NO DATA ATTACHED | | | | | 1965 | Jan | 16-17 | | | | | | | - | | Irish Times | flood maps | 18/01/1965 | | - |
| 33-1k | Other | Tidal | Kilkee | Kilkee | | 1965 | Jan | | | | | | Winds, hails, snow, thunder & lighting | Two cattle was reported killed when struck by lighting. Hundreds of dead fish were washed ashore. | - | | Irish Independent | flood maps | 18/01/1965 | | - |
| 33-1l | NO DATA ATTACHED | | | | | 1965 | Jan | 16-17 | | | | | | | - | | Irish Independent | flood maps | 18/01/1965 | | - |
| 33-1m | Other | Tidal | Kilkee | Kilkee, Loop Head to Black Head, Kilmihil | | 1965 | Jan | 16-17 | "Sea were breaking 500ft over the cliffs & sending spray inland for a distance of one mile". | | | | Storm & gale | The town was in complete darkness because of power failure & portions of the promenade wall were pounded to bits by the huge waves. Widespread damage from Loop Head to Black Head. 2 cows were killed by lighting & damaged an outhouse in the Kilmihil area. | - | | Cork Examiner | flood maps | 18/01/1965 | | - |
| 33-1n | NO DATA ATTACHED | | | | | 1965 | Jan | 16-17 | | | | | | | - | | Limerick Chronicle | flood maps | 19/01/1965 | | - |
| 33-1o | Other | Tidal | Kilkee | Kilkee, Loop Head to Black Head, Kilmihil | | 1965 | Jan | 16-17 | "Sea were breaking 500ft over the cliffs & sending spray inland for a distance of one mile". 2ft flooding to houses along the front of the wall. | | | Properties | Rain, winds, hail, sleet, thunders & lighting | The town was in complete darkness because of power failure & portions of the promenade wall were pounded to bits by the huge waves. Wall collapsed causing flooding to houses along the front of the wall. Windows were smashed by the waves. Widespread damage from Loop Head to Black Head. 2 cows were killed by lighting & damaged an outhouse in the | - | | Limerick Leader | flood maps | 18/01/1965 | | - |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
| | | | | | | | | | | | | | | Kilmihil area. | | | | | | | |
| 33-1p | NO DATA ATTACHED | | | | | 1965 | Jan | 09-10 | | | | | | | - | | Clare Champion | flood maps | 16/01/1965 | | - |
| 33-1q | NO DATA ATTACHED | | | | | 1965 | Jan | 13 | | | | | | | - | | Clare Champion | flood maps | 16/01/1965 | | - |
| 33-1r | Other | Tidal | Kilkee | Kilkee | | 1954 | Oct | 18 | | | | Railway | Heavy rain. | A railway embankment nr Glenfarne subsided & the goods train to Ennis-Killen was delayed. Another landslide occurred further down the line & the train & its crew were isolated for some times. | - | | Irish Times | flood maps | 19/10/1954 | | - |
| 33-1s | Other | Tidal | Kilkee | Kilkee | | 1954 | Oct | 18 | | | | Roads & lands | Heavy rain. | Low lying roads & lands were flooded. | - | | Irish Independent | flood maps | 19/10/1954 | | - |
| 33-1t | NO DATA ATTACHED | | | | | 1954 | Oct | 18 | | | | | | | - | | Cork Examiner | flood maps | 19/10/1954 | | - |
| | | | | | | | | | | | | | | | | | | | | | |
| **CAR 36 KILRUSH** | | | | | | | | | | | | | | | | | | | | | |
| 36-1a, 2a, 3a | Other | Tidal | Kilrush | R483 | Q 997 548 | 2005 | Jan | 7 | 500mm max depth (road flooding) | | | Land & road | Rainfall/Runoff & poor drainage | Low lying land, cut away bog, at each side of road with very poor drainage results in lands and road flooding. Road is impassable during floods. Cause is rainfall/runoff. Frequency is twice per year.*The CC intend to raise road in future. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 26/02/2006 | | 4 |
| 36-1a, 2a, 3a | Other | Tidal | Kilrush | R483 on Kilrush Road from Cooracle | Q 997 548 | | Recurring | | | | | Road | Backing up of Cooraclare River. *The river used to be cleaned/maintained by local landowners up to the late 1950's. | R483 on Kilrush Road from Cooraclare is flooded on average once per year but passable. No houses affected. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 26/02/2006 | | 4 |
| 36-1a, 2a, 3a | Other | Tidal | Kilrush | Cappagh Road (R473) | Q 985 542 | | Recurring | | 1.2m (road flood depth) | | | Road | Tidal and exacerbated by the operation of Marina lock gates, which may have the effect of prolonging high water levels. | Road is flooded on the Cappagh side of the Creek Lodge Hotel on average every 2 or 3 years. Road is impassable. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 26/02/2006 | | 4 |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | | | | | | | |
| 36-3b | NO DATA ATTACHED | | | | | 1986 | Aug | 25 | | | | | | | - | | Dungarvan Observer | flood maps | 06/09/1986 | | - |
| 36-3c | Other | Tidal | Kilrush | Kilrush | Q 997 548 | 1961 | Oct | 22 | 10ft of water (@ mudflat nr Moyasta) | | | Lands & factories | Storm & gales | Breaches in the River Shannon causing thousands of acres of lands flooded and two factories inundated. A man was surrounded by water up to his waist at a mudflat near Moyasta. | - | | Clare Champion | flood maps | 28/10/1961 | | - |
| 36-3d | NO DATA ATTACHED | | | | | 1961 | Oct | 22&24 | | | | | | | - | | Clare Champion | flood maps | 28/10/1961 | | - |
| 36-3e | NO DATA ATTACHED | | | | | - | | | | | | | | | - | | Clare Champion | flood maps | 25/04/1954 | | - |
| 36-3f | NO DATA ATTACHED | | | | | | Recent weekend | | | | | | | | - | | Clare Champion | flood maps | 09/11/1968 | | - |
| 36-3g | NO DATA ATTACHED | | | | | 1968 | Dec | 24-26 | | | | | | | - | | Clare Champion | flood maps | 04/01/1969 | | - |
| 36-3h | NO DATA ATTACHED | | | | | | Recent | | | | | | | | - | | Clare Champion | flood maps | 18/01/1969 | | - |
| 36-3i | NO DATA ATTACHED | | | | | 1969 | Jan | 19-20 | | | | | | | - | | Clare Champion | flood maps | 25/01/1969 | | - |
| 36-3j | NO DATA ATTACHED | | | | | 1949 | Oct | 24 | | | | | | | - | | Clare Champion | flood maps | 29/10/1949 | | - |
| 36-3k | NO DATA ATTACHED | | | | | 1965 | Jan | 09-10 | | | | | | | - | | Clare Champion | flood maps | 16/01/1965 | | - |
| 36-3l | NO DATA ATTACHED | | | | | - | | | | | | | | | - | | Irish Times | flood maps | 09/12/1924 | | - |
| 36-3m | TB REVIEWED - CAN'T READ | Tidal | Kilrush | | | - | | | | | | | | | - | | Irish Times | flood maps | 19/10/1886 | | - |
| 36-3n | Other | Tidal | Kilrush | Kilrush | | 1886 | Oct | 14 | | | | | Storm | Damage to vessels. | - | | Freemans Journal | flood maps | 19/10/1886 | | - |
| 36-3o | NO DATA ATTACHED | | | | | 1924 | Decr | 12 | | | | | | | - | | Kerryman | flood maps | 13/12/1924 | | - |
| 36-3p | NO DATA ATTACHED | | | | | 1886 | Octr | 14 | | | | | | | - | | Clare Journal | flood maps | 21/10/1886 | | - |
| | | | | | | | | | | | | | | | | | | | | | |
| **CAR 38 LISSAN WEST** | | | | | | | | | | | | | | | | | | | | | |
| 38-1 | NO DATA FROM DATABASE | | | | | | | | | | | | | | - | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| **CAR 53 SHANNON** | | | | | | | | | | | | | | | | | | | | | |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | | | | | | | |
| 53-1a | Other | | Shannon | Ballycally | | 2005 | Jan | | | | | Road | Surface water runoff | Surface water runoff to road L3169. The runoff was from land to south of the road. Water flowed around one residential property but not flooded. *This is a rare event. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |
| 53-1a | Other | | Shannon | Ballycally | | c2000 | | | | | | Road | Tidal backing up from the estuary | The L7174 was flooded. *A flap valve have been installed and since then the problem has not recurred. | - | | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |
| | | | | | | | | | | | | | | | | | | | | | |
| **CAR 55 SIXMILEBRIDGE** | | | | | | | | | | | | | | | | | | | | | |
| 55-1a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 478 658 | 2009 | Nov | 26 | | | | Map showing extent of flooding | | Roads at Sixmilebridge flooded and impassable. | 1 | | Clare CC | flood maps | 26/11/2009 | | 4 |
| 55-2a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1995 | | | | | | Properties, sewage treatment plant | Increased rainfall & lack of maintenance. | 14 homes affected (6 flooded & 8 at immediate risk - flooded 5 times since Christmas 1994). Flooding worsened when the nearby sewage treatment plant flooded resulting in sewerage backing up in the sewer pipe & manhole system affecting all of the gardens, many outbuildings, some houses & threatened the others. 6 houses were rendered totally uninhabitable for several weeks & one nationally known prize winning garden was also flooded. | - | | OPW FAS Report | flood maps | - | | 1 |
| 55-2a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1994 | | | | | | Properties | | Severe flooding of houses in Sixmilebridge. | - | | OPW FAS Report | flood maps | - | | 1 |
| 55-2a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1991 | | | | | | | | *Public licensed premises owner relieved the 1991 flood situation by cutting a hole in the wall separating the millpond from the road to allow the water to flow down the road. No damage to property resulted from this action. | - | | OPW FAS Report | flood maps | - | | 1 |
| 55-2a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1959 | Decr | | Figure 1 showing the flood water levels is MISSING! | | | | Long slow recession of the floods (e.g drop <0.3m in 24hours) | | - | | OPW FAS Report | flood maps | - | | 1 |
| 55-2a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1946 | Jan/ Feb | | 6.1" | | | | | | - | | OPW FAS Report | flood maps | - | | 1 |

JACOBS

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
| 55-2b | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1995 | Jan | 27 | | | | Aerial photographs showing extent of flooding | | | - | | OPW Dublin | flood maps | 27/01/1995 | | 2 |
| 55-2c | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1995 | Jan/ Feb | | Level book showing flood levels - Houses flood level ranging btw 24.46 to 26.29mOD (no unit given but believed to be ft (Poolbeg)). *Other flood mark levels available. | | | Properties | | | - | | OPW Mungret | flood maps | 01/02/1995 | | 2 |
| 55-2d, 7a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654, R 477 659 | 1991 | | | | | | | | | - | | Consultants Report | flood maps | 01/12/1995 | | 3 |
| 55-2d, 7a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654, R 477 659 | 1994 | | | | | | | | | - | | Consultants Report | flood maps | 01/12/1995 | | 3 |
| 55-2d, 7a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654, R 477 659 | 1995 | Jan | | | | | Properties, sewage treatment works | Very heavy & prolonged rainfall (flooding lasted for approximately 2 weeks). Back up of flood waters in the small tributary stream btw the County Council sewage plant & nearby houses. Back up of surface water. | 14 dwelling houses affected (6 houses totally uninhabitable for several weeks) & threatening a number of other properties in the village including the local garage, church, public house and farmland in the surrounding area. Sewage works on the left bank completely inundated & inability of the works to discharge resulting in backing up of the sewerage system. Premises adjacent to millpond threatened. Part of square in the centre of the town flooded due to surface runoff backing up and flowed out into the street. | - | | Consultants Report | flood maps | 01/12/1995 | | 3 |
| 55-2e | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 479 654 | 1994 /95 | Dec - Jan | | | | | | | Severe flooding in Sixmilebridge. | - | | OPW Note | flood maps | - | | 3 |
| 55-3a, 8a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Setrights Cross to Sixmilebridge R462 | R 479 637 | 2005 | Jan | | 450mm road flooding on road close to railway line. | | | Road | Prolonged heavy rainfall resulting in surface runoff off land to east of road. | Road flooded and impassable. *This is an unusual occurrence. | 2 | 5-10% (1:10 to 20 yrs) | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |

| Ref | Where? | | | | | When? | | | Magnitude? | | | | Flooding mechanism | Impact? | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | River Basin | Tributary | CAR | Location | Grid Ref | Year | Month | Day | Peak level | Rainfall | Flow | Flood Extent | | Any damage caused | Rank | Estimated AEP | Source | | Date | Authenticity | Flood Quality Code |
| 55-4a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | R462 at Junction with L7026 | R 477 673 | 2005 | Jan | | | | | Road | Heavy rainfall/runoff and lack of capacity of culvert | Water overflowed across the R462 due to the overflow of an open drain which was culverted under the R462. Road was however passable. | 2 | | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |
| 55-5a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Broadford Road | R 495 673 | 2005 | Jan | | | | | Road & land | Heavy rainfall & runoff. There is no stream or drain. It is a low point & flooding due to sheer volume of water & inadequate drainage due to dip. | Road & surrounding land flooded. *This is an exceptional event & has only occurred once. | 2 | | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |
| 55-6a, 9a | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Rossmanagher Bridge | R 475 651 | 2005 | Jan | | | | | Road | Culvert under railway bridge which outfalls to the Ratty River nearby was unable to cope with volume of water | Road was impassable. | 2 | 10-20% (1 in 5 to 10 yrs) | OPW Flood Hazard Mapping Phase 1 | flood maps | 23/01/2006 | | 4 |
| 55-7b | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 477 659 | 1994 / 1995 | Winter | | | | | Properties | Owenogarney River burst its banks. | Severe flooding of a number of dwellings in Sixmilebridge. | - | | Consultants Report | flood maps | 10/1998 | | 3 |
| 55-7b | Owenogarney (Ratty) | Owenogarney | Sixmilebridge | Sixmilebridge | R 477 659 | 1991 | | | | | | | | Severe flooding in Sixmilebridge. | - | | Consultants Report | flood maps | 10/1998 | | 3 |
| 55-9b | NO DATA ATTACHED | | | | R 475 651 | - | | | | | | | | | - | | Irish Times | flood maps | 09/11/1954 | | - |
| 55-9c | NO DATA ATTACHED | | | | R 475 651 | - | | | | | | | | | - | | Clare Champion | flood maps | 06/11/1954 | | - |

**Further Information on the December 1999 Flood Event in Ennis (from the Ennis Flood Study Report, February 2004)**

The flooding at Ennis was divided into five separate reaches:

**(a) Fergus Lower (from Tulla Road and downstream of Knox's Bridge to the Clarecastle Barrage)**

River inflows to this reach were from the Gaurus, Fergus Minor and Fergus Middle Rivers. The Clarecastle Barrage at the downstream end prevented inflow of the tide while at the same time prevented outflow from the Fergus causing water levels to build up.

In December 1999, water levels rose to 2.85mOD (Malin) in the Fergus at Doora Bridge. Hydraulic observations during floods have shown that practically all water that enters the lower reach is evacuated through the Barrage on the same tidal cycle. During the large floods in December 1999, 3$Mm^3$ of water enter the Fergus Lower, outflowing at periods of lower water leave during each tidal cycle.

*Gaurus Floodplain*

During the December 1999 event, the water level rose to 2.7mOD (Malin) at the Gaurus floodplain (as opposed to 2.85m (Malin) in the Fergus) and fell to approximately 1.9 to 2.0mOD (Malin) (as opposed to 1.65mOD (Malin) in the Fergus) over a tidal cycle. The connection from the Gaurus floodplain to the Fergus was through a narrow open channel and also via a sluice gate. Observations during this event showed that there was restriction to flow entering and leaving the floodplain and thus did not allow the full utilisation of the Gaurus floodplain i.e. not able to rise or fall to the same levels as in the river channel over the tidal cycle.

**(b) Fergus Middle (from the Mill Weirs through the town centre to downstream of Knox's Bridge)**

During the December 1999, flooding in Ennis occurred at Fergus Park, Lifford and the town centre mainly at Parnell Street, Woodquay and Mill Road.

Flooding in the Lifford and Fergus Park areas was not due to river levels overtopping the flood walls or embankment but due to the water ingress through the walls by seepage and/or backwater flow through storm runoff pipes and other openings. At Fergus Park, pumping operations commenced on the 24th December and continued for a number of days. According to local residents, the water would have entered some houses if the pumping operation was not in place. Fergus Park also suffered from surface water flooding due to the high river flow which prevented the surface water from discharging to it. The water level at Knox's Bridge was never lower than 2.00mOD (Malin) during this flood.

At Woodquay, water levels rose marginally above the top of the flood protection walls and only over a short length of wall of less than 20m. The flooding was through the floodwalls via storm runoff pipes or gullies and other openings in the walls. The failure of the local storm water runoff in this area to discharge to the river also contributed to the flooding.

The tidal effect on flood levels in the town was present as far upstream as the Mill weirs. There was no tidal effect above the Mill weirs. During the December 1999 flood, the water variation due to the tide is 0.8m downstream of Knox's bridge reducing upstream to a variation of approximately 0.15m at Mill Bridge. During this event, water level at Mill Bridge reached its maximum level of 4.02mOD (Malin). Without the tidal effect, it would have reached 3.85mOD (Malin) which was more than sufficient to cause flooding as flooding in Ennis town begins when water levels reached 3.4m to 3.5mOD (Malin) at Mill Bridge during heavy rainfall. Without heavy rainfall, a level of 3.5m to 3.6mOD (Malin) would cause flooding to Ennis town. It should be noted that Mill Bridge water levels were higher than 3.4mOD (Malin) continuously for several days from about 6 a.m. on the 22nd December 1999 onwards.

The maximum flood levels at Parnell Street were 3.85mOD (Malin) (the street level was 3.6mOD (Malin)).

### (c) Fergus Upper (south of Ballycorey to the Mill Weirs)

In the Fergus Upper reach, a maximum flood level of 5.7mOD (Malin) was observed in the vicinity of the Auburn Lodge and 5.2mOD (Malin) at Victoria Bridge (Cusack Road). There were no properties flooded in this reach.

The water levels in the Fergus Upper were controlled by the Mill weir complex and channel conveyance. Water levels were not affected by the downstream tidal influence.

### (d) Fergus Minor (immediately south of the Gort Road Industrial Estate to south of the Tulla Road)

There was no flooding occurred in this reach for the December 1999 event. The flood level in the river at Carravorrin was approximately 0.8m below the lowest property floor levels.

The Fergus Minor functioned as a small diversion channel via a large diameter sewage pipe which crossed the channel adjacent to the Gort Road Industrial Estate Sewage Pumping Plant. During the December 1999 event, peak flows of 10 to 12$m^3/s$ were diverted down this channel and away from the town.

The downstream of Carravorrin Bridge was tide influenced but upstream of the bridge, there was no evidence of any tidal influence.

### (e) Claureen (Inch Bridge to its confluence with the Fergus, north of the Cusack Road)

During the December 1999 event, the maximum levels upstream of Cloghleagh were approximately 5.9 to 6.1mOD (Malin). No dwellings were known to have flooded in this event.

The flood levels in the Fergus Upper and flow rate in the Claureen impacted on the flood levels in the downstream reach of the Claureen (Cloghleagh, Keelty and Kilnacally areas). Although the Claureen only drains a catchment area of less than 10% of the Fergus catchment area, it can have flood peaks that are up to 50% of the flood peak in the Fergus. However, Claureen floods were short lived, less than one day and conveyed much less water volume than Fergus floods which can last for a number of weeks.

Apart from the flooding at the five reaches mentioned above, flooding also occurred in Drumcliffe Road and lands at Knockannoura/Cappaghard.

During this flood event, a number of houses experience flooding in their gardens and driveways at Drumcliffe Road. The road itself was flooded and the road running northwest from the cross roads to the Ennistimon Road became impassable by car.

At Knockkanoura/Cappaghard, the water level reached 2.48mOD (Malin) and extended over an area of approximately 24ha. The flooding was caused by either overtopping of the embankment (from Tulla Road in the North as far southwards as the northern boundary of the Doora floodplain) at points towards its southern end or by seepage or by both methods.  The water came within millimetres of entering a house and close to the neighbouring nursing home.