Cork County Council

Douglas Flood Relief Scheme (Including Togher Culvert)

Hydrology Report

234335-00

Issue | 19 May 2017

Job number 234335-00

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Document Verification

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Job title	Douglas Flood Relief Scheme (Including Togher Culvert)	**Job number** 234335-00
Document title	Hydrology Report	**File reference**
Document ref	234335-00	

Revision	**Date**	**Filename**	20140411_Hydrology Report_V1.0.docx		
Draft 1	11 Apr 2014	**Description**	First draft		
			Prepared by	Checked by	Approved by
		Name	Emer Nic Aoidh	Alan Leen	Ken Leahy
		Signature			
Draft 2	1 Jul 2014	**Filename**	20140701_Hydrology Report_V1.1.docx		
		Description	FSU index flows revised.		
			Prepared by	Checked by	Approved by
		Name	Alan Leen/ Emer Nic Aoidh	Luke Ballantyne	Ken Leahy
		Signature			
Draft 3	17 Nov 2014	**Filename**	234335-00_2014-10-30_Hydrology Report_Draft Final.docx		
		Description	Draft Final		
			Prepared by	Checked by	Approved by
		Name	Alan Leen / Emer NicAoidh	Luke Ballantyne	Ken Leahy
		Signature			
Issue	19 May 2017	**Filename**	234335-00_Hydrology Report_Issue 1.docx		
		Description	Issue 1		
			Prepared by	Checked by	Approved by
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Issue Document Verification with Document ✓

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Executive Summary

Cork County Council, acting as Agents for the Office of Public Works (OPW) has commissioned a project to develop a Flood Relief Scheme for Douglas. The preferred option for Togher, as recommended in the draft Lee Catchment Flood Risk Management Plan (CFRMP), will also be included in the Scheme.

A detailed hydrological analysis has been undertaken to determine design flows for the Scheme. The analysis has applied a number of methods to establish a range of possible flood flows at various points in the study area.

The outputs from this study will be used in the hydraulic modelling stage of the project. These key outputs are outlined below.

A set of index flow (Qmed) estimates were produced for key points in the study area. Given that the catchments in the study area are small predominantly ungauged, it was considered important to compare the index flows estimated using a range of methods. The analysis is presented in Section 5.

A rating review of the existing EPA hydrometric gauge at Cork Landfill was also carried out and a revised rating curve was generated. The revised rating curve was then used to update the high flow series at the gauge. The updated flows were then analysed to provide an alternative estimate of Qmed at the gauge site (HEP_08) of approximately 5m^3/s. However, since the length of the gauge record is only four years, the confidence in the estimate produced by this method is low.

Based on the index flows estimated, it is apparent that there is a wide range of flows which could be adopted for the study. It is acknowledged that each of the index flood estimation methods used contain a significant amount of uncertainty. This is in part due to the limited resolution of mapped and digital data, and also due to the fact that many methods are calibrated to large catchments. No single method is entirely suitable for the full range of catchment sizes in the study areas.

Notwithstanding the above, and due to the uncertainty associated with the flow estimation, it was felt appropriate to adopt the FSU index flows, as they appear to be conservative, while still remaining reasonably consistent with other methods. The design index flows are shown in Table 34 below.

A flood frequency analysis was carried out, which established a study growth curve and in turn a set of design peak flows. The adopted growth curve was produced using the FSU pooling group methodology. The analysis is presented in Section 6. The design flows are tabulated in the table below.

Table 1: Design Flows

Return Period (years)	**Design Peak Flow (m^3/s)**								
	HEP_01	**HEP_02**	**HEP_03**	**HEP_04**	**HEP_05**	**HEP_06**	**HEP_07**	**HEP_08**	**HEP_09**
2 (Qmed)	15.22	9.95	5.48	5.16	2.59	2.84	0.90	8.47	2.97
5	20.39	13.33	7.34	6.91	3.47	3.81	1.20	11.35	3.98
10	24.20	15.81	8.71	8.20	4.12	4.52	1.43	13.47	4.72
25	30.44	19.89	10.96	10.31	5.18	5.68	1.80	16.95	5.94
50	34.09	22.28	12.27	11.55	5.80	6.37	2.01	18.98	6.65
100	38.96	25.46	14.03	13.20	6.63	7.28	2.30	21.69	7.60

A design flood hydrograph shape was also established. The adopted shape was produced using the FSR unit hydrograph method.

1 Introduction

1.1 Context

The Office of Public Works (OPW) in partnership with Cork City and Cork County Councils have carried out a Catchment Flood Risk Assessment and Management (CFRAM) Study for the Lee Catchment, which included Douglas and Togher in the Tramore River catchment. The Draft Catchment Flood Risk Management Plan (CFRMP) which was published in February 2010 identified a preferred flood risk management option in Togher, but did not identify a scheme for Douglas. However, Douglas was badly affected by flooding in June 2012. Cork County Council, acting as Agents for the OPW has now commissioned a project to carry out the design of the recommended scheme in Togher and also to develop a Flood Relief Scheme for Douglas. The scheme will consist of:

- Upgrading the existing culverts on the Tramore River between Lehenaghmore Industrial Estate and Greenwood Estate in Togher.
- Flood alleviation measures along the Tramore River/Ballybrack stream as necessary to provide the required standard of protection to properties in Douglas.

The project consists of five stages:

- Stage I - Development of a number of flood defence options and the identification of a preferred Scheme.
- Stage II - Public exhibition.
- Stage III - Detailed design, confirmation and tender.
- Stage IV - Construction.
- Stage V - Handover of works.

This Draft Hydrology report is produced as part of Stage I of the project.

1.2 Scope

The purpose of this report is as follows:

- Review the hydrological analysis undertaken for the Lee CFRAM Study, and incorporate as appropriate.
- Review the available records of historic flooding in the study area, in order to to inform the selection of design flows.
- Review the stage-discharge relationship at Cork Landfill hydrometric station (19052).
- Estimate flood flows and hydrograph shapes at key locations on the Tramore River and Ballybrack Stream for the design flood events using a range of methodologies including the Flood Studies Report, Flood Studies Update, etc.

1.3 Catchment Description

1.3.1 General

The study areas for the project are as follows.

Area 1: The catchment of the Douglas River. The Douglas River is more commonly known as the Ballybrack Stream, and will be referred to as such in this report.

Area 2: The length of the Tramore River between Lehenaghmore Industrial Estate and Greenwood Estate in Togher.

The study areas are shown in Figure 1 and Figure 2 below.

Figure 1: Douglas Flood Relief Scheme (including Togher Culvert) Study Areas

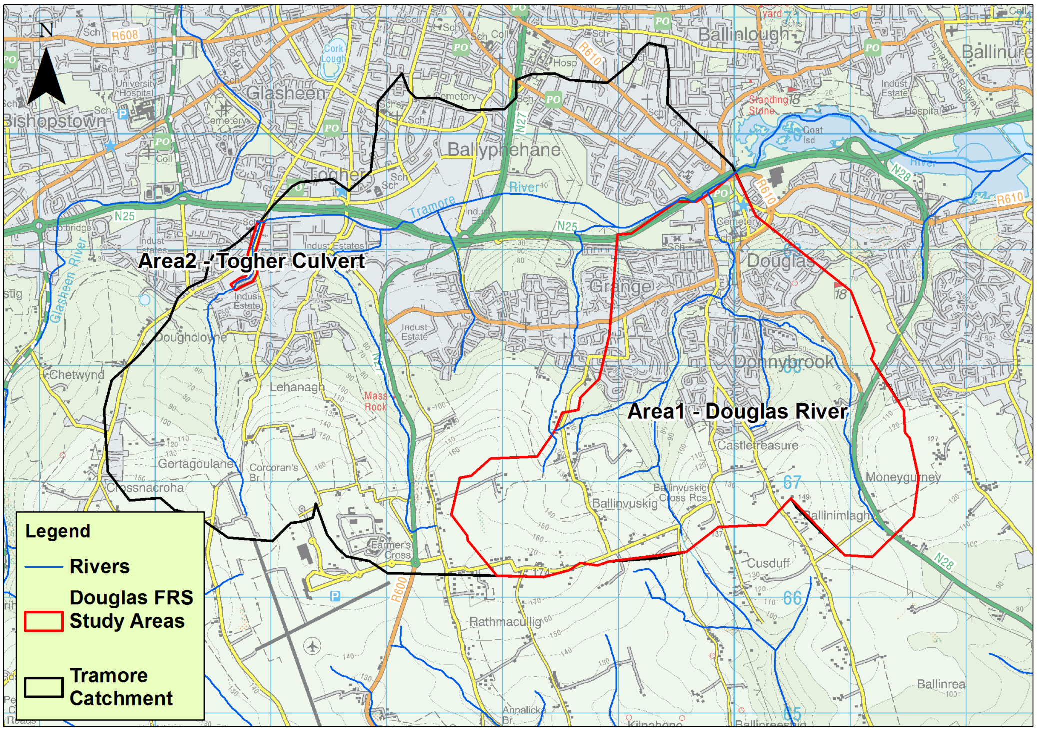
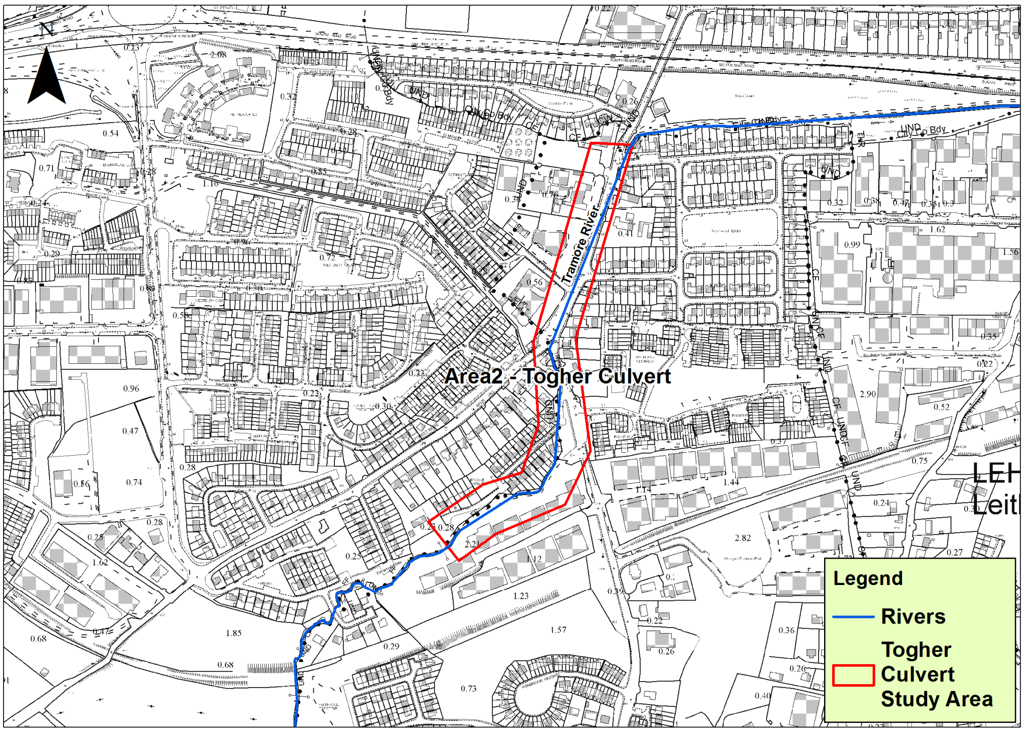


Figure 2: Study Area 2 – Togher Culvert



Both study areas are located south of the Cork City South Ring Road. The Tramore River rises in the southwest of the catchment and flows eastwards into the Douglas River estuary, which discharges into Lough Mahon. A number of tributaries join the Tramore River, the largest of which is the Ballybrack Stream, which flows north through Douglas before joining the Tramore River in a culverted section at Douglas Village Shopping Centre.

1.3.2 Topography

The land in study area 1 (Ballybrack Stream catchment) generally slopes from south to north, before levelling out towards Douglas Village. The highest point in area 1 is at approximately 170mOD. Ground levels at the downstream end of the catchment in Douglas Village are typically circa 3.1mOD

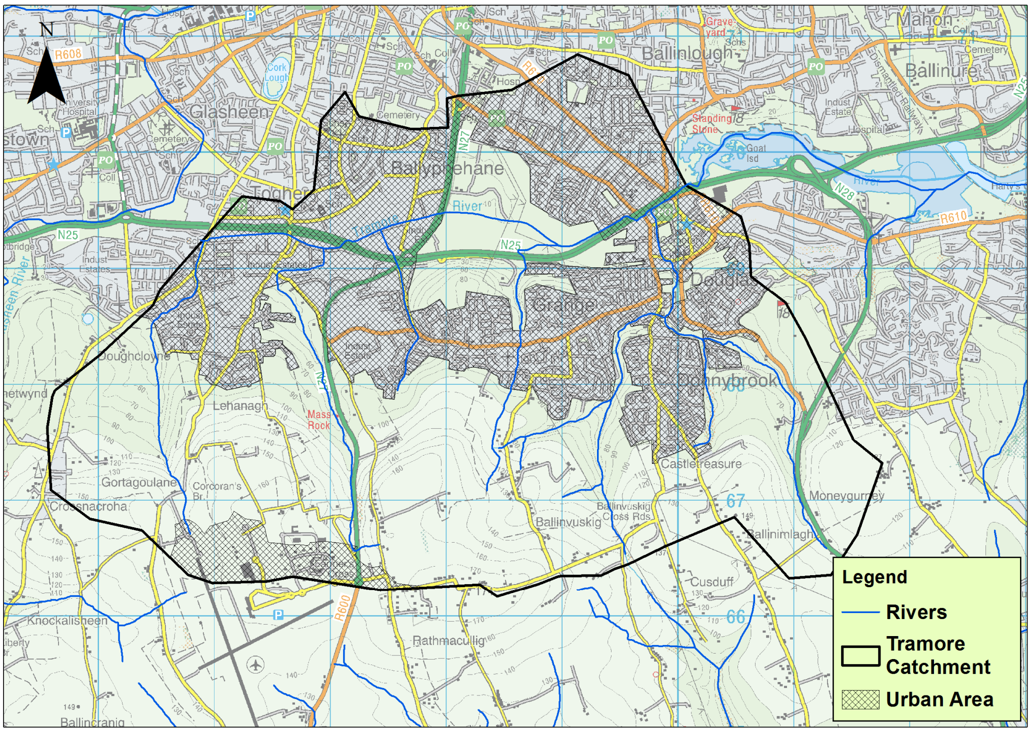
The land in study area 2 (Togher) slopes gently south to north, with a local low point of approximately 12.5mOD occurring in the centre of Togher at the northern end of the study area.

1.3.3 Land Use

The northern half of the greater Tramore catchment is largely urbanised as shown in Figure 3. The urbanised area comprises approximately 42% of the Tramore catchment. The southern half of the study area typically consists of agricultural land and one-off houses.

Information sources: Ordnance Survey Discovery Series Mapping and OSi NTF data.

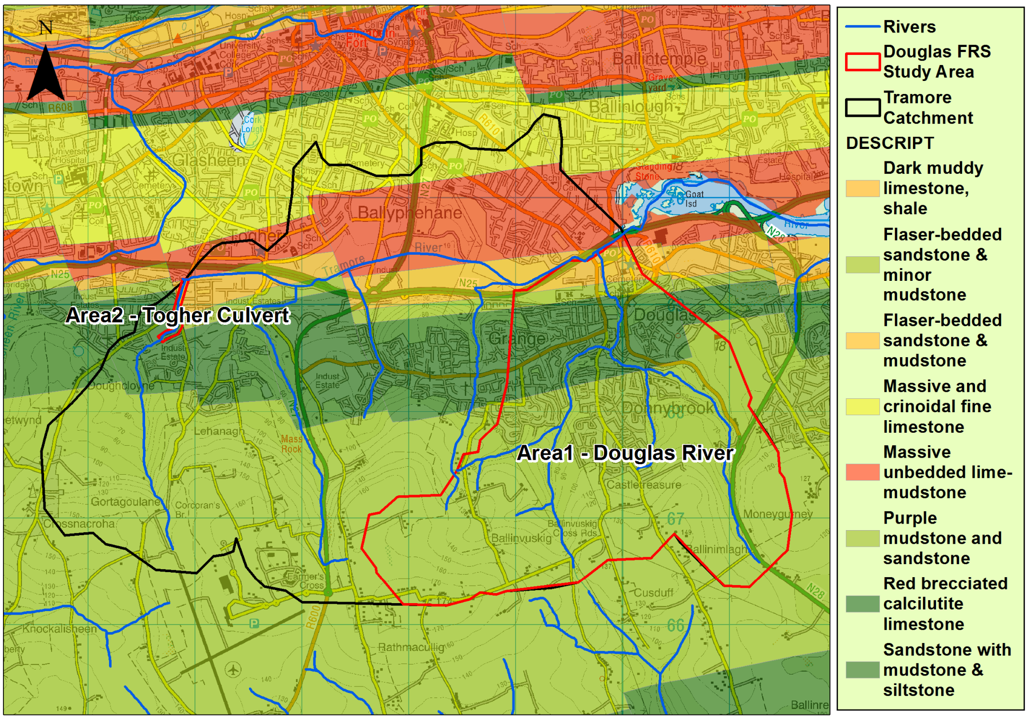
Figure 3: Urbanised Catchment Area



1.3.4 Geology and Soils

The Geological Survey of Ireland (GSI) mapping, as shown in Figure 4 below indicates that the dominant rock type in the southern portion of study area 1 comprises 'Purple mudstone and sandstone' (Ballytrasna Formation). Further north, the dominant rock type is 'Sandstone with mudstone and siltstone' (Gyleen Formation). To the north of this, the dominant rock type is classified as 'Flaser-bedded sandstone and minor mudstone' (Old Head Sandstone Formation). Further north again, the dominant rock type is classified as 'Flaser-bedded sandstone and mudstone (Cuskinny Member).

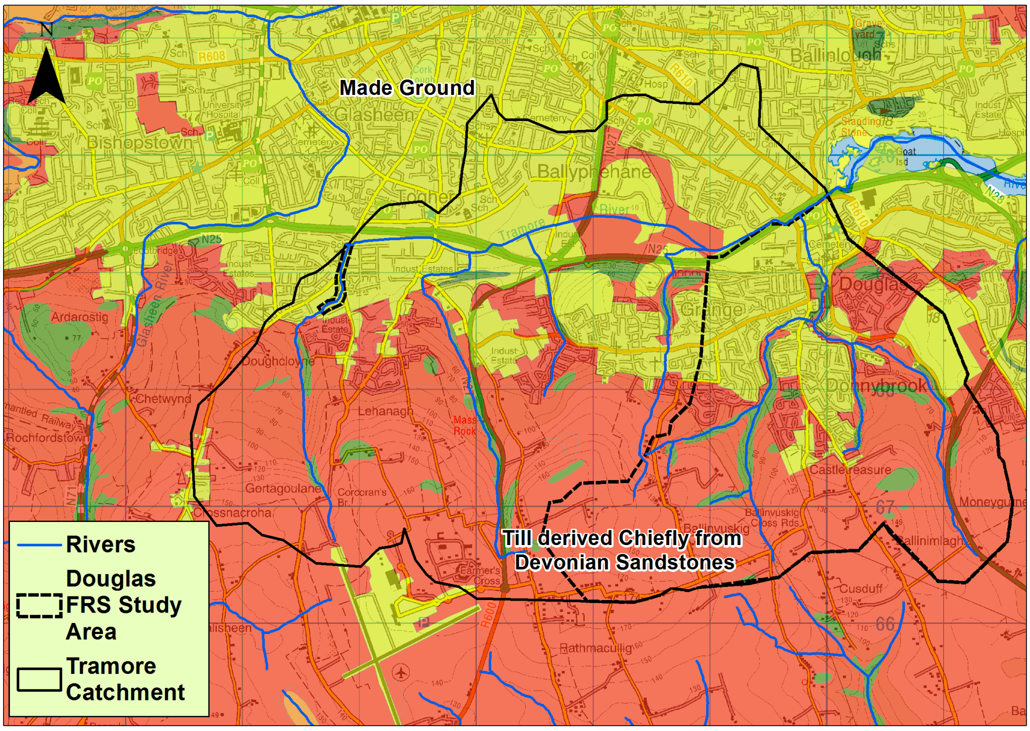
Figure 4: GSI Bedrock Map



1.3.5 Soils

EPA/Teagasc soil mapping, as shown in Figure 5 below indicates that the dominant soil type in the upper part of the Tramore catchment consists of '*Till derived chiefly from Devonian sandstones*'. *Made ground* is the dominant soil type in the lower part of the catchment, which is associated with urbanised areas.

Figure 5: Soils Map



2 Data Review

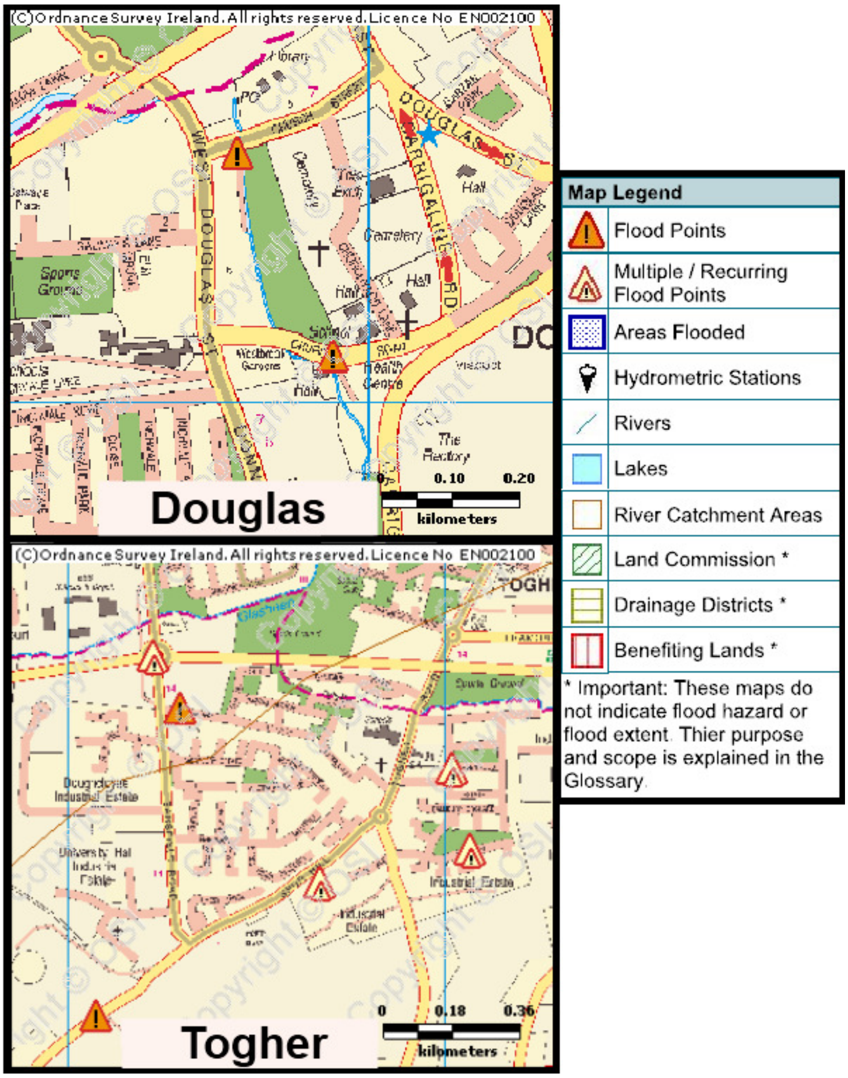
2.1 Review of Historical Events

2.1.1 National Flood Hazard Mapping Website

The National Flood Hazard Mapping website operated by OPW (www.floodmaps.ie) has collated records of historic flooding events throughout Ireland. The website shows numerous historical flood events in both Douglas Village and in the vicinity of the Togher culvert, primarily related to the 2012, 2009 and 2002 events.

Copies of summary reports for Douglas and Togher from the floodmaps.ie website are included in Appendix A. An extract from the reports is shown in Figure 6 below.

Figure 6: Extract from floodmaps.ie reports

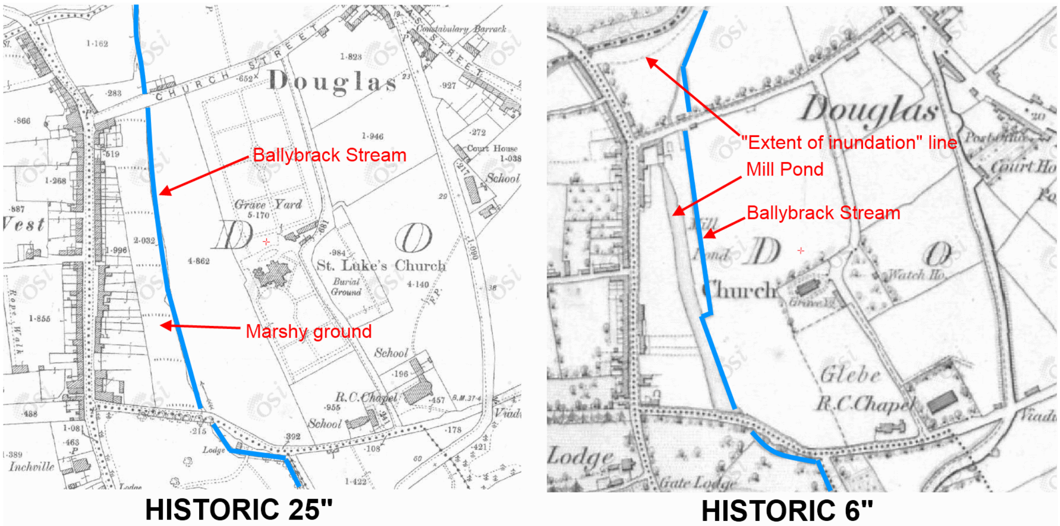


2.1.2 Historic Maps

Historic mapping was found to contain evidence of historical flooding in the study areas. The Ordnance Survey 6" map contains a reasonably detailed "extent of inundation" line along the Tramore River as far as the current day Cork Landfill. . The line indicates a wide floodplain upstream, which narrowed through Douglas before widening again as the Tramore River entered the Douglas River estuary.

The Ordnance Survey 25" map shows areas of marshy ground along the left bank of the Ballybrack Stream between Church Road and Church Street (since filled in). The older 6" map suggests that this area was once a pond which fed a mill at the corner of Church Street and West Douglas Street. Refer to Figure 7 below for extracts from historic maps showing the above features.

Figure 7: Extract from Historic Maps



2.1.3 Information Provided by Cork County Council & Office of Public Works

Reports and other information on past flooding in the study areas were supplied by Cork County Council and the Office of Public Works (OPW). Anecdotal evidence from CCC staff suggests that Douglas experienced infrequent minor flooding in the past from backing-up/blockage at the entrance to the old Ballybrack culvert at Church Street.

2.1.4 Information Provided by the Public

A significant amount of information on flooding issues in the study areas was submitted by the public during the initial public consultation process. An analysis of the information submitted is included in the Project Constraints Study Report.

2.1.5 Other Sources

An internet search for evidence of historic flooding in Douglas was carried out.

The Dáil debate record from 10 November 1949 contains a reference that “heavy flooding occurs at frequent intervals at Douglas, County Cork, causing serious hardship and loss to the residents”.

Foley, 1991 [1] reports major flooding in Douglas in 1892, 1895 and 1947, each of which were preceded by a significant rainfall event. Foley also states that there were reports of “two feet of water on the surface of the ground” during the 1892 event.

2.1.6 Summary

Based on the above review, a timeline of flood events in the study areas has been created and is summarised in Table 2 below.

Table 2: Timeline of major flood events in the study areas

Date of Flood Event	Mechanism	Areas Affected
29 & 30 December 2015	Fluvial	Togher
28 June 2012	Fluvial	Togher, Douglas village
December 2009	Fluvial	Tramore River (Kinsale Road roundabout area only)
27 November 2002	Fluvial	Togher
21 November 2002	Fluvial	Togher, Douglas village
3 December 2001	Fluvial	Togher
30 November 2000	Fluvial	Togher
5 November 2000	Fluvial	Togher, Douglas
1998	Fluvial	Togher
27 November 1953 (Date unconfirmed)	Fluvial	Douglas
17 March 1947	Fluvial	Togher, Douglas
24 December 1895	Fluvial	Douglas
19 November 1892	Fluvial	Douglas
Historic recurring	Fluvial / Tidal	Tramore River downstream of current Cork landfill site, Douglas

2.2 Review of Previous Studies

2.2.1 Lee CFRAM Study

The Lee Catchment Flood Risk Assessment and Management Study (CFRAMS) was commissioned by OPW in August 2006. The Lee CFRAMS covered the River Lee catchment and included the Tramore river catchment.

[1] Foley, C. *A History of Douglas*, Cork, 1991

The study was commissioned as a means of understanding the flooding problem and managing the flood risk through the development of a Catchment Flood Risk Management Plan (CFRMP). The outputs from the Lee CFRAMS are available for download at www.leecframs.ie.

Of particular importance in the context of this study is the Lee CFRAMS analysis of the flooding issue at Togher. This analysis recommended the option of a new culvert, which is to be developed as part of this study.

The CFRAMS reports state that the new culvert was designed for the 1% AEP MRFS flow, including a 95% confidence factor.

3 Analysis of Hydrometric Data

3.1 River Gauge Data

3.1.1 Cork Landfill Gauge

Within the Tramore River catchment, limited hydrometric data is available for analysis. There is a single hydrometric gauge (station 19052) on the Tramore River at Cork Landfill in operation since January 2010. The hydrometric station is located approximately 0.2km downstream of the South Link Road (N27) Bridge. This gauge is reviewed in detail in Section 4.

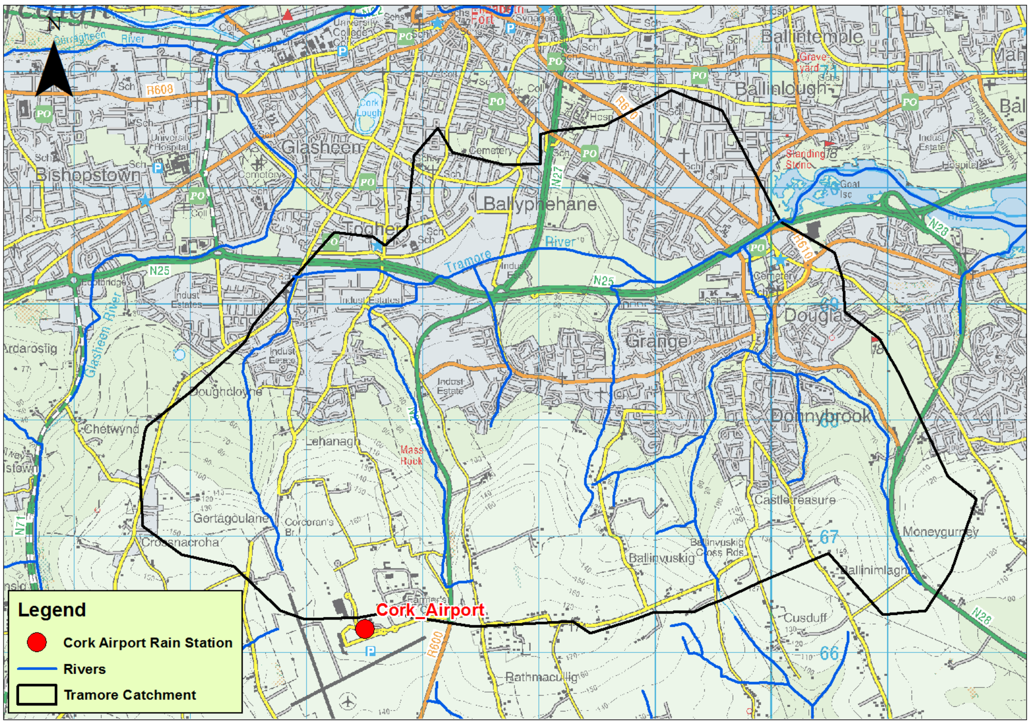
3.1.2 Ballybrack Stream

As part of this study, Cork County Council/OPW undertook to install a staff gauge at the entrance to the Ballybrack culvert. During the course of the project, EPA carried one spot flow measurement at this location at 11am on 14 March 2014. A flow of 0.262m³/s was recorded. While the information from the gauge is useful, it was deemed inappropriate to consider it further as part of the hydrology study.

3.2 Rainfall Data

The Met Éireann rain gauge which of most relevance to the study is located at Cork Airport, immediately southwest of the Ballybrack catchment as shown in Figure 8 below. The gauge is at an elevation of 154mOD, and records hourly rainfall depths.

Figure 8: Cork Airport Rain Gauge Location



As recommended in the Lee CFRAMS, it is proposed to adopt the Flood Studies Update (FSU) rainfall data for use in the hydrological analysis. This research was undertaken by Met Éireann as part of work package 1.2 of the FSU, and produced a grid of parameters that summarise the rainfall depth-duration-frequency relationship, allowing estimation of point rainfall frequencies for a range of durations for any location in Ireland.

4 Rating Review of Gauge 19052

4.1 Introduction

A rating review of the Cork Landfill Gauge (Station No. 19052) was carried out as part of this study. The gauge is maintained by the EPA/Cork City Council.

The objective of the rating review was to revise the existing rating curve by extending it to highest recorded water level recorded at the gauge. This is to allow a Qmed value be estimated with improved confidence from the four years of data at the site.

The rating review consisted of the following steps:

- Collate and review the EPA data from the gauge.
- Check for evidence of tidal influence at the gauge.
- Develop a hydraulic model of the reach to simulate a series of flows through the reach.
- Revise the rating curve based on the results of the hydraulic model.

4.2 Gauge Description

The gauge is located at Irish Grid coordinates E 168014m, N 69256m, approximately 250m downstream of the South Link Road Bridge and gauges a catchment area of approximately 9.9km^2. Refer to Figure 9 showing a location plan for the gauge.

The gauging site consists of a staff gauge, depth sensor and data logger located on the left bank approximately 5m upstream of a small weir. The weir is 6m long and approximately 0.64m high. At high flood flows the river can spill out onto the floodplain either side of the channel. The left overbank is relatively confined while the right overbank slopes gently away from the channel.

The existing EPA rating curve was based on a curve fitted to spot gaugings taken at relatively low water levels at the gauge site. EPA advised that the rating is still under development and that flow data above 1.3m^3/s has been extrapolated and therefore should be treated with extreme caution.

The gauge records began in January 2010. The maximum recorded water level at the gauge is 0.982m above gauge zero, or 4m OD, and was recorded during the flood event of 28 June 2012.

A photograph of the gauge site is shown in Figure 10.

Figure 9: Location of Cork Landfill hydrometric station

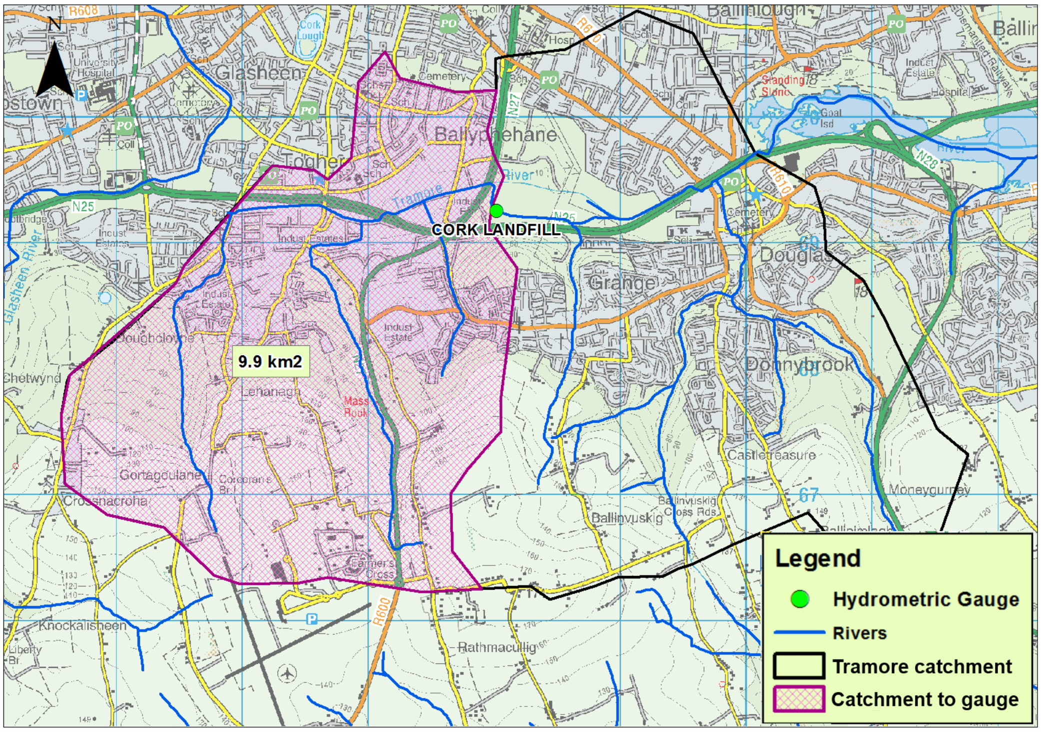


Figure 10: Cork Landfill hydrometric station

4.3 Data Collection

A site visit was initially carried out on 7 February 2014 to inspect the gauge and to develop an understanding of the local topography and flow regime.

Data on the gauge was supplied by the EPA. The data consisted of:

- Water depth recordings at 15 minute intervals, and associated estimated flows based on the EPA rating. The gauge data was recorded in 15 minute intervals with the majority of records classified as "Good" (the highest data quality rating on the EPA's scale), and within the validated range of the rating curve. The data supplied had no gaps in the record.
- 14 spot flow gaugings (all at relatively low flows).
- EPA rating curve.
- Information on gauge zero. Staff gauge zero was surveyed by the EPA to be 3.018mOD (Malin). As part of this study, the gauge zero was surveyed as 3.019mOD (Malin). Given the minor difference, and for consistency with the EPA gauge depth readings, a gauge zero of 3.018m OD was adopted.

Data covering the February 2014 tidal flood events from the tidal gauges at Ringaskiddy and Tivoli were obtained from OPW and Port of Cork respectively.

As part of the hydrographic survey carried out for the project, several cross sections and a longitudinal section of the gauge site were surveyed. This data was used to supplement the existing hydrographic survey data collected as part of the Lee CFRAMS.

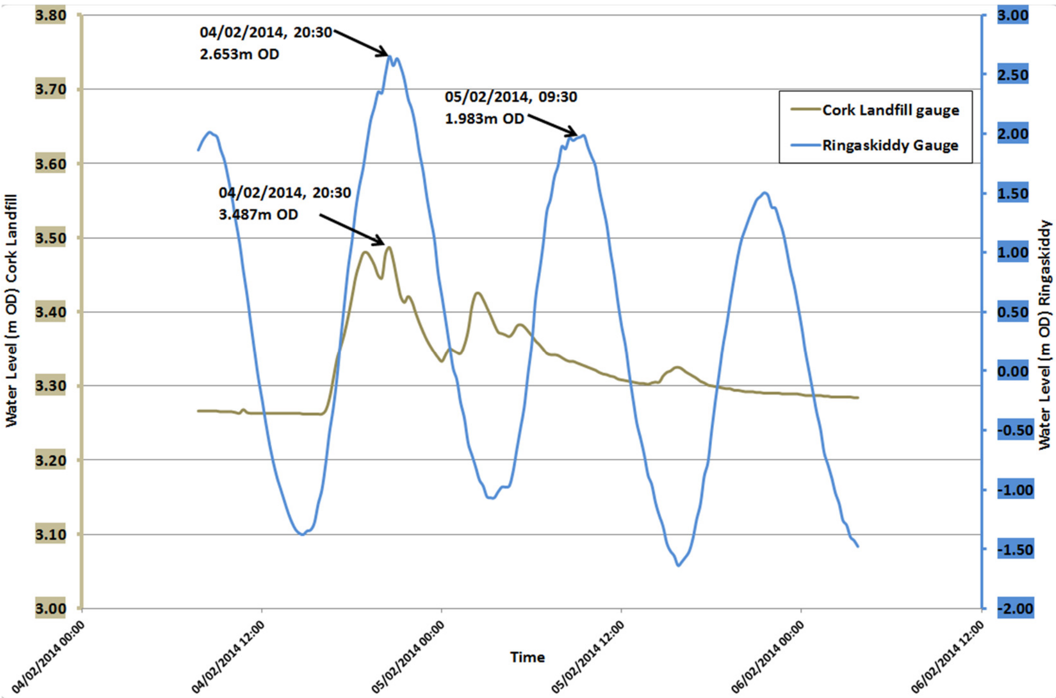
4.4 Tidal Influence on the Gauge

Due to the low elevation of the gauge, (gauge zero is 3.018m OD Malin) there were concerns that the gauge record could potentially have been influenced by extreme tides.

The period that was examined for tidal influence was 3-4 February 2014. During this period, a tidal flood event occurred which was the largest since Cork Landfill gauge records began.

Data from the tidal gauge at Ringaskiddy was plotted against the recorded water levels at the Cork Landfill gauge for comparison. Figure 11 shows the recorded levels at both gauges. (Levels recorded by the tidal gauge at Tivoli were also checked and found to be very close to the Ringaskiddy levels).

Figure 11: Water levels at the Cork Landfill Gauge and Ringaskiddy Tidal Gauge



On the above graph, it can be seen that the peak water level recorded at the Cork Landfill gauge is reasonably close in timing to that of the tidal peak. However, the river gauge water levels do not appear to match the tidal pattern over the course of the flood event (note that the river level temporarily falls as the tide is still rising). Furthermore, the tide level did not rise above the crest of the weir at the gauge site (2.9mOD).

From the analysis carried out it was deemed likely that the Cork Landfill gauge peak on 4 February was solely due to high flows in the Tramore River. Therefore, given that the tide levels on 4 February 2014 were the highest for the period of the gauge record, it is reasonable to assume that the gauge has not been tidally influenced for the duration of the record. However, it is possible that tide levels higher than the February 2014 event could influence water levels at the gauge site.

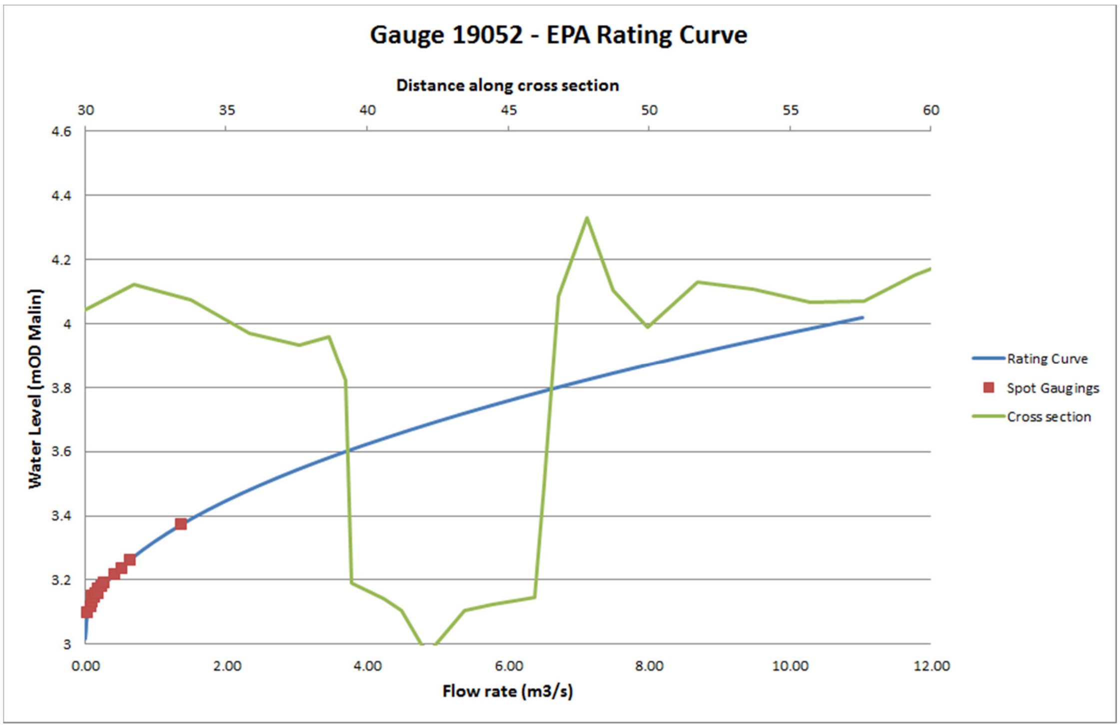
4.5 Review of EPA Rating

The EPA have developed their own rating curve for the Landfill site gauge. It is based on the 14 spot gauging recorded at the gauge. The rating curve comprises of 2 separate segments:

$Q = 27.1074*(h)^{2.6052}$: for 3.099m ODM – 3.235m ODM :
$Q = 11.0323*(h)^{2.0168}$: for 3.235m ODM – 3.373m ODM :

This rating curve is plotted in Figure 12 along with the spot gaugings and gauge cross section. It is clear from the figure that the highest recorded spot reading is in fact a relatively low water level in the cross section (3.373m ODM). The EPA rating curve beyond this elevation is an extrapolation.

Figure 12: EPA rating curve and spot gaugings plotted against the gauge cross section



4.6 Hydraulic modelling and Development of Revised Rating Curve

A hydraulic model of the Tramore River was developed as part of the Lee CFRAM. We have taken this model and made a number of modifications to it to develop our rating review model. The modifications included:

- Additional cross sectional data from the infill and validation survey was added to it.
- The parameters of the model were revised and updated.
- The geometry of a number of cross sections were modified.

The model reach extends from cross section 6TRA_3397 (just downstream of the N25 Bridge) to section 6TRA_619 (just upstream of the N25 Bridge) at Douglas village (see the following figure). The model build follows the best practice guidelines as described in ‘Extension of Rating Curves at Gauging Stations Best Practice Manual, D M Ramsbottom and C D Whitlow’, EA 2003.

The model was calibrated against three of the EPA spot gaugings:

- The spot gauging associated with the lowest recorded water level (Q=0.04 m^3/s; WL = 3.099 mOD Malin).
- The spot gauging associated with the mid-range recorded water level (Q=1.37 m^3/s; WL = 3.373 mOD Malin).
- The spot gauging associated with the highest recorded water level (Q=0.52 m^3/s; WL = 3.236 mOD Malin).

For each of the calibration runs, the recorded flow from the spot gauging was used as the upstream boundary condition of the model. A normal depth boundary was used as the downstream boundary condition of the model. It was situated far enough downstream of the gauge in the model to ensure it did not affect water levels at the gauge. The model was run with steady state boundary conditions.

The water level at the location of the gauge in the model was then compared with the recorded water level from the spot gaugings.

The results of the calibration are presented in Table 3. As can be seen from the results, the modelled water level closely matches the spot gauging water levels.

Table 3: Model Calibration

Q (m^3/s)	**WL from model (m ODM)**	**WL (spot gaugings - m ODM)**
0.04	3.099	3.099
0.52	3.23	3.236
1.37	3.37	3.373

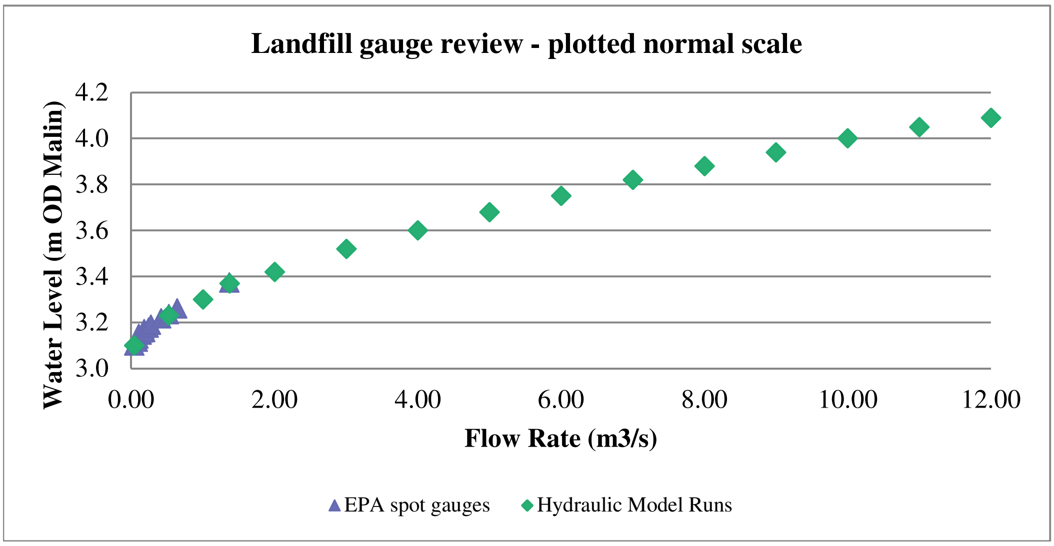
Ideally the model would also be calibrated against higher water level spot gaugings. This data however is not available for this gauge as it has not been collected by the EPA as part of their operation of the gauge.

In order to extend the existing rating curve beyond the current EPA rating, the hydraulic model was run with a number of flows ranging from $1m^3/s$ to $12m^3/s$. The model results are presented in the following table and a plot of the data against the EPA spot gaugings is presented in the figures below. The good calibration between the spot gaugings and model is evident from the plot.

Table 4: Hydraulic Model Results

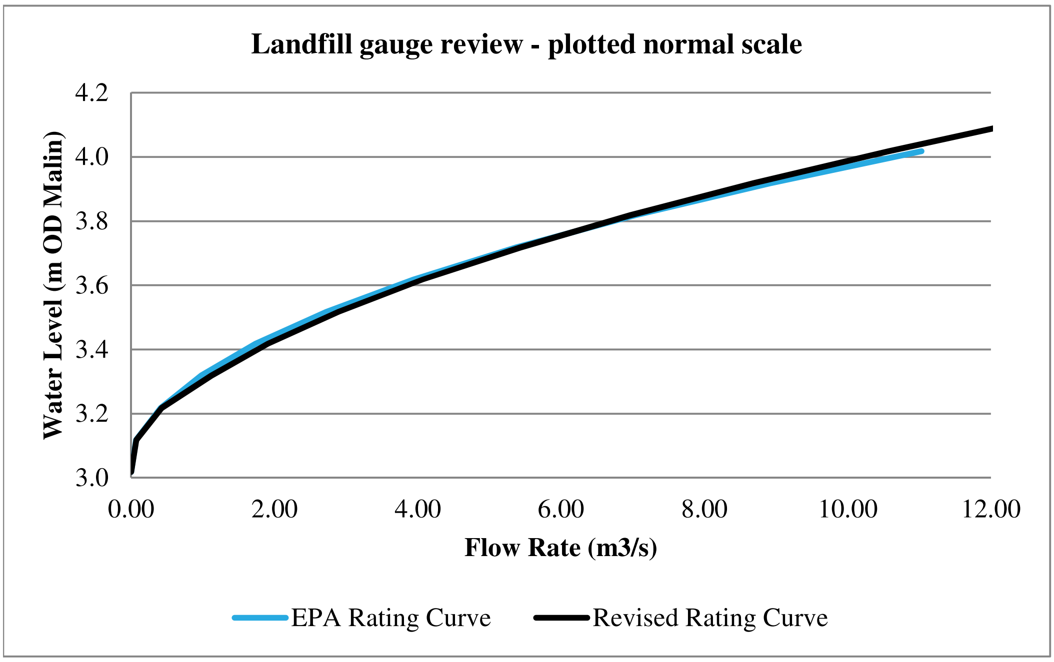
Q m^3/s	**WL at gauge - m ODM**
0.04	3.10
0.52	3.23
1.00	3.30
1.37	3.37
2.00	3.42
3.00	3.52
4.00	3.60
5.00	3.68
6.00	3.75
7.00	3.82
8.00	3.88
9.00	3.94
10.00	4.00
11.00	4.05
12.00	4.09

Figure 13: EPA Spot Gauge Readings and the Results from the Hydraulic Model



Deriving a rating curve based on the model results involves fitting a power-type equation to the data points. The results of this are presented in the following figure. It is evident from the plot that the revised rating curve is in fact very similar to EPA's existing rating curve.

Figure 14: EPA Rating Curve and Revised Rating Curve



The equation of the revised rating curve is as follows:

Q(WL) = 28.005 * (WL-0)^2.6021 (lower segment of curve: 3.018 – 3.283mOD Malin)

Q(WL) = 10.576 * (WL-0)^1.8687 (higher segment of curve: above 3.283 mOD Malin. Note that the revised rating curve is only applicable up to the max modelled flow of 12m^3/s which equates to an approximate level of 4.1mOD Malin)

4.7 Summary

A rating review of the Cork Landfill gauge was carried out. The review involved data collection, hydraulic modelling, and development of a revised rating curve for the gauge. Refer to Section 5.3, where the revised flows are used to develop estimates of Qmed at the gauging site.

It should be noted that there is significant uncertainty associated with the revised rating, due to the short gauge record and lack of spot gaugings at high flows.

5 Estimation of Index Flood

5.1 Overview

In order to establish the existing flood risk and design flood defence measures, it is necessary to provide estimates of flood flows for a range of return periods, up to and including the 1% AEP fluvial flood event.

This is typically achieved by calculating an index flood flow, and scaling it up by a flood frequency growth curve.

As part of this study, a range of methods have been applied to give estimates of the index flood, namely:

- Direct analysis of gauge data (refer to Section 5.3)
- Flood Studies Update methods (refer to Section 5.4)
- Flood Studies Report Statistical Method (refer to Section 5.5)
- Flood Studies Report Rainfall-Runoff Method (refer to Section 5.6)
- Institute of Hydrology Report No. 124 Method (refer to Section 5.7)
- Modified Rational Method (refer to Section 5.8)

The flow estimates produced by previous studies are included in Section 5.9.

A discussion of the results of the analysis is presented in Section 5.10, followed by the selection of a set of design index floods in Section 5.11.

5.2 Hydrological Estimation Points

To carry out flood flow estimations, it is necessary to establish a number of Hydrological Estimation Points (HEPs) at appropriate locations along the watercourses. HEPs are typically located at confluences, and at the upstream and downstream ends of modelled watercourses. Hydrological analysis has been carried out on the catchments contributing to each HEP in order to calculate flows at each HEP. These HEPs also act as hydrological “check points” along a river’s course and are useful for integrating hydrology with the hydraulic modelling.

The locations of each HEP are shown in Figure 15 and summarised in Table 5 below. The typical arrangement of HEPs at a confluence is shown in Figure 16 below.

Figure 15: Hydrological Estimation Points

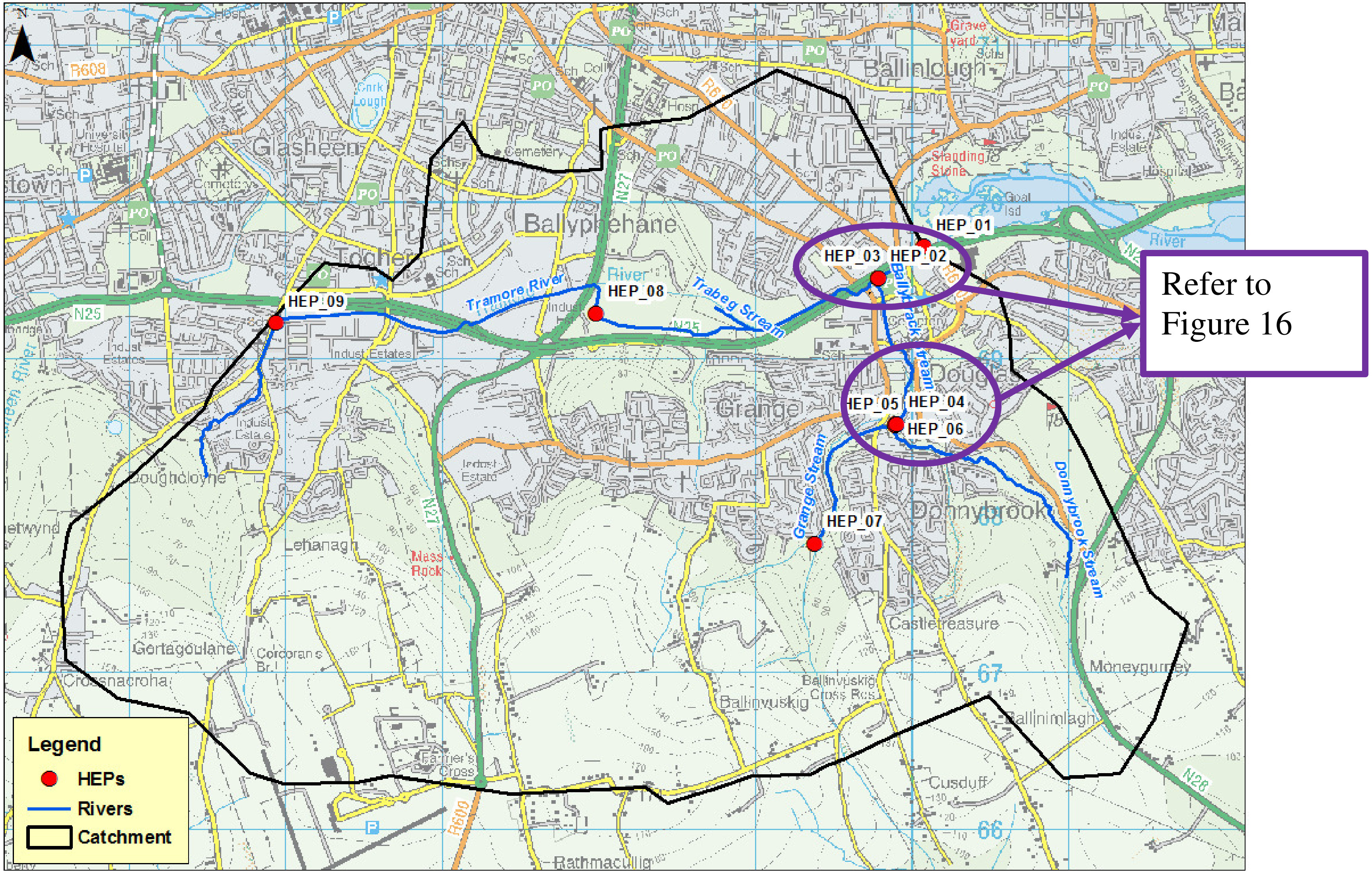


Figure 16: Arrangement of HEPs at confluences

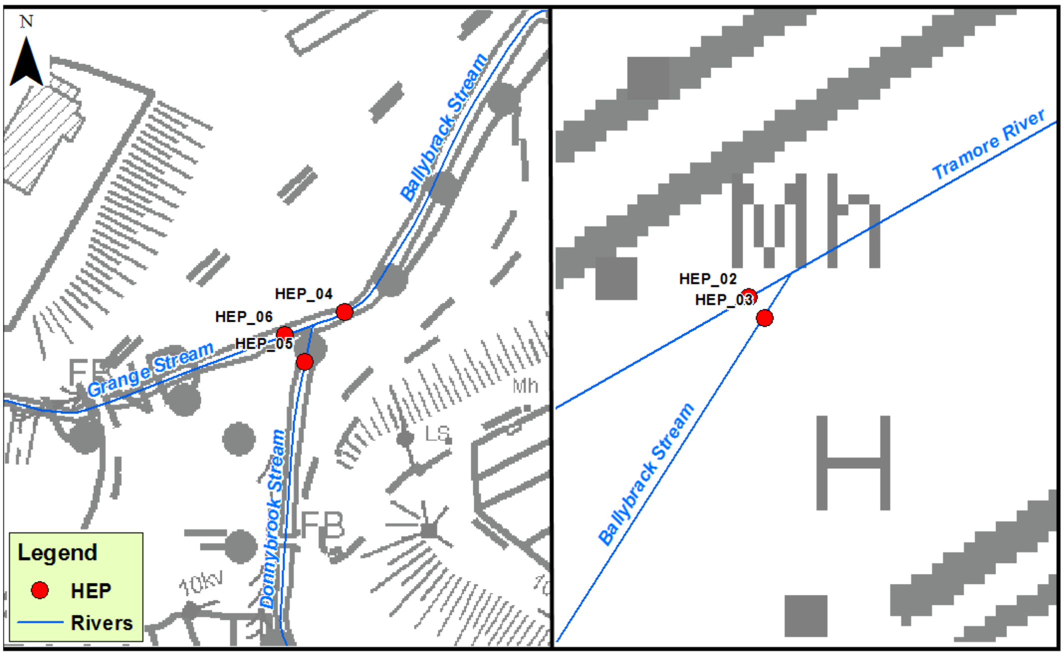


Table 5: HEP Locations

HEP	HEP Location	Catchment Area (km^2)	Upstream Channel length (km)	Easting (ING)	Northing (ING)
HEP_01	Downstream end of the Tramore Catchment	22.03	7.57	170072.1	69715.6
HEP_02	Tramore River, upstream of the confluence with the Ballybrack Stream	13.53	7.24	169777.7	69514.1
HEP_03	Ballybrack Stream, upstream of the confluence with the Tramore River	7.45	3.88	169886.6	68580.2
HEP_04	Ballybrack Stream, downstream of the confluence with the Grange Stream	7.13	2.85	169890.2	68575.6
HEP_05	Donnybrook stream, upstream of the confluence with the Grange Stream	3.5	2.84	169777.3	69514.1
HEP_06	Grange Stream, upstream of the confluence with the Donnybrook Stream.	3.63	2.46	169897.1	68584.1
HEP_07	Grange Stream, at the upstream end of the channel	1.34	1.11	169375.3	67821.6
HEP_08	Landfill Gauge on the Tramore River	9.89	5.24	167981.4	69290.4
HEP_09	Tramore River, Downstream end of the Togher Culvert	3.79	2.86	165856.3	68818.3

5.3 Analysis of Gauge Data

5.3.1 Introduction

As outlined in section 4 of this report, a rating review of the Cork Landfill gauge was carried out in order to improve confidence in the high flow readings at the gauge. In this section, the revised rating curve will be used to develop estimates of Qmed. It should be noted that because the gauge record is so short, the confidence in the estimates produced by this method is very low. However, they serve as a useful check on the ungauged catchment flow estimations. For the purposes of this analysis, the following data series were extracted from the gauge records:

- Annual maximum flood series (AMAX)
- Peaks over threshold series (POT)

5.3.2 AMAX Series

There are three complete hydrometric years of data available at the gauge. Details of these years are set out in Table 6 below. The median annual flow (Qmed) of this series is 4.98m^3/s. The mean annual flow of this series (Qbar) is 6.7m^3/s.

Table 6: Amax series for Cork Landfill Gauge, Station 19052

Hydrometric year	Year start date	Year end	Date of highest flow	Max water level (m OD)	Max Flow (m^3's)
2010	01/10/2010	30/09/2011	16/11/2010	3.680	4.89
2011	01/10/2011	30/09/2012	28/06/2012	4.0	10.22
2012	01/10/2012	30/09/2013	21/03/2013	3.686	4.98

5.3.3 Peaks-Over-Threshold Series

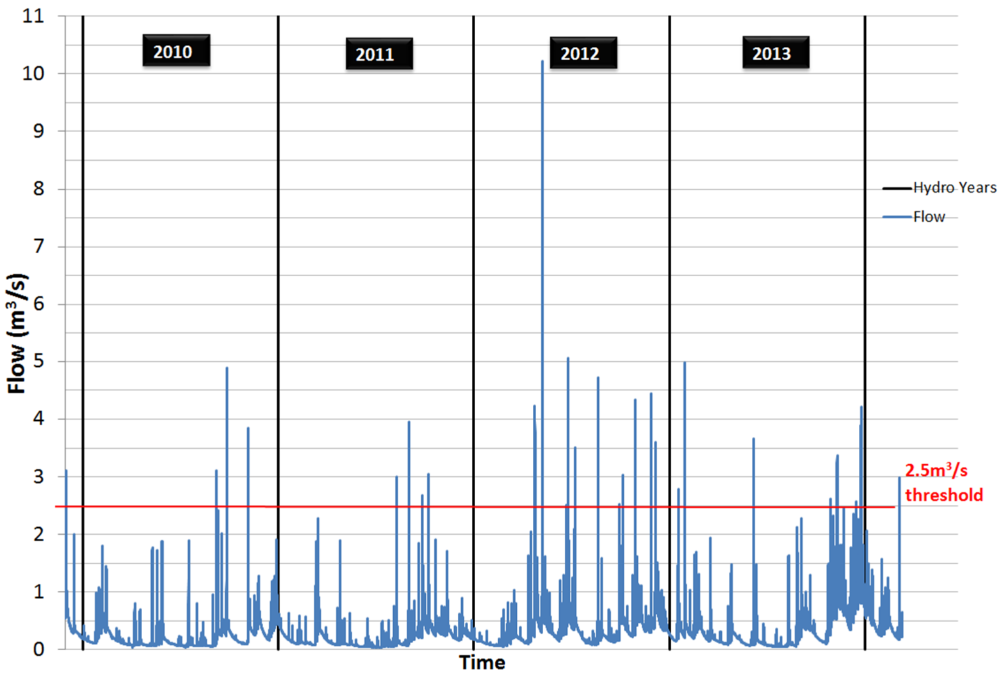
The peaks-over-threshold (POT) series consists of a series of flood flows that are greater than a selected threshold. The FEH and FSU both note that using the POT series method can provide a better estimate of Qmed when less than 14 years of gauged data is available. This is because the POT series can contain more floods than the AMAX series.

The UK Flood Estimation Handbook (FEH) contains a methodology for estimating Qmed at a gauged site using a POT series. This method was applied to the Cork Landfill gauge records and is summarised below.

Only three complete hydrometric years of data was available for the Cork Landfill gauge. However, the FEH states that for very short record lengths, the start/finish dates of the hydrometric years can be moved to provide an additional year of data, as a small amount of additional data can greatly enhance the analysis. Therefore, for this analysis, to provide four years of data, the hydrometric year was taken to start on 21 February.

Figure 17 below shows the complete flow for the record period as estimated by the revised rating with a threshold of 2.5m^3/s marked along with the revised hydrometric years.

Figure 17: Complete flow record using revised rating equation for the revised hydrometric years



A threshold of 2.5m^3/s was set for the analysis. All 24 independent flood peaks which exceeded the selected threshold were identified, and ranked in descending order with the greatest peak being Q_1, the next largest flood peak Q_2 and so on down to Q_{16}, the smallest flood peak exceeding the 2.5m^3/s threshold. Table 7 below shows the ranked POT series.

Table 7: Ranked POT Series

Rank	Flow (m^3/s)	Date	Rank	Flow (m^3/s)	Date
1	10.22	28/06/2012	13	3.85	12/02/2014
2	5.06	15/08/2012	14	3.66	28/07/2013
3	4.98	21/03/2013	15	3.60	25/01/2013
4	4.89	16/11/2010	16	3.51	28/08/2012
5	4.73	11/10/2012	17	3.37	31/12/2013
6	4.45	18/01/2013	18	3.27	15/06/2012
7	4.34	19/12/2012	19	3.10	29/10/2010
8	4.34	19/12/2013	20	3.05	29/11/2011
9	4.24	14/06/2012	21	3.04	25/11/2012
10	4.21	14/02/2014	22	3.01	30/09/2011
11	3.96	23/10/2011	23	2.79	10/03/2013
12	3.85	27/12/2010	24	2.67	17/11/2011

The index flood was calculated using the following equation (FEH equation 12.13)

$$Qmed = wQ_i + (1 - w)Q_{i+1}$$

Where:

- Q_i = the flood just larger than Qmed,
- Q_{i+1} = the flood just less than Qmed
- w = the weighted average of Q_i and Q_{i+1}.

For four years of data, i = 3 and w = 0.298 (FEH table 12.1).

Using this method, Qmed was calculated to be 4.92m^3/s.

Based on a record length of four years, the standard factorial error of the Qmed estimate (assuming a UK-average dispersion of floods) is 1.204 (FEH table 12.3).

The range of flows predicted using the POT analysis is presented in Table 8 below.

Table 8: POT Qmed Estimates

Qmed	4.92	m^3/s
Qmed (68% confidence)	5.92	m^3/s
Qmed (95% confidence)	7.12	m^3/s

5.4 Flood Studies Update

5.4.1 Introduction

In 2005, the Office of Public Works (OPW) began the Flood Studies Update (FSU) Programme with the goal of developing new flood estimation methods for Ireland which could significantly improve the quality of flood estimation to aid flood risk management.

At time of writing, the use of the FSU method is not yet widespread. However, it was deemed appropriate to apply the method in conjunction with the use of traditional methods.

The following issues were identified with regards the applicability of the methods to this study:

- OPW states that the FSU method is typically suitable for catchments greater than 25km^2 in area. However, a recent paper[2] prepared by OPW states that the method is also suitable for use in catchments as small as 5km^2. Below this limit, the resolution of the underlying FSU data is expected to become a significant source of error; along with the fact that the FSU gauging stations are typically on much larger catchments (the median catchment area of the FSU stations is 215km^2).

[2] Fasil Gerbre & Oliver Nicholson, *"Flood Estimation in Small and Urbanised Catchments in Ireland*", (2012)

- The hydrology study for the Lower Lee Flood Relief Scheme was ongoing at the time of preparation of this report. As part of the Lower Lee study, JBA Consulting (working as sub-consultants for Arup) carried out an analysis of four gauged catchments in the upper Lee catchment, and derived a standard adjustment factor for Qmed for the Lower Lee scheme. It was felt that the analysis for Douglas should take cognisance of any relevant results from that study. For further details, refer to section 5.4.3.3.
- The findings of the Cork Landfill gauge rating review should be taken into account in determining the adjustment factor for the Qmed estimates. For further details, refer to section 5.4.3.2.

5.4.2 FSU 7-variable Equation

The FSU adopts the median annual flood, Qmed as the index flood. FSU Work package 2.3 contains a method to estimate Qmed using a regression equation which uses seven different physical catchment descriptors (PCD's). The equation estimates Qmed for a rural catchment.

$$Qmed_{Rural} = 1.237\ x\ 10^{-5} AREA^{0.937} BFIsoils^{-0.922} SAAR^{1.306} FARL^{2.217} DRAIND^{0.341}\ S1085^{0.185} (1 + ARTDRAIN2)^{0.408}$$

Where:

- AREA is the catchment area (km^2).
- BFIsoils is the base flow index derived from soil data.
- SAAR is long-term mean annual rainfall amount in mm. Data from Met Éireann 1981-2010 was used.
- FARL is the flood attenuation by reservoir and lake.
- DRAIND is the drainage density.
- S1085 is the slope of the main channel between 10% and 85% of its length measured from the downstream end of the catchment (m/km).
- ARTDRAIN2 is the percentage of the catchment river network included in the Drainage Schemes.

The FSU 7-variable equation has a standard factorial error of approximately 1.37.

The physical catchment descriptors used in the FSU index flow estimation for each HEP are detailed in Appendix B.

Table 9 below summarises the Qmed estimated at each HEP using the FSU 7-variable equation.

Table 9: FSU Qmed (rural) estimates

Location	**Flow (m^3/s)**
HEP_01	5.92
HEP_02	3.80
HEP_03	2.63
HEP_04	2.56

Location	Flow (m^3/s)
HEP_05	1.30
HEP_06	1.40
HEP_07	0.56
HEP_08	3.15
HEP_09	1.34

5.4.3 Adjustment of Qmed (rural) Estimates

FSU provides a method for improving the Qmed (rural) estimate at the subject site using a data transfer procedure. Several possible methods for carrying out the data transfer are outlined in the sections below. The data transfer procedures are also compared with the standard factorial error of the FSU 7-variable equation.

5.4.3.1 FSU Pivotal Site Adjustment

A pivotal site is a gauging station that is geographically close or hydrologically similar to the subject site. Ideally, a pivotal site will lie a short distance upstream or downstream from the subject site. The Qmed rural estimate at the subject site is adjusted as follows:

Qmed at the pivotal site is estimated both from gauged records and using the FSU 7-variable equation. From these an adjustment factor is established and applied to the Qmed estimate at the subject site.

The FSU web portal (currently in beta stage) was used to identify candidate pivotal sites. Based on an assessment of hydrological and geographical similarity, station 19020 (Ballyedmond) was selected as the pivotal site for all HEPs. The Ballyedmond gauge is located approximately 20km north east of the Tramore catchment on the Owennacurra River and gauges a catchment area of $74km^2$ which is primarily rural in nature. Gauge data (flow and water level) is available at Ballyedmond since 1977.

The Ballyedmond AMAX series gives a Qmed estimate (gauged) of $23.16m^3/s$. Qmed (gauged) was then adjusted for standard error in accordance with FSU WP2.2, section 13.1. For 28 years of record, this gave a final Qmed (gauged) estimate at Ballyedmond of $24.74m^3/s$. Comparing this with a Qmed of $16.04m^3/s$ calculated using the FSU equation, implies an adjustment factor of **1.54**.

5.4.3.2 Cork Landfill Gauge Adjustment

In Section 5.3.3, Qmed at the Cork Landfill gauge was estimated using a peaks-over-threshold method, resulting in a Qmed (gauged) estimate of $4.92m^3/s$. Comparing this with the FSU 7-variable estimate at HEP_08 (Qmed rural = $3.15m^3/s$) implies an adjustment factor of **1.56**.

5.4.3.3 Lower Lee FRS Adjustment

As part of the Lower Lee Flood Relief Scheme, JBA established a Qmed adjustment factor based on four "standard" gauges in the Lee catchment. Gauges used excluded those which are influenced by a karst landscape, by hydraulic controls such as the operations of a dam, or by significant lake attenuation. The four gauges analysed, and their respective adjustment factors are as follows:

Table 10: Lower Lee FRS adjustment factors for "standard" catchments

Station	Station Number	Lower Lee FRS Adjustment Factor
Macroom (Sullane)	19031	1.69
Healy's Bridge	19015	1.53
Kill (Laney)	19027	1.67
Dripsey	19028	2.03
Average catchment adjustment factor		1.73

5.4.3.4 Standard Error Adjustment

Given that the Ballybrack catchment and its subcatchments are small in the context of the FSU, discussions were held with OPW on the issue. OPW suggested that if the FSU method were to be applied to very small catchments (<5km^2), it would be inappropriate to use a pivotal site to adjust Qmed, as the FSU gauged sites would be so dissimilar to the subject site.

The normal standard factorial error of the FSU equation **1.37**. However, a recent paper[3] which analysed a set of small gauged catchments concluded that the FSU equation has a standard factorial error of **1.86** when applied to small catchments.

5.4.3.5 Selection of Design Adjustment Factor

The four possible adjustment factors identified are tabulated below:

Table 11: Possible FSU Qmed adjustment factors

Method	Factor
Ballyedmond pivotal site	1.54
Cork Landfill pivotal site	1.56
Lower Lee FRS adjustment	1.73
FSU standard factorial error	1.37
FSU standard factorial error (small catchments)	1.86

Given that each of the calculated adjustment factors are higher than the standard factorial error, it was not felt appropriate to adopt FSE in lieu of a data transfer adjustment, even for the smallest catchments under consideration.

[3] Gebre, F. & Nicholson, O., *Flood Estimation in Small and Urbanised Catchments in Ireland* (2012)

While the Lower Lee adjustment factor serves as a useful check, no strong basis was found for adopting the factor for this study since the catchments used to derive the factor differ significantly from the subject site in terms of AREA, SAAR, etc.

There is low confidence in the gauged flow estimate used to estimate the Cork Landfill adjustment factor, primarily due to the short length of gauge record. A further potential issue is the fact that the gauge record is significantly influenced by urbanisation in the upstream catchment. Therefore, deriving an adjustment factor based on a comparison with a Qmed (rural) estimate may not be appropriate. If the gauge record were to be adjusted to account for this influence, it is expected that the resulting adjustment factor would be significantly lower.

Therefore, the adjustment factor of 1.54 calculated using the Ballyedmond pivotal site was adopted.

Table 12 below sets out the index flood flows estimated at each HEP using the selected adjustment factor.

Table 12: Adjusted FSU Qmed (rural) estimates

Location	Flow (m^3/s)
HEP_01	9.14
HEP_02	5.87
HEP_03	4.07
HEP_04	3.95
HEP_05	2.01
HEP_06	2.16
HEP_07	0.87
HEP_08	4.87
HEP_09	2.07

5.4.4 Adjustment for Urbanisation

To estimate Qmed for a partly urbanised catchment, an urban adjustment factor is applied. The urban adjustment is as follows:

$$UAF = (1 + URBEXT)^{1.482}$$

$$Qmed_{Urban} = UAF\ x\ Qmed_{Rural}$$

Where:

UAF = Urban adjustment factor

URBEXT = Fraction of urbanised area in the catchment

The calculated urban adjustment factors are shown in Table 13.

Table 13: FSU Urban Adjustment Factors

Location	Urban Adjustment Factor (UAF)
HEP_01	1.66
HEP_02	1.7
HEP_03	1.35
HEP_04	1.31
HEP_05	1.29
HEP_06	1.32
HEP_07	1.04
HEP_08	1.74
HEP_09	1.5*

* Includes an allowance for future urbanisation, based on lands zoned for development in the Cork County Development Plan.

5.4.5 Summary

Index flows were estimated using the Flood Studies Update ungauged catchment procedure and a set of index flows were produced.

The results of the calculations are tabulated below.

Table 14: Adjusted FSU Qmed (urban) estimates

Location	Flow (m^3/s)
HEP_01	15.22
HEP_02	9.95
HEP_03	5.48
HEP_04	5.16
HEP_05	2.59
HEP_06	2.84
HEP_07	0.90
HEP_08	8.47
HEP_09	2.97

5.5 Flood Studies Report Statistical Method

The Flood Studies Statistical approach estimates the index flood (Qbar) using catchment characteristics in the absence of flow data.

The FSR six-variable catchment characteristics equation for Ireland is:

$$Qbar_{Rural} = C\, xAREA^{0.95} Fs^{0.22} SOIL^{1.18} SAAR^{1.01} (1 + LAKE)^{0.16}$$

Where:

- For Ireland C = 0.00042
- AREA is the catchment area (km^2).

- FS (stream frequency) is the number of stream junctions per km^2 on a 1:25,000 scale map.
- S1085 is the slope of the main channel between 10% and 85% of its length measured from the downstream end of the catchment (m/km).
- SAAR is long-term mean annual rainfall amount in mm. Data from Met Éireann 1981-2010 was used.
- SOIL is an index of how the soil may accept infiltration and is a measure of the Winter Rainfall Acceptance Potential (WRAP). The index is based on five classifications. The fraction of catchment in each of the five soil classes is calculated, from this the SOIL index is calculated by the formula:

$$SOIL = 0.15\,SOIL1 + 0.3\,SOIL2 + 0.4\,SOIL3 + 0.45\,SOIL4 + 0.5\,SOIL5$$

  where SOILn is the fraction of the catchment in WRAP class n

- LAKE is an index defined as the fraction of catchment draining through lakes or reservoirs and the areas contributing to lakes whose surface area exceeds 1% of the contributing area is recorded.

The FSR equation has a standard factorial error of approximately 1.5.

The catchment characteristics used in the FSR statistical method for index flow estimation for each HEP are detailed in Appendix B.

An adjustment for urbanisation is then applied to $Qbar_{Rural}$ to get $Qbar_{Urban}$

Table 15 below sets out the index flood flows estimated at each HEP using the FSR Statistical method.

Table 15: Qbar (urban) using FSR Statistical Method

Location	**Flow**	
	Qbar urban (m^3/s)	**Qbar (68% confidence) (m^3/s)**
HEP_01	8.69	13.03
HEP_02	5.53	8.29
HEP_03	3.47	5.21
HEP_04	3.35	5.03
HEP_05	1.55	2.33
HEP_06	1.94	2.91
HEP_07	0.63	0.94
HEP_08	4.32	6.48
HEP_09	1.66	2.49

5.6 Flood Studies Report Rainfall-Runoff Method

The rainfall-runoff method uses a unit hydrograph model to transform rainfall of a given return period into a runoff hydrograph (given assumed antecedent catchment wetness conditions).

The model assumes that the designed rain storm falls over the entire catchment area over a critical duration, with a specified profile. For this study, rainfall-runoff models were developed for each HEP.

In addition to the rainfall statistics, there are three key parameters in the rainfall-runoff model; the time to peak (which controls the rise of the hydrograph), the Standard Percentage Runoff (which controls the volume of runoff) and the Baseflow (which represents the antecedent conditions). These parameters have been estimated from topographical and hydrological maps for the catchments in this study.

The rainfall-runoff model produces an estimate of the design flood hydrograph, rather than just a peak flow estimate.

The FSR 75% winter storm profile was applied to rural catchments, i.e. those with an urban fraction of less than 0.25. The 50% summer profile was applied to urban catchments, i.e. with an urban fraction of greater than 0.25 (HEP_01, HEP_02, HEP_08), as is recommended in the FSR.

The catchment characteristics used in the FSR rainfall-runoff method for Q100 for each HEP are detailed in Appendix B.

Table 16 below outlines the Qbar estimates from the FSR Rainfall-Runoff method.

Table 16: Qbar Estimates using FSR Rainfall-Runoff Method

Location	**Flow (m^3/s)**
HEP_01	13.19
HEP_02	10.13
HEP_03	5.24
HEP_04	5.20
HEP_05	2.49
HEP_06	2.63
HEP_07	1.00
HEP_08	7.76
HEP_09	3.43

5.7 Institute of Hydrology Report No. 124

The Institute of Hydrology Report No. 124 (IH124) is applicable to small rural catchments (<25km^2). The runoff estimate ($Qbar_{Rural}$) can be extended to estimate runoff from a partially urban catchment, $Qbar_{Urban}$.

$$Qbar_{Rural} = 0.00108\, x AREA^{0.89} SOIL^{12.17} SAAR^{1.17}$$

$$\mathrm{Qbar_{Urban}} = \mathrm{Qbar_{Rural}}\,(1 + \mathrm{URBAN})^{2\mathrm{NC}} \left[1 + \mathrm{URBAN}\left(\frac{21}{\mathrm{CIND}} - 0.3\right)\right]$$

Where

- $CIND = 102.4SOIL + 0.28(CWI - 125)$.
- AREA is the catchment area (km^2).
- SOIL is an index of how the soil may accept infiltration and is a measure of the Winter Rainfall Acceptance Potential (WRAP). The index is based on five classifications (very high, high, moderate, low and very low WRAP). The fraction of catchment in each of the five soil classes is calculated, from this the SOIL index is calculated by the formula:
  - $SOIL = 0.15\,SOIL1 + 0.3\,SOIL2 + 0.4\,SOIL3 + 0.45\,SOIL4 + 0.5\,SOIL5$
  - where SOILn is the fraction of the catchment in WRAP class n
- SAAR is long-term mean annual rainfall amount in mm. Data from Met Éireann 1981-2010 was used.
- URBAN is the proportion of urbanised area within the catchment.
- CWI is the Catchment Wetness Index (mm).

And $NC = 0.92 - 0.00024SAAR$ for SAAR between 500mm and 1100mm

$NC = 0.74 - 0.000082SAAR$ for SAAR between 1100mm and 3000mm

The IH124 equation has a standard factorial error of approximately 1.65

The catchment characteristics used in the IH124 method for index flow estimation for each HEP are detailed in Appendix B.

Table 17 below sets out the index flows using IH124 methodologies.

Table 17: Qbar using IH124 Methodology

Location	**Flow**	
	Qbar urban (m^3/s)	**Qbar urban (68% confidence) (m^3/s)**
HEP_01	6.82	11.26
HEP_02	4.88	8.05
HEP_03	1.98	3.26
HEP_04	1.84	3.04
HEP_05	0.98	1.61
HEP_06	0.99	1.64
HEP_07	0.28	0.46
HEP_08	3.37	5.57
HEP_09	1.20	1.98

5.8 Rational Method

Given the limitations of the FSU and FSR when applied to small catchments such as the Ballybrack, it was considered prudent to carry out a check using an alternative flood estimation method.

Therefore, the rational method was applied to the following subcatchments on the Ballybrack Stream: HEP_03, HEP_04, HEP_05, and HEP_06.

The rational method is normally applied to small urban catchments. The method is traditionally used for estimating storm sewer sizes, by calculating a peak flow by using catchment runoff coefficients, a routing coefficient, rainfall intensity and the catchment area.

The subcatchments of the Ballybrack Stream are all larger than the catchment size typically used when applying the rational method, and also contain significant areas of non-urban land. It is acknowledged that this method inherently contains a significant level of uncertainty.

Rainfall intensity for the critical storm duration was estimated using Met Éireann rainfall data of Depth-Duration-Frequency.

$$Q = 0.278CiA$$

Where:

- Q is flow in m^3/s
- C is the runoff coefficient
- i is the rainfall intensity (mm/hr)
- A is the catchment area in km^2.

Runoff coefficients for each HEP were estimated using the breakdown of land usage contained in OSi NTF data. Land use categories and their assigned runoff coefficients are detailed in Table 18 below. The catchment characteristics and runoff coefficients used in the rational method for index flow estimation for each HEP are detailed in Appendix B.

Table 18: Runoff Coefficients

Group	**NTF Feature Name**	**Runoff Coefficient (C)**	
		Average	**Max**
Forestry	Deciduous forestry	0.15	0.25
	Coniferous forestry	0.15	0.25
	Mixed forest	0.15	0.25
Roads	National primary route	0.825	0.95
	National secondary route	0.825	0.95
	Regional road network	0.825	0.95
	Third class road network	0.825	0.95
	Fourth class road network	0.825	0.95
Open spaces	Open spaces	0.175	0.25
	Special facility	0.21	0.35
	Cemetery	0.175	0.25
Buildings	Dwelling house	0.4	0.5

Group	NTF Feature Name	Runoff Coefficient (C)	
		Average	Max
	Other general buildings	0.85	0.95
	Glasshouses	0.85	0.95
Other	Land parcel - urban	0.3	0.35
	Land parcel - rural	0.35	0.5

The proportional area of each feature code per catchment was calculated and the runoff coefficients weighted accordingly. The resulting runoff coefficients for each catchment are shown in Table 19 below.

Table 19: Catchment - Average Runoff Coefficients

	Rational Method - Runoff Coefficients	
HEP	$C_{(ave)}$	$C_{(max)}$
03	0.37	0.5
04	0.37	0.5
05	0.36	0.49
06	0.38	0.51
09	0.4	0.53

Design rainfall depths were estimated as follows:

- The time of concentration (Tc) for each HEP was estimated using the Bransby-Williams formula:

$$Tc = \frac{L}{D} A^{0.4} S^{0.2}$$

Where:

- Tc = time of concentration (hours)
- L = Length of main channel (km)
- S = Channel slope
- A = Catchment area (km^2)

D is the diameter of a circle whose area is equal to the catchment area

The estimated times of concentration for each HEP are included in Appendix B. As a check on the estimated times, the Cork Airport rain gauge records were compared with the flows recorded at the Cork Landfill gauge for the June 2012 event. The "lag" between the peak rainfall and the peak flow at the gauge was found to be approximately 2 hours, which is in reasonable agreement with the estimated Tc at the gauge location.

- Rainfall depths for durations corresponding to the Tc for each catchment were then taken from the Met Éireann depth-duration-frequency GIS dataset.
- An areal reduction factor was then applied to the rainfall in accordance with FSR procedures. This areal reduction factor transforms the rainfall intensity for a single point in the catchment, to a uniform distribution throughout the catchment.

Table 20 below sets out the index flow using the Rational Method with both the “average” runoff coefficient applied, and the “maximum” runoff coefficient applied.

Table 20: Qmed using the Rational Method

Location	**Flow**	
	Qmed (m^3/s) (average Cv)	**Qmed (m^3/s) (Max Cv)**
HEP_03	8.1	10.9
HEP_04	9.1	12.3
HEP_05	4.1	5.5
HEP_06	4.7	6.3
HEP_09	4.1	5.5

5.9 Previous Studies

5.9.1 Lee CFRAMS

The hydrological schematisation of the Tramore catchment used in the Lee CFRAMS is shown in Figure 18 below. The flows for each of the subcatchments are tabulated in Table 21 below, along with the sum of flows, which would be roughly equivalent to the flow at HEP_01. (Note that the peak flows from the subcatchments would not necessarily coincide at this location at the same time, therefore this value should be treated with caution)

Figure 18: Lee CFRAMS hydrological schematisation

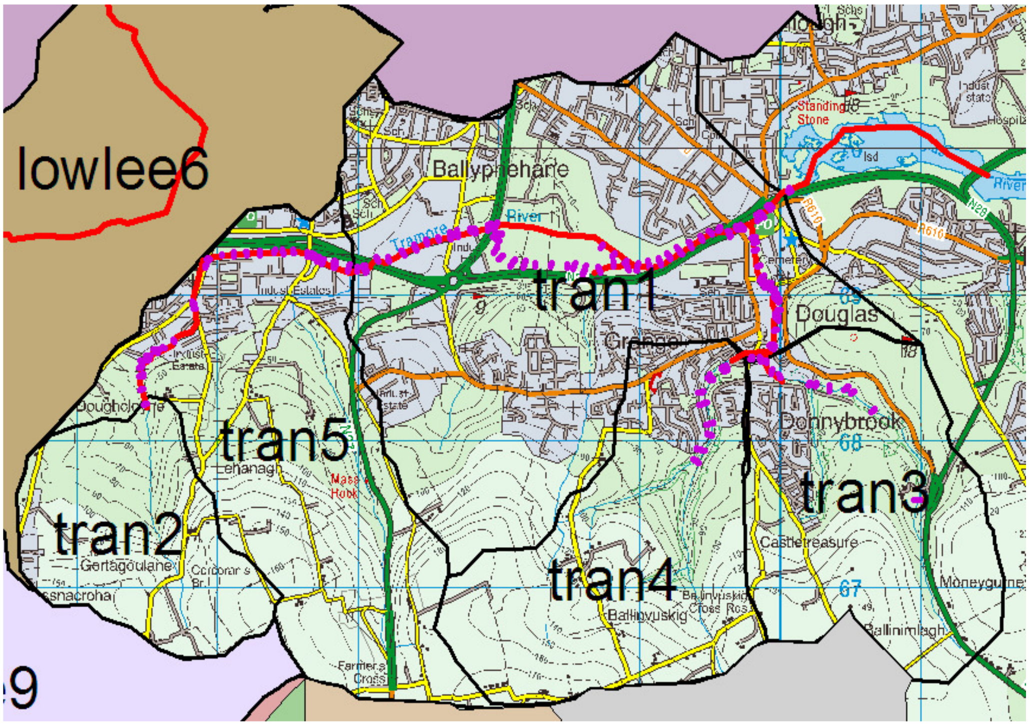


Table 21: Lee CFRAMS Design Index Flows

Sub Catchment	Existing Conditions	
	Duration (hr)	Qmed (m^3/s)
tran1	7	4.16
tran2	3	1.20
tran3	5	1.45
tran4	3	2.02
tran5	5	2.60
Sum of flows (approximately equivalent to flow at HEP_01)		11.43

5.9.2 Douglas Village Shopping Centre Section 50

As part of the design of the upgraded Tramore/Ballybrack culverts under the redeveloped Douglas Village Shopping Centre, a detailed hydrological analysis was carried out to satisfy the requirements of Section 50 of the Arterial Drainage Act. For this analysis, flows were estimated at three points:

- The downstream end of the Ballybrack Stream.
- The Tramore River just upstream of the confluence with the Ballybrack Stream.
- The total Tramore River catchment.

The calculated index flows are presented in Table 22 below.

Table 22: DVSC Section 50 Index Flows

Catchment	Qbar (rural) (m^3/s)	Qbar (urban) (m^3/s)
Tramore	3.5	7.2
Ballybrack	2	3.2
Total Tramore Catchment	5.2	10.1

5.10 Comparison of Results

Given that the catchments in the study area are small predominantly ungauged, it was considered important to compare the index flows estimated using a range of methods.

It is acknowledged that each of the flood estimation methods used in this study contain a significant amount of uncertainty. This is in part due to the limited resolution of mapped and digital data, and also due to the fact that many methods are calibrated to large catchments.

The various estimated index flows are tabulated below:

Table 23: Comparison of Index Flow Estimates

Location	Qbar urban (m^3/s)				Qmed urban (m^3/s)			
	FSR - Stat	FSR - RR	IH124	DVSC Section 50	FSU	Rational (average C to maximum C)	POT (Landfill gauge	Lee CFRAMS
HEP_01	8.69	13.19	6.82	10.1	15.22			11.43
HEP_02	5.53	10.13	4.88	7.2	9.95			
HEP_03	3.47	5.24	1.98	3.2	5.48	8.1 – 10.9		
HEP_04	3.35	5.20	1.84		5.16	9.1 – 12.3		
HEP_05	1.55	2.49	0.98		2.59	4.1 – 5.5		
HEP_06	1.94	2.63	0.99		2.84	4.7 – 6.3		
HEP_07	0.63	1.00	0.28		0.90			
HEP_08	4.32	7.76	3.37		8.47		4.92	
HEP_09	1.66	3.43	1.20		2.97	4.1 – 5.5		

5.11 Selection of Design Index Flows

The estimation of index flows using a variety of methods has highlighted that there is a wide range of index flows which could be adopted. No single method is entirely suitable for the full range of catchment sizes in the study areas.

Notwithstanding the above, and due to the uncertainty associated with the flow estimation, it was felt appropriate to adopt the FSU flows, as they appear to be conservative, while still remaining reasonably consistent with other methods.

Table 24: Adopted Design Index Flows

Location	**Qmed urban (m^3/s)**
	FSU
HEP_01	15.22
HEP_02	9.95
HEP_03	5.48
HEP_04	5.16
HEP_05	2.59
HEP_06	2.84
HEP_07	0.90
HEP_08	8.47
HEP_09	2.97

6 Flood Frequency Analysis

6.1 Introduction

Once the index flood has been calculated, a growth curve must then be established in order to allow estimation of flows at higher return period events.

6.2 FSU Pooling Group

The FSU growth curve is developed by using a pooling group of gauged catchments selected by their similarity with the subject catchment. A detailed pooling group calculation is included in Appendix B. A summary of the procedure is outlined below.

It was deemed appropriate to carry out the pooling group analysis at two HEPs: HEP01 and HEP03.

In accordance with the FSU, the pooling group stations were selected using a measure of similarity indicator (dij). The indicator is based on three physical catchment descriptors, AREA, SAAR and BFISOILS. Equation 10.2 of FSU Work Package 2.2 was used to calculate the similarity of all FSU gauging stations to the subject site. The gauges were then ranked in order of similarity from the most similar gauge to the least similar gauge.

A screening exercise was then carried out on the gauges. Only gauges which were classified with either an A1 or an A2 rating in the FSU dataset were included in the pooling groups. Gauges in catchments containing significant Arterial Drainage Schemes were excluded, along with catchments containing regionally important aquifers.

The FSU recommends that a pooling group contains 5T years of data, where T is the return period of interest. As the 1 in 100 year flood is of interest to this study, 500 years of data was included in the initial pooling groups.

The growth curve was estimated from the annual maxima datasets for each gauge in the pooling group using WINFAP-FEH software to fit distributions by the L-median method. Some modifications to the standard FEH approach were necessary to adapt to the FSU method, including the following:

- It is standard FEH procedure to reject sites that have URBEXT >0.05, and it would appear logical that this should be the case in the FSU process. However, there is no reference to such a procedure in the FSU guidance. OPW stated that there are not enough urbanised catchments in Ireland on which to formulate a rule similar to FEH. Therefore, to address this particular point, sensitivity analyses were carried out for the growth curves, including and excluding the urbanised sites.

Goodness of fit measures suggested that the Generalised Extreme Variable (GEV) and Pearson Type III distributions give the best fit to the data. Of these, FSU recommends use of the GEV.

The resulting growth curve fittings are as follows:

Table 25: Summary of FSU pooling group growth curves

	Growth Factors			
Return period (years)	**HEP_01A (excluding urban sites)**	**HEP_01B (including urban sites)**	**HEP_03A (excluding urban sites)**	**HEP_03B (including urban sites)**
2	1	1	1.00	1
5	1.21	1.23	1.24	1.34
10	1.36	1.39	1.42	1.59
25	1.57	1.60	1.70	1.95
50	1.74	1.77	1.94	2.24
100	1.92	1.93	2.21	2.56

It can be seen that growth curves 1A and 1B are relatively insensitive to the presence of urbanised sites in the pooling group. However, growth curves 3A and 3B are more sensitive to the presence of urbanised sites, affecting the 100 year event by a factor of 1.16. This is contrary to the conventionally predicted influence of urbanisation, which is that it should flatten the growth curve, not steepen it (this is due to the lack of storage in the system, so the growth curve is much closer related to the rainfall DDF).

6.3 Growth Curve from FSR Rainfall-Runoff Model

The rainfall-runoff model was run for a range of return period at each HEP location to derive a growth curve based on the modelling results. This growth curve reflects the rainfall statistics in the catchment, and the results of this can be seen in Table 26 below.

It was found that the models produce similar growth curves for each sub-catchment. Therefore a catchment average growth curve is presented below.

Table 26: Growth Curve (Q/Qbar) derived from the FSR Rainfall-Runoff Model

Return Period (years)	Catchment Average Growth factor
2.34	1
5	1.39
10	1.62
25	2.03
50	2.35
100	2.67

For comparison purposes, the above growth curve was re-indexed to Qmed, assuming a 5% difference between Qbar and Qmed. See Table 27: Approximate FSR Rainfall-Runoff Growth Curve (Q/Qmed)Table 27 below.

Table 27: Approximate FSR Rainfall-Runoff Growth Curve (Q/Qmed)

Return Period (years)	Approximate Catchment Average Growth factor
2	1
5	1.46
10	1.7
25	2.13
50	2.47
100	2.8

6.4 FSR Regional Growth Curve

The FSR provides a regional growth curve for Ireland, which may be applied to any river in the country to produce an estimate of flow for a given return period. The growth curve ordinates for the FSR regional growth curve for Ireland are given in Table 28 below.

Table 28: FSR Irish Regional Growth Curve

Return period (years)	FSR Irish Regional (1975) (QT/Qbar)
2	0.95
5	1.20
10	1.37
25	1.60
50	1.77
100	1.96

6.5 Growth Curves from Previous Studies

6.5.1 Lee CFRAM Study Growth Curve

The Lee CFRAM Study used gauges within its study area for a pooled gauge analysis with a total record length of 157 years, producing a growth curve up to the 1 in 40 year event. The growth curve developed for the Lee CFRAM Study was found to have a close correlation with the FSR Ireland growth curve up to the 1 in 50 year event. Based on this, the Lee CFRAM Study used a pooled growth curve up to the 1 in 50 year event, and the FSR Ireland growth curve for events with a greater return period. Table 29 shows the Lee CFRAM Study Growth Curve.

Table 29: Lee CFRAM Study Growth Curve

Return Period (Years)	Lee CFRAM Study Growth Curve (QT/Qmed)
2	1.00
5	1.30
10	1.40
20	1.60
50	1.90
100	2.10

6.5.2 DVSC Section 50 Growth Curve

The DVSC section 50 application utilised the FSR Irish Regional growth curve as shown in Section 6.4.

The design flows for the DVSC culverts are shown in Table 30 below.

Table 30: DVSC Section 50 flows

Return Period	Design Peak Flow (m^3/s)		
	Total (similar to HEP_01)	Tramore (similar to HEP_02)	Ballybrack (similar to HEP_03)
1 in 100 year + factorial standard error	37	26	12.3
1 in 100 year + climate change + factorial standard error	44.4	31.2	14.7

6.6 Selection of Design Growth Curve

As recommended in the FSU, and in order to avoid possible contradictions in growth curves, a single growth curve was adopted for the study. Growth curve HEP_03B was selected as it reflects the expected steeper growth curve of the smaller catchments such as the Ballybrack. While there are potentially some issues with the inclusion of urbanised sites as noted above, in the absence of further guidance it was deemed appropriate to adopt the more conservative curve.

Table 31: Design Growth Curve

Return Period (Years)	Growth Factor (QT/Qmed)
2	1
5	1.34
10	1.59
20	1.95
50	2.24
100	2.56

6.7 Design Peak Flows

The design peak flows for each HEP are presented in Table 32 below.

Table 32: Design Peak Flows

Return Period (years)	Design Peak Flow (m^3/s)								
	HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09
2	15.22	9.95	5.48	5.16	2.59	2.84	0.90	8.47	2.97
5	20.39	13.33	7.34	6.91	3.47	3.81	1.20	11.35	3.98
10	24.20	15.81	8.71	8.20	4.12	4.52	1.43	13.47	4.72
25	30.44	19.89	10.96	10.31	5.18	5.68	1.80	16.95	5.94
50	34.09	22.28	12.27	11.55	5.80	6.37	2.01	18.98	6.65
100	38.96	25.46	14.03	13.20	6.63	7.28	2.30	21.69	7.60

7 Flow Hydrograph Analysis

In order to produce a design hydrograph to provide input to the unsteady-state hydraulic modelling, a hydrograph shape is required in addition to a design peak flow. Two different methods to estimate the design hydrograph shape were considered for this study as described below:

1. FSU includes a methodology to estimate flood hydrographs in ungauged catchments using a process of fitting a curve to a set of recorded flood hydrographs from similar gauges.
2. The FSR rainfall-runoff method, or the unit hydrograph method, is the traditional method of hydrograph generation, and provides the shape and volume of a flood hydrograph. The unit hydrograph is derived from catchment characteristics.

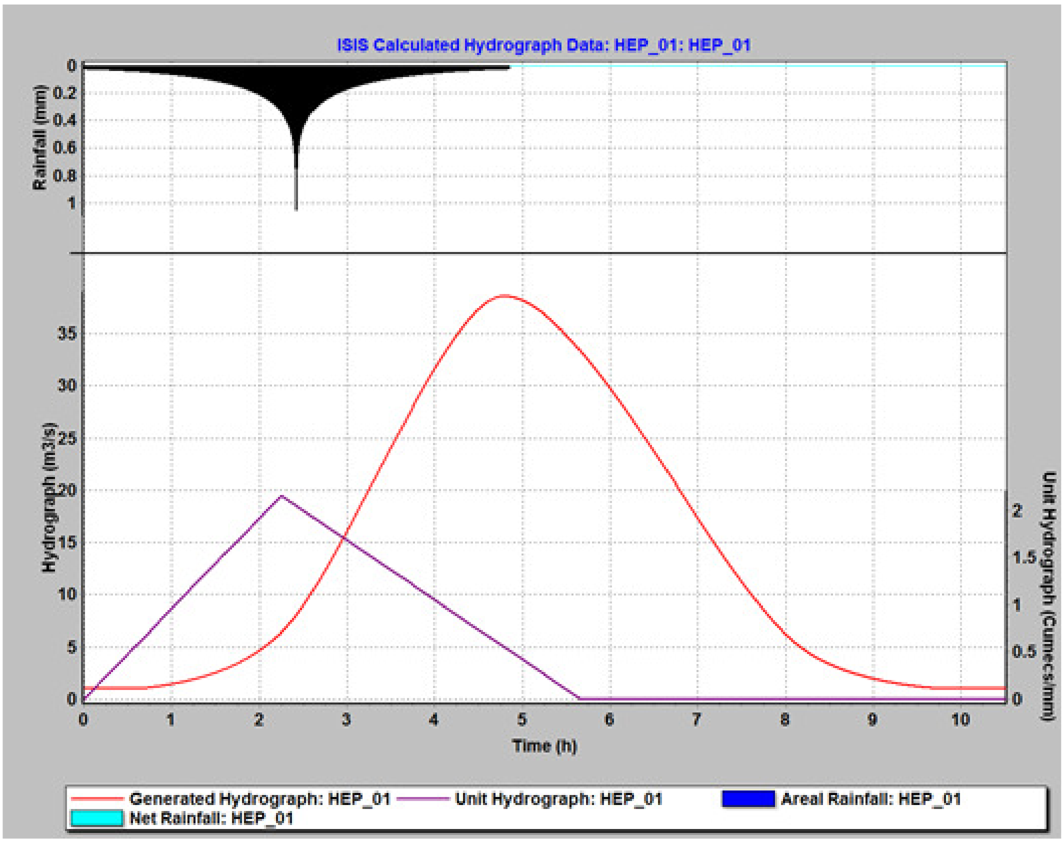
While either method above could be adopted for this study, some drawbacks associated with the FSU method were noted, including:

- The FSU method has no direct link to rainfall, which could be a significant factor in the context of the small and heavily urbanised Tramore catchment.
- Most catchments available for hydrograph width analysis are much larger than the Tramore/Ballybrack catchments. Therefore the fitted hydrograph is likely to be significantly distorted compared with the reality on the smallest catchments.

Therefore, the FSR rainfall runoff method was selected as the design hydrograph shape. The catchment characteristics were input to the FSSR16 module in ISIS to generate the flow hydrographs.

The design flow hydrograph shape is shown in Figure 19 below (HEP_01 used as an example; note that the peak flow shown is the calculated FSR-RR peak flow).

Figure 19: Design Flow Hydrograph Shape



8 Tidal and Fluvial Joint Probability

A tidal-fluvial joint probability analysis was carried out as part of the Lee CFRAM Study. This established combinations of tide levels and fluvial flows for each design event. The Lee CFRAMS analysis was based on an application of UK guidance using certain assumptions about the dependence of tidal/fluvial floods in the Lee catchment. The Lee CFRAMS acknowledged that the design combinations were conservative.

Given that it is outside the scope of this study to carry out a detailed joint probability analysis, it is proposed to adopt the Lee CFRAMS joint probability scenarios for this study. The scenarios are tabulated in Table 33 below.

Table 33: Design Tidal-Fluvial Joint Probability Scenarios

Scenario	**Design Event (AEP)**	**Boundary**		
		Fluvial (AEP)	**Tidal (AEP)**	**Lee CFRAMS Tidal Flood Level (node 6TRA_0)** **(mOD Malin)**
1	50%	50%	50%	2.44
2	20%	20%	50%	2.44
3	20%	50%	20%	2.54
4	10%	10%	50%	2.44
5	10%	50%	10%	2.62
6	4%	4%	50%	2.44
7	4%	50%	4%	2.71
8	2%	2%	50%	2.44
9	2%	50%	2%	2.78
10	1%	1%	20%	2.54
11	0.5%	10%	0.5%	2.92

9 Climate Change

OPW has produced a draft guidance document entitled "Assessment of Potential Future Scenarios for Flood Risk Management". The guidance addresses potential future climate change and presents two possible future scenarios - the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS), as described below:

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

Figure 20: Extract from draft OPW Guidance on Potential Future Scenarios

Table 1: Allowances for Future Scenarios (100 year time horizon)

	MRFS	HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Flood Flows	+ 20%	+ 30%
Mean Sea Level Rise	+ 500 mm	+ 1000 mm
Land Movement	- 0.5 mm / year[1]	- 0.5 mm / year[1]
Urbanisation	*No General Allowance – Review on Case-by-Case Basis*	*No General Allowance – Review on Case-by-Case Basis*
Forestation	- 1/6 Tp[2]	- 1/3 Tp[2] + 10% SPR[3]

Note 1: Applicable to the southern part of the country only (Dublin – Galway and south of this)

Note 2: Reduce the time to peak (Tp) by a third: This allows for potential accelerated runoff that may arise as a result of drainage of afforested land

Note 3: Add 10% to the Standard Percentage Runoff (SPR) rate: This allows for increased runoff rates that may arise following felling of forestry.

For the design and implementation of flood relief schemes, OPW's preferred approach is the "Adaptive Approach", whereby provision is made in the design for measures to be adapted or enhanced in the future as changes occur (or reliable evidence builds).

Notwithstanding the above, should the design of the scheme require works to bridges and culverts, the requirements of Section 50 of the Arterial Drainage Act and Section 50 of the Assessment and Management of Flood Risks Regulations will need to be taken into account for those elements. Current Section 50 guidance effectively advocates an "assumptive" approach, where measures are designed and implemented to the 95% confidence, MRFS scenario standard.

10 Conclusion

A detailed hydrological analysis has been undertaken to determine design flows for the Douglas Flood Relief Scheme (including Togher Culvert). The analysis has applied a number of methods to establish a range of possible flood flows at various points in the study area.

The outputs from this study will be used in the hydraulic modelling stage of the project. These key outputs are outlined below.

A set of index flow (Qmed) estimates were produced for key points in the study area. Given that the catchments in the study area are small, predominantly ungauged, it was considered important to compare the index flows estimated using a range of methods, including FSU, FSR, IH124 and the Rational Method. The analysis is presented in Section 5.

A rating review of the existing EPA hydrometric gauge at Cork Landfill was also carried out and a revised rating curve was generated. The revised rating curve was then used to update the high flow series at the gauge. The updated flows were then analysed to provide an alternative estimate of Qmed, of approximately 5m^3/s at the gauge site (HEP_08). However, since the length of the gauge record is only four years, the confidence in the estimate produced by this method is low.

Based on the index flows estimated, it is apparent that there is a wide range of flows which could be adopted for the study. It is acknowledged that each of the index flood estimation methods used contain a significant amount of uncertainty. This is in part due to the limited resolution of mapped and digital data, and also due to the fact that many methods are calibrated to large catchments. No single method is entirely suitable for the full range of catchment sizes in the study areas.

Notwithstanding the above, and due to the uncertainty associated with the flow estimation, it was felt appropriate to adopt the FSU index flows, as they appear to be conservative, while still remaining reasonably consistent with other methods. The design index flows are shown in Table 34 below.

A flood frequency analysis was carried out, which established a study growth curve and in turn a set of design peak flows. The adopted growth curve was produced using the FSU pooling group methodology. The analysis is presented in Section 6. The design flows are tabulated in Table 34 below.

Table 34: Design Flows

Return Period (years)	Design Peak Flow (m^3/s)								
	HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09
2 (Qmed)	15.22	9.95	5.48	5.16	2.59	2.84	0.90	8.47	2.97
5	20.39	13.33	7.34	6.91	3.47	3.81	1.20	11.35	3.98
10	24.20	15.81	8.71	8.20	4.12	4.52	1.43	13.47	4.72

Return Period (years)	Design Peak Flow (m^3/s)								
	HEP_01	**HEP_02**	**HEP_03**	**HEP_04**	**HEP_05**	**HEP_06**	**HEP_07**	**HEP_08**	**HEP_09**
25	30.44	19.89	10.96	10.31	5.18	5.68	1.80	16.95	5.94
50	34.09	22.28	12.27	11.55	5.80	6.37	2.01	18.98	6.65
100	38.96	25.46	14.03	13.20	6.63	7.28	2.30	21.69	7.60

A design flood hydrograph shape was also established. The adopted shape was produced using the FSR unit hydrograph method. A discussion on the adopted shape is included in Section 7.

Appendix A

National Flood Hazard Mapping Reports

A1 National Flood Hazard Mapping Reports

Please see National Flood Hazard Mapping Reports overleaf.

OPW *National Flood Hazard Mapping*

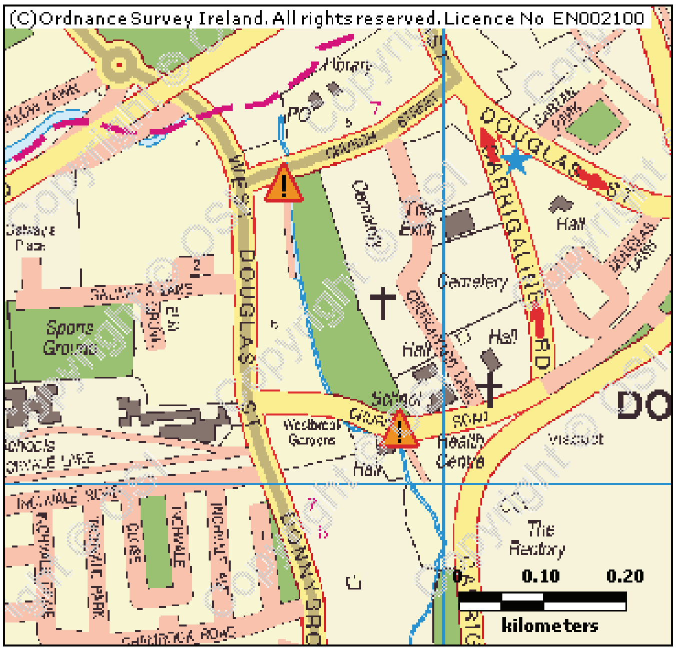
Summary Local Area Report

This Flood Report summarises all flood events within 2.5 kilometres of the map centre.

The map centre is in:

County: Cork

NGR: W 698 691



Map Scale 1:8,341

Map Legend

- Flood Points
- Multiple / Recurring Flood Points
- Areas Flooded
- Hydrometric Stations
- Rivers
- Lakes
- River Catchment Areas
- Land Commission *
- Drainage Districts *
- Benefiting Lands *

* Important: These maps do not indicate flood hazard or flood extent. Thier purpose and scope is explained in the Glossary.

5 Results

1. Tramore Stream Culvert,Kinsale Rd.Cork 30th.December 2009 — Start Date: 30/Dec/2009
County: Cork — Flood Quality Code:3
Additional Information: Reports (1) More Mapped Information

2. Kinsale Rd Roundabout Cork 30/01/2009 — Start Date: 30/Jan/2009
County: Cork — Flood Quality Code:3
Additional Information: Reports (1) More Mapped Information

3. Turner's Cross, Cork 28th June 2012 — Start Date: 28/Jun/2012
County: Cork — Flood Quality Code:3
Additional Information: Reports (1) More Mapped Information

4. Flooding at Douglas, Co. Cork, 28th June 2012 — Start Date: 28/Jun/2012
County: Cork — Flood Quality Code:3
Additional Information: Reports (2) More Mapped Information

5. Ballybrack Stream Douglas Nov 2002 — Start Date: 20/Nov/2002
County: Cork — Flood Quality Code:3

Report Produced: 22-Apr-2014 14:03

OPW *National Flood Hazard Mapping*

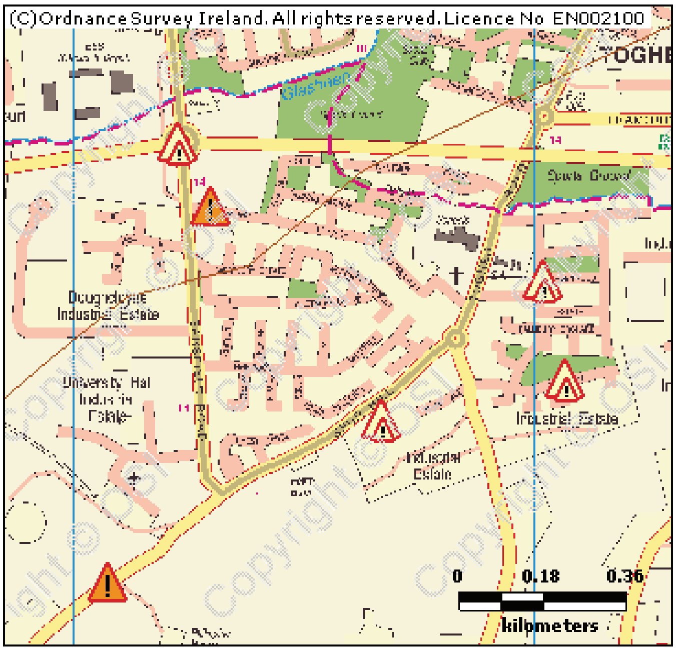
Summary Local Area Report

This Flood Report summarises all flood events within 2.5 kilometres of the map centre.

The map centre is in:

County: Cork

NGR: W 655 689



Map Scale 1:15,036

Map Legend
Flood Points
Multiple / Recurring Flood Points
Areas Flooded
Hydrometric Stations
Rivers
Lakes
River Catchment Areas
Land Commission *
Drainage Districts *
Benefiting Lands *

* Important: These maps do not indicate flood hazard or flood extent. Thier purpose and scope is explained in the Glossary.

21 Results

1. Sarsfield Road Roundabout N22 Cork 12th January 2010 — Start Date: 12/Jan/2010
   County: Cork — Flood Quality Code:3
   Additional Information: Reports (1) More Mapped Information

2. Tramore Stream Culvert,Kinsale Rd.Cork 30th.December 2009 — Start Date: 30/Dec/2009
   County: Cork — Flood Quality Code:3
   Additional Information: Reports (1) More Mapped Information

3. Cork City Flooding 19th.Nov. 2009 — Start Date: 19/Nov/2009
   County: Cork — Flood Quality Code:2
   Additional Information: Reports (4) More Mapped Information

4. Flooding at Bishopstown Co Cork Nov 2009 — Start Date: 19/Nov/2009
   County: Cork — Flood Quality Code:4
   Additional Information: Reports (1) More Mapped Information

5. Kinsale Rd Roundabout Cork 30/01/2009 — Start Date: 30/Jan/2009
   County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

---

6. Lee Cork City August 1986 — Start Date: 05/Aug/1986
County: Cork — Flood Quality Code:2

Additional Information: Reports (2) Press Archive (3) More Mapped Information

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7. Lee Inniscarra to Cork City Aug 1986 — Start Date: 05/Aug/1986
County: Cork — Flood Quality Code:2

Additional Information: Reports (7) Press Archive (3) More Mapped Information

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8. Lee Victoria Cross November 2000 — Start Date: 28/Nov/2000
County: Cork — Flood Quality Code:2

Additional Information: Photos (1) Reports (1) More Mapped Information

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9. Lee University Athletic Grounds Feb 1990 — Start Date: 06/Feb/1990
County: Cork — Flood Quality Code:2

Additional Information: Photos (1) More Mapped Information

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10. Lee Victoria Cross Feb 1990 — Start Date: 03/Feb/1990
County: Cork — Flood Quality Code:2

Additional Information: Photos (1) Press Archive (1) More Mapped Information

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11. Togher Cork City November 2000 — Start Date: 05/Nov/2000
County: Cork — Flood Quality Code:3

Additional Information: Reports (3) More Mapped Information

---

12. Spur Hill LP2452 Nov 2002 — Start Date: 27/Nov/2002
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

---

13. Greenwood Estate, Togher, Co. Cork Nov 2002 — Start Date: 21/Nov/2002
County: Cork — Flood Quality Code:3

Additional Information: Reports (2) More Mapped Information

---

14. Doughcloyne, Togher Cork City Nov 2002 — Start Date: 21/Nov/2002
County: Cork — Flood Quality Code:3

Additional Information: Photos (1) Reports (1) More Mapped Information

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15. Pouladuff Togher, Cork Nov 2002 — Start Date: 20/Nov/2002
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

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16. Togher Upper Nov 2000 — Start Date: 05/Nov/2000
County: Cork — Flood Quality Code:3

Additional Information: Reports (2) Press Archive (3) More Mapped Information

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17. Glasheen river, Cork City Feb 1994 — Start Date: 22/Feb/1994
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

---

18. Sarsfield Road Wilton Cork City Jan 1993 — Start Date: 08/Aug/1993
County: Cork — Flood Quality Code:1

Additional Information: Photos (1) Reports (2) More Mapped Information

19. Sarsfield Road, Wilton, Cork City recurring County: Cork Additional Information: Reports (2) More Mapped Information	Start Date: Flood Quality Code:1
20. Road flooding N71 viaduct Co. Cork Recurring County: Cork Additional Information: Reports (2) More Mapped Information	Start Date: Flood Quality Code:3
21. Palmbury Estate Flooding, Togher, recurring County: Cork Additional Information: Reports (2) More Mapped Information	Start Date: Flood Quality Code:3

Ceisteanna—Questions. Oral Answers. - Flooding at Douglas (County Cork).

Dáil Éireann Debate
Vol. 118 No. 6

Thursday, 10 November 1949

Mr. P.D. Lehane: asked the Minister for Local Government whether he is aware that heavy flooding occurs at frequent intervals at Douglas, County Cork, causing serious hardship and loss to the residents; and, if so, whether he will state if his Department or the [745] local authority propose to take immediate steps to prevent this flooding.

Mr. Corish: It is a matter for the local authority to select suitable works for execution under the Local Authorities (Works) Act, 1949.

In regard to the flooding at Douglas a small scheme was submitted by Cork County Council and is at present under examination in the Department. A decision thereon will be issued in the near future.

It is understood that the submission of a further scheme is under consideration locally. The proposal will be duly considered on its merits, if and when submitted.

Last Updated: *31/08/2012 10:11:00*

Appendix B

Hydrology Calculations

B1 Hydrology Calculations

Please see Hydrology Calculations overleaf.

ARUP	Job No. 234335-00	Sheet No.	Rev.
Job Title: Douglas Flood Relief Scheme	Member/Location: Cork		
Calculation: Flood Studies Update - Pivotal Site	Drg. Ref.		
	Made by	Date: 04/03/2014	Chd.

1.0 Subcatchment: HEP_01

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	22.03	km^2	catchment area
BFIsoils	=	0.59		base flow index derived from soils data
SAAR	=	1152	mm	standard annual average rainfall (1961-1990)
FARL	=	1		flood attenuation by resevoirs and lakes
DRAIND	=	1.10		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	11.70	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **5.92** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac	=	**1.44**
error of estimate for pivot st	=	**1.07**
Total adjustment factor	=	**1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **9.11** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	9.04	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.41**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.66**		

Qmed (urban, adjusted) = **15.17** m^3/s

ARUP	Job No. 234335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: Flood Studies Update - Pivotal Site	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_02

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	13.53	km^2	catchment area
BFIsoils	=	0.61		base flow index derived from soils data
SAAR	=	1174	mm	standard annual average rainfall (1961-1990)
FARL	=	1		flood attenuation by resevoirs and lakes
DRAIND	=	1.06		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	13.37	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **3.80** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac	=	**1.44**
error of estimate for pivot	=	**1.07**
Total adjustment factor	=	**1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **5.85** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	5.79	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.43**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.70**		

Qmed (urban, adjusted) = **9.91** m^3/s

ARUP	Job No.	Sheet No.	Rev.
	234335-00		
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Flood Studies Update - Pivotal Site	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_03

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	7.45	km^2	catchment area
BFIsoils	=	0.62		base flow index derived from soils data
SAAR	=	1176.00	mm	standard annual average rainfall (1961-1990)
FARL	=	1.00		flood attenuation by resevoirs and lakes
DRAIND	=	1.28		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	28.96	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0.00		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **2.63** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac = **1.44**

error of estimate for pivot = **1.07**

Total adjustment factor = **1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **4.06** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	1.65	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.22**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.35**		

Qmed (urban, adjusted) = **5.46** m^3/s

1.0 Subcatchment: HEP_04

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	7.13	km^2	catchment area
BFIsoils	=	0.62		base flow index derived from soils data
SAAR	=	1187.00	mm	standard annual average rainfall (1961-1990)
FARL	=	1.00		flood attenuation by resevoirs and lakes
DRAIND	=	1.19		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	32.84	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0.00		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **2.56** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac = **1.44**

error of estimate for pivot = **1.07**

Total adjustment factor = **1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **3.94** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	1.41	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.20**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.31**		

Qmed (urban, adjusted) = **5.14** m^3/s

ARUP	Job No. 234335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Flood Studies Update - Pivotal Site	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_05

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	3.50	km^2	catchment area
BFIsoils	=	0.62		base flow index derived from soils data
SAAR	=	1187.00	mm	standard annual average rainfall (1961-1990)
FARL	=	1.00		flood attenuation by resevoirs and lakes
DRAIND	=	1.15		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	32.84	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0.00		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **1.30** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac	=	**1.44**
error of estimate for pivot	=	**1.07**
Total adjustment factor	=	**1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **2.00** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	0.66	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.19**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.29**		

Qmed (urban, adjusted) = **2.58** m^3/s

ARUP	Job No.	Sheet No.	Rev.
	234335-00		
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Flood Studies Update - Pivotal Site	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_06

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	3.63	km^2	catchment area
BFIsoils	=	0.62		base flow index derived from soils data
SAAR	=	1169.00	mm	standard annual average rainfall (1961-1990)
FARL	=	1.00		flood attenuation by resevoirs and lakes
DRAIND	=	1.23		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	40.14	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0.00		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **1.40** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac	=	**1.44**
error of estimate for pivot	=	**1.07**
Total adjustment factor	=	**1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **2.15** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	0.74	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.20**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.32**		

Qmed (urban, adjusted) = **2.83** m^3/s

ARUP	Job No. 234335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Flood Studies Update - Pivotal Site	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_07

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	1.34	km^2	catchment area
BFIsoils	=	0.63		base flow index derived from soils data
SAAR	=	1187.00	mm	standard annual average rainfall (1961-1990)
FARL	=	1.00		flood attenuation by resevoirs and lakes
DRAIND	=	1.02		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	63.57	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0.00		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **0.56** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac	=	**1.44**
error of estimate for pivot	=	**1.07**
Total adjustment factor	=	**1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **0.86** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	0.03	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.03**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.04**		

Qmed (urban, adjusted) = **0.89** m^3/s

ARUP	Job No. 234335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Flood Studies Update - Pivotal Site	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_08

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	9.89	km^2	catchment area
BFIsoils	=	0.59		base flow index derived from soils data
SAAR	=	1176.00	mm	standard annual average rainfall (1961-1990)
FARL	=	1.00		flood attenuation by resevoirs and lakes
DRAIND	=	0.99		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	23.50	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0.00		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **3.15** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = Qmed piv (gauged)/Qmed piv (rural, PCD)

AdjFac	=	**1.44**
error of estimate for pivot	=	**1.07**
Total adjustment factor	=	**1.54**

Qmed (rural, adjusted) = AdjFac x Qmed (rural, PCD)

Qmed (rural, adjusted) = **4.85** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	4.49	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.45**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.74**		

Qmed (urban, adjusted) = **8.44** m^3/s

ARUP	Job No. 234335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: Flood Studies Update - Pivotal Site	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_09

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	3.79	km^2	catchment area
BFIsoils	=	0.66		base flow index derived from soils data
SAAR	=	1176.00	mm	standard annual average rainfall (1961-1990)
FARL	=	1.00		flood attenuation by resevoirs and lakes
DRAIND	=	0.96		drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	55.83	m/km	slope of the main channel between 10% and 85% of its length measured upstream from the HEP
ARTDRAIN2	=	0.00		Proportion of the river network that is included in arterial drainage schemes

3.0 Median Annual Flood (Rural)

Qmed (rural, PCD) = $1.237 \times 10^{-5}\ AREA^{0.937}\ BFIsoils^{-0.922}\ SAAR^{1.306}\ FARL^{2.217}\ DRAIND^{0.341}\ S1085^{0.185}\ (1+ARTDRAIN2)^{0.408}$

Qmed (rural, PCD) = **1.34** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name = Ballyedmond

Pivotal Site Station Number = 19020

Qmed piv (gauged)	=	23.16	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.04	m^3/s	Qmed at the pivotal site estimated from PCD equation

AdjFac = *Qmed piv (gauged)/Qmed piv (rural, PCD)*

AdjFac = **1.44**

error of estimate for pivot = **1.07**

Total adjustment factor = **1.54**

Qmed (rural, adjusted) = *AdjFac x Qmed (rural, PCD)*

Qmed (rural, adjusted) = **2.06** m^3/s

5.0 Adjustment for Urbanisation

Urban area	=	1.05	km^2	Urbanised area as per Corine landcover 2000
URBEXT	=	**0.28**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.44**		

Qmed (urban, adjusted) = **2.96** m^3/s

ARUP	Job No. 234335-00	Sheet No.	Rev.
Job Title: Douglas Flood Relief Scheme	Member/Location: Cork		
Calculation: Flood Studies Update - Pivotal Site	Drg. Ref.		
	Made by	Date 04/03/2014	Chd.

1.0 Flood Studies Update Physical Catchment Descriptors:

		HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09
AREA	km^2	22.03	13.53	7.45	7.13	3.50	3.63	1.34	9.89	3.79
BFIsoils		0.59	0.61	0.62	0.62	0.62	0.62	0.63	0.59	0.66
SAAR	mm	1152	1174	1176	1187	1187	1169	1187	1176	1176
Farl		1	1	1	1	1	1	1	1	1
DRAIND		1.10	1.06	1.28	1.19	1.15	1.23	1.02	0.99	0.9615
S1085	m/km	11.70	13.37	28.96	32.84	32.84	40.14	63.57	23.50	55.83
ARTDRAIN2		0	0	0	0	0	0	0	0	0

2.0 Median Annual Flood (Rural)

Qmed (rural, PCD)		5.92	3.80	2.63	2.56	1.30	1.40	0.56	3.15	1.34
Qmed piv (gauged)		23.157	23.157	23.157	23.157	23.157	23.157	23.157	23.157	23.157
Qmed piv (rural, PCD)		16.035	16.035	16.035	16.035	16.035	16.035	16.035	16.035	16.035

3.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name =		Ballyedmond	Ballyedmond	Ballyedmond	Ballyedmond	Ballyedmond	Ballyedmond	Ballyedmond	Ballyedmond	Ballyedmond
Pivotal Site Station Number =		19020	19020	19020	19020	19020	19020	19020	19020	19020

AdjFac		1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
Error of estimate at Ballyedmond		1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
Ballyed adjustment		1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
Qmed (rural, adjusted) =		9.14	5.87	4.07	3.95	2.01	2.16	0.87	4.87	2.07

4.0 Adjustment for Urbanisation

Urban area	km2	9.04	5.79	1.65	1.41	0.66	0.74	0.03	4.49	1.05
URBEXT		0.41	0.43	0.22	0.20	0.19	0.20	0.03	0.45	0.28
UAF		1.66	1.70	1.35	1.31	1.29	1.32	1.04	1.74	1.44
Qmed (urban, adjusted) =		15.22	9.95	5.48	5.16	2.59	2.84	0.90	8.47	2.97

6.0 Growth Curve

Return period (years)	Douglas FRS (2014) Growth Curve
2	1.00
5	1.34
10	1.59
25	2.00
50	2.24
100	2.56

7.0 Flood Frequencies

Return period (years)		Current Scenario Flows (m^3/s) Urban adjusted for Ballyedmond errors								
		HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09
2		15.22	9.95	5.48	5.16	2.59	2.84	0.90	8.47	2.97
5		20.39	13.33	7.34	6.91	3.47	3.81	1.20	11.35	3.98
10		24.20	15.81	8.71	8.20	4.12	4.52	1.43	13.47	4.72
25		30.44	19.89	10.96	10.31	5.18	5.68	1.80	16.95	5.94
50		34.09	22.28	12.27	11.55	5.80	6.37	2.01	18.98	6.65
100		38.96	25.46	14.03	13.20	6.63	7.28	2.30	21.69	7.60

ARUP

Job Title: Douglas Flood Relief Scheme	Job No.: 234335-00	Sheet No.	Rev.
Calculation: FSR Rainfall-Runoff Summary	Member/Location: Cork		
	Drg. Ref.		
	Made by	Date: 10/09/2014	Chd.

Catchment Characteristics

	HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09	Units
Area	22.029	13.528	7.453	7.13	3.504	3.36	1.342	9.89	3.79	km2
Length	7.569	7.24	3.881	2.853	2.842	2.455	1.11	5.24	2.86	km
Slope	10.392	11.6	29.206	32.252	32.376	43.441	57.632	23.66	55.83	m/km
SAAR	1152	1174	1176	1187	1187	1169	1187	1176	1176	mm
M5-2D	78.1	78.1	77.9	78.1	78.1	77.9	77	77	77	mm
M5-25D	243.5	243.5	239	239	243.5	239	243.5	245.8	245.8	mm
Jenkinsons r	0.21	0.21	0.22	0.22	0.21	0.22	0.21	0.22	0.22	
Urban Fraction	0.39	0.435	0.233	0.213	0.22	0.104	0.03	0.38	0.31	
SPR	27.15	32.59	30.00	30.00	30.00	30.00	30.00	30.00	30.00	%

Estimation For 100 year Return Period Flood

Critical storm duration	4.84	4.30	3.88	3.63	3.64	3.17	3.47	3.48	2.60	Hour
Hydrograph peak	34.76	26.61	13.98	13.91	6.67	7.08	2.48	20.64	9.25	m^3/s

Estimation For 2.34 year Return Period Flood (Qbar)

Critical Storm Duration	4.84	4.30	3.88	3.63	3.64	3.17	3.47	3.48	2.60	Hour
Hydrograph Peak	13.19	10.13	5.24	5.20	2.49	2.63	1.00	7.76	3.43	m^3/s

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Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_01

2.0 Flood Studies Report Catchment Characteristics:

AREA	=	22.03	km^2	Contributing catchment area
MSL	=	7.57	km	Main Stream Length
J_{50K}		9		No. of stream junctions measured on 1:50000 map
J_{1inch}		9.27		
Fs	=	1.01	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10		4	mOD	Measured at 10% of the MSL from downstream end
H85		65	mOD	Measured at 85% of the MSL from downstream end
S1085	=	10.74	m/km	Stream slope
LAKE	=	0		Fraction of catchment draining through lakes
Urban Area		8.60	km^2	
URBAN	=	0.39		Fraction of urbanised area in the catcment
SAAR	=	1152	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
22.03	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 22.03 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) $= 0.00042 \times AREA^{0.95} Fs^{0.22} SOIL^{1.18} SAAR^{1.05} (1+LAKE)^{-0.93} S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **4.59** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.64 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.34** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.89**

Qbar_urban = **8.69** m^3/s

5.0 Standard Error

Standard Factorial Error	=	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence)	=	13.03	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence)	=	19.54	m^3/s	

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Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_02

2.0 Flood Studies Report Catchment Characteristics:

AREA	=	13.53	km^2	Contributing catchment area
MSL	=	7.24	km	Main Stream Length
J_{50K}	=	4		No. of stream junctions measured on 1:50000 map
J_{1inch}		4.15		
Fs	=	0.69	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10		7	mOD	Measured at 10% of the MSL from downstream end
H85		70	mOD	Measured at 85% of the MSL from downstream end
S1085	=	11.60	m/km	Stream slope
LAKE	=	0		Fraction of catchment draining through lakes
Urban Area		5.89	km^2	
URBAN	=	0.44		Fraction of urbanised area in the catcment
SAAR	=	1174	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
13.53	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 13.53 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95} Fs^{0.22} SOIL^{1.18} SAAR^{1.05} (1+LAKE)^{-0.93} S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **2.75** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.69 — Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) — Percentage Runoff

PR = **30.35** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **2.01**

Qbar_urban = **5.53** m^3/s

5.0 Standard Error

Standard Factorial Error	=	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence)	=	8.29	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence)	=	12.44	m^3/s	

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Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_03

2.0 Flood Studies Report Catchment Characteristics:

AREA	=	7.45	km^2	Contributing catchment area
MSL	=	3.88	km	Main Stream Length
J_{50K}	=	6		No. of stream junctions measured on 1:50000 map
J_{1inch}		**6.21**		
Fs	=	**2.16**	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10		8	mOD	Measured at 10% of the MSL from downstream end
H85		92	mOD	Measured at 85% of the MSL from downstream end
S1085	=	**28.87**	m/km	Stream slope
LAKE	=	0		Fraction of catchment draining through lakes
Urban Area		1.74	km^2	
URBAN	=	**0.23**		Fraction of urbanised area in the catcment
SAAR	=	1176	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
7.45	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 7.45 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95} Fs^{0.22} SOIL^{1.18} SAAR^{1.05} (1+LAKE)^{-0.93} S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **2.32** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.70 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.36** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.50**

Qbar_urban = **3.47** m^3/s

5.0 Standard Error

Standard Factorial Error	=	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence)	=	**5.21**	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence)	=	**7.82**	m^3/s	

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Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_04

2.0 Flood Studies Report Catchment Characteristics:

AREA	=	7.13	km^2	Contributing catchment area
MSL	=	2.85	km	Main Stream Length
J_{50K}	=	6		No. of stream junctions measured on 1:50000 map
J_{1inch}		**6.21**		
Fs	=	**2.27**	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10		28	mOD	Measured at 10% of the MSL from downstream end
H85		97	mOD	Measured at 85% of the MSL from downstream end
S1085	=	**32.28**	m/km	Stream slope
LAKE	=	0		Fraction of catchment draining through lakes
Urban Area		1.52	km^2	
URBAN	=	**0.21**		Fraction of urbanised area in the catcment
SAAR	=	1187	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
7.13	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 7.13 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5
where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95}\ Fs^{0.22}\ SOIL^{1.18}\ SAAR^{1.05}\ (1+LAKE)^{-0.93}\ S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **2.31** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.72 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.36** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.45**

Qbar_urban = **3.35** m^3/s

5.0 Standard Error

Standard Factorial Error	=	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence)	=	**5.03**	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence)	=	**7.54**	m^3/s	

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Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_05

2.0 Flood Studies Report Catchment Characteristics:

AREA =	3.50	km^2	Contributing catchment area
MSL =	2.84	km	Main Stream Length
J_{50K} =	2		No. of stream junctions measured on 1:50000 map
J_{1inch}	2.09		
Fs =	1.50	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10	28	mOD	Measured at 10% of the MSL from downstream end
H85	97	mOD	Measured at 85% of the MSL from downstream end
S1085 =	32.39	m/km	Stream slope
LAKE =	0		Fraction of catchment draining through lakes
Urban Area	0.74	km^2	
URBAN =	0.21		Fraction of urbanised area in the catcment
SAAR =	1187	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
3.5	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 3.50 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95} Fs^{0.22} SOIL^{1.18} SAAR^{1.05} (1+LAKE)^{-0.93} S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **1.08** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.72 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.36** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.44**

Qbar_urban = **1.55** m^3/s

5.0 Standard Error

Standard Factorial Error =	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence) =	2.33	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence) =	3.50	m^3/s	

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Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_06

2.0 Flood Studies Report Catchment Characteristics:

AREA	=	3.63	km^2	Contributing catchment area
MSL	=	2.46	km	Main Stream Length
J_{50K}	=	4		No. of stream junctions measured on 1:50000 map
J_{1inch}		4.15		
Fs	=	3.03	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10		25	mOD	Measured at 10% of the MSL from downstream end
H85		105	mOD	Measured at 85% of the MSL from downstream end
S1085	=	43.36	m/km	Stream slope
LAKE	=	0		Fraction of catchment draining through lakes
Urban Area		0.77	km^2	
URBAN	=	0.21		Fraction of urbanised area in the catcment
SAAR	=	1169	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
3.63	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 3.63 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95} Fs^{0.22} SOIL^{1.18} SAAR^{1.05} (1+LAKE)^{-0.93} S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **1.34** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.68 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.35** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.45**

Qbar_urban = **1.94** m^3/s

5.0 Standard Error

Standard Factorial Error	=	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence)	=	2.91	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence)	=	4.36	m^3/s	

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Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_07

2.0 Flood Studies Report Catchment Characteristics:

AREA =	1.34	km^2	Contributing catchment area
MSL =	1.11	km	Main Stream Length
J_{50K} =	2		No. of stream junctions measured on 1:50000 map
J_{1inch}	2.09		
Fs =	4.20	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10	51	mOD	Measured at 10% of the MSL from downstream end
H85	99	mOD	Measured at 85% of the MSL from downstream end
S1085 =	57.66	m/km	Stream slope
LAKE =	0		Fraction of catchment draining through lakes
Urban Area	0.04	km^2	
URBAN =	0.03		Fraction of urbanised area in the catcment
SAAR =	1187	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
1.34	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 1.34 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5
where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95} Fs^{0.22} SOIL^{1.18} SAAR^{1.05} (1+LAKE)^{-0.93} S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **0.59** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.72 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.36** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.06**

Qbar_urban = **0.63** m^3/s

5.0 Standard Error

Standard Factorial Error =	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence) =	0.94	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence) =	1.41	m^3/s	

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1.0 Subcatchment: HEP_08

2.0 Flood Studies Report Catchment Characteristics:

AREA	=	9.89	km^2	Contributing catchment area
MSL	=	5.24	km	Main Stream Length
J_{50K}	=	3		No. of stream junctions measured on 1:50000 map
J_{1inch}		3.12		
Fs	=	0.71	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10		4	mOD	Measured at 10% of the MSL from downstream end
H85		97	mOD	Measured at 85% of the MSL from downstream end
S1085	=	23.66	m/km	Stream slope
LAKE	=	0		Fraction of catchment draining through lakes
Urban Area		3.79	km^2	
URBAN	=	0.38		Fraction of urbanised area in the catcment
SAAR	=	1176	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
9.89	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 9.89 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5
where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95}\ Fs^{0.22}\ SOIL^{1.18}\ SAAR^{1.05}\ (1+LAKE)^{-0.93}\ S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **2.31** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.70 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.36** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.87**

Qbar_urban = **4.32** m^3/s

5.0 Standard Error

Standard Factorial Error	=	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence)	=	6.48	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence)	=	9.71	m^3/s	

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Calculation: FSR Statistical Method	Made by	Date 04/03/2014	Chd.

1.0 Subcatchment: HEP_09

2.0 Flood Studies Report Catchment Characteristics:

AREA	=	3.79	km^2	Contributing catchment area
MSL	=	2.86	km	Main Stream Length
J_{50K}	=	1.00		No. of stream junctions measured on 1:50000 map
J_{1inch}		1.05		
Fs	=	**0.61**	$Jncts/km^2$	Stream Frequency adjusted to1 inch map scale
H10		15.5	mOD	Measured at 10% of the MSL from downstream end
H85		135.1	mOD	Measured at 85% of the MSL from downstream end
S1085	=	**55.76**	m/km	Stream slope
LAKE	=	0		Fraction of catchment draining through lakes
Urban Area		1.08	km^2	
URBAN	=	**0.29**		Fraction of urbanised area in the catcment
SAAR	=	1176	mm	Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
3.789	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 3.79 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5
where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00042 \times AREA^{0.95}\, Fs^{0.22}\, SOIL^{1.18}\, SAAR^{1.05}\, (1+LAKE)^{-0.93}\, S1085^{0.16}$

FSR equation *(Cawley & Cunnane, 2003)*

Qbar_rural = **1.03** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.72 Catchment Wetness Index (FSR, 1975)

PR = (102.4 x SOIL) + 0.28 x (CWI-125) Percentage Runoff

PR = **30.36** %

Qu bar/Qr bar = (1+ URBAN)1.5(1 + 0.3 x URBAN x (70/PR-1))

Qu bar/Qr bar = **1.62**

Qbar_urban = **1.66** m^3/s

5.0 Standard Error

Standard Factorial Error	=	1.50		(Cawley & Cunnane, 2003)
$Qbar_{Urban}$ (68% Confidence)	=	**2.49**	m^3/s	with standard factorial error applied
$Qbar_{Urban}$ (95% Confidence)	=	**3.74**	m^3/s	

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Calculation FSR Statistical Method	Made by	Date 04/03/2014	Chd.

Flood Studies Report Catchment Characteristics:

		HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09
AREA	km^2	22.03	13.53	7.45	7.13	3.5	3.63	1.34	9.89	3.789
MSL	km	7.57	7.24	3.88	2.85	2.84	2.46	1.11	5.24	2.86
m junctions		9	4	6	6	2	4	2	3	1
J_{1inch}		9.27	4.15	6.21	6.21	2.09	4.15	2.09	3.12	1.05
Fs	Jncts/ km^2	1.01	0.69	2.16	2.27	1.50	3.03	4.20	0.71	0.61
H10	mOD	4	7	8	28	28	25	51	4	15.48
H85	mOD	65	70	92	97	97	105	99	97	135.08
S1085	m/km	10.74	11.60	28.87	32.28	32.39	43.36	57.66	23.66	55.76
LAKE		0	0	0	0	0	0	0	0	0
Urban Area	km^2	8.6	5.89	1.74	1.52	0.74	0.77	0.04	3.79	1.08
URBAN		0.39	0.44	0.23	0.21	0.21	0.21	0.03	0.38	0.29
SAAR	mm	1152	1174	1176	1187	1187	1169	1187	1176	1176

WRAP Class		Area								
1	km^2	0	0	0	0	0	0	0	0	0
2	km^2	22.03	13.53	7.45	7.13	3.5	3.63	1.34	9.89	3.789
3	km^2	0	0	0	0	0	0	0	0	0
4	km^2	0	0	0	0	0	0	0	0	0
5	km^2	0	0	0	0	0	0	0	0	0
Area check	km^2	22.03	13.53	7.45	7.13	3.50	3.63	1.34	9.89	3.79

SOIL	check	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30

Mean Annual Flood (Rural)

Qbar_rural	m^3/s	4.59	2.75	2.32	2.31	1.08	1.34	0.59	2.31	1.03

Adjustment for Urbanisation

CWI		123.64	123.69	123.70	123.72	123.72	123.68	123.72	123.70	123.72
PR	%	30.34	30.35	30.36	30.36	30.36	30.35	30.36	30.36	30.36

bar/Qr bar		1.89	2.01	1.50	1.45	1.44	1.45	1.06	1.87	1.62
Qbar_urban	m^3/s	8.69	5.53	3.47	3.35	1.55	1.94	0.63	4.32	1.66

Standard Error

torial Error		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Confidence)	m^3/s	13.03	8.29	5.21	5.03	2.33	2.91	0.94	6.48	2.49
Confidence)	m^3/s	19.54	12.44	7.82	7.54	3.50	4.36	1.41	9.71	3.74

ARUP	Job No. 235335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_01

2.0 Flood Studies Report Catchment Characteristics:

AREA = 22.03 km^2 Contributing catchment area

SAAR = 1152 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
22.03	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 22.03 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = 7.01 m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.64 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.34**

Urban Area 8.6 km^2

URBAN = **0.39** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\ [1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR *for 500 ≤ SAAR ≤ 1100mm*

or

Nc = 0.74-0.000082.SAAR *for 1100 ≤ SAAR ≤ 3000mm*

Nc = **0.65**

Qu bar/Qr bar = **1.44**

Qbar_urban = **10.08** m^3/s

5.0 Standard Error

Standard Factorial Error = 1.65

$Qbar_{Urban}$ (68% Confidence) = **16.64** m^3/s with standard factorial error applied

$Qbar_{Urban}$ (95% Confidence) = **27.45** m^3/s

ARUP	Job No.	Sheet No.	Rev.
	235335-00		
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_02

2.0 Flood Studies Report Catchment Characteristics:

AREA = 13.53 km^2 Contributing catchment area

SAAR = 1174 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
13.53	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 13.53 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = 0.00108 x $AREA^{0.89}$ $SAAR^{1.17}$ $SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **4.64** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.69 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.35**

Urban Area 5.89 km^2

URBAN = **0.44** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}$ *[1 + URBAN{(21/CIND) - 0.3}]*

Nc = 0.92-0.00024.SAAR for 500 ≤ SAAR ≤ 1100mm

or

Nc = 0.74-0.000082.SAAR for 1100 ≤ SAAR ≤ 3000mm

Nc = **0.64**

Qu bar/Qr bar = **1.55**

Qbar_urban = **7.21** m^3/s

5.0 Standard Error

Standard Factorial Error = 1.65

$Qbar_{Urban}$ (68% Confidence) = **11.89** m^3/s with standard factorial error applied

$Qbar_{Urban}$ (95% Confidence) = **19.62** m^3/s

ARUP	Job No. 235335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_03

2.0 Flood Studies Report Catchment Characteristics:

AREA = 7.45 km^2 Contributing catchment area

SAAR = 1176 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
7.45	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 7.45 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **2.73** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.70 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.36**

Urban Area 1.74 km^2

URBAN = **0.23** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\ [1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR for 500 ≤ SAAR ≤ 1100mm

or

Nc = 0.74-0.000082.SAAR for 1100 ≤ SAAR ≤ 3000mm

Nc = **0.64**

Qu bar/Qr bar = **1.07**

Qbar_urban = **2.92** m^3/s

5.0 Standard Error

Standard Factorial Error = 1.65

$Qbar_{Urban}$ (68% Confidence) = **4.82** m^3/s with standard factorial error applied

$Qbar_{Urban}$ (95% Confidence) = **7.96** m^3/s

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	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_04

2.0 Flood Studies Report Catchment Characteristics:

AREA = 7.13 km^2 Contributing catchment area

SAAR = 1187 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
7.13	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 7.13 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **2.66** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.72 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.36**

Urban Area 1.52 km^2

URBAN = **0.21** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\ [1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR for $500 \le SAAR \le 1100$mm

or

Nc = 0.74-0.000082.SAAR for $1100 \le SAAR \le 3000$mm

Nc = **0.64**

Qu bar/Qr bar = **1.02**

Qbar_urban = **2.72** m^3/s

5.0 Standard Error

Standard Factorial Error = 1.65

$Qbar_{Urban}$ (68% Confidence) = **4.50** m^3/s with standard factorial error applied

$Qbar_{Urban}$ (95% Confidence) = **7.42** m^3/s

ARUP	Job No. 235335-00	Sheet No.	Rev.
Job Title Douglas Flood Relief Scheme	Member/Location Cork		
Calculation Institute of Hydrology Report No. 124	Drg. Ref.		
	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_05

2.0 Flood Studies Report Catchment Characteristics:

AREA = 3.50 km^2 Contributing catchment area

SAAR = 1187 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
3.5	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 3.5 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **1.41** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.72 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.36**

Urban Area 0.74 km^2

URBAN = **0.21** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\ [1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR for 500 ≤ SAAR ≤ 1100mm

or

Nc = 0.74-0.000082.SAAR for 1100 ≤ SAAR ≤ 3000mm

Nc = **0.64**

Qu bar/Qr bar = **1.02**

Qbar_urban = **1.44** m^3/s

5.0 Standard Error

Standard Factorial Error = 1.65

$Qbar_{Urban}$ (68% Confidence) = **2.38** m^3/s with standard factorial error applied

$Qbar_{Urban}$ (95% Confidence) = **3.92** m^3/s

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	235335-00		
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_06

2.0 Flood Studies Report Catchment Characteristics:

AREA = 3.63 km^2 Contributing catchment area

SAAR = 1169 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
3.63	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 3.63 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **1.43** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.68 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.35**

Urban Area 0.77 km^2

URBAN = **0.21** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\,[1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR for 500 ≤ SAAR ≤ 1100mm

or

Nc = 0.74-0.000082.SAAR for 1100 ≤ SAAR ≤ 3000mm

Nc = **0.64**

Qu bar/Qr bar = **1.03**

Qbar_urban = **1.47** m^3/s

5.0 Standard Error

Standard Factorial Error = 1.65

$Qbar_{Urban}$ (68% Confidence) = **2.42** m^3/s with standard factorial error applied

$Qbar_{Urban}$ (95% Confidence) = **4.00** m^3/s

ARUP	Job No. 235335-00	Sheet No.	Rev.
Job Title: Douglas Flood Relief Scheme	Member/Location: Cork		
	Drg. Ref.		
Calculation: Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_07

2.0 Flood Studies Report Catchment Characteristics:

AREA = 1.34 km^2 Contributing catchment area

SAAR = 1187 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
1.34	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 1.34 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **0.60** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.72 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.36**

Urban Area 0.04 km^2

URBAN = **0.03** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\ [1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR for 500 ≤ SAAR ≤ 1100mm

or

Nc = 0.74-0.000082.SAAR for 1100 ≤ SAAR ≤ 3000mm

Nc = **0.64**

Qu bar/Qr bar = **0.69**

Qbar_urban = **0.41** m^3/s

5.0 Standard Error

Standard Factorial Error = 1.65

$Qbar_{Urban}$ (68% Confidence) = **0.68** m^3/s with standard factorial error applied

$Qbar_{Urban}$ (95% Confidence) = **1.13** m^3/s

ARUP	Job No. 235335-00	Sheet No.	Rev.
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

1.0 Subcatchment: HEP_08

2.0 Flood Studies Report Catchment Characteristics:

AREA = 9.89 km^2 Contributing catchment area

SAAR = 1176 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
9.89	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 9.89 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **3.52** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.70 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.36**

Urban Area 3.79 km^2

URBAN = **0.38** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\,[1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR for $500 \le SAAR \le 1100mm$

or

Nc = 0.74-0.000082.SAAR for $1100 \le SAAR \le 3000mm$

Nc = **0.64**

Qu bar/Qr bar = **1.42**

Qbar_urban = **4.98** m^3/s

5.0 Standard Error

Standard Factorial Error	1.65
$Qbar_{Urban}$ (68% Confidence)	**8.22**
$Qbar_{Urban}$ (95% Confidence)	**13.57**

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	235335-00		
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 20/10/2014	Chd.

1.0 Subcatchment: HEP_09

2.0 Flood Studies Report Catchment Characteristics:

AREA = 3.79 km^2 Contributing catchment area

SAAR = 1176 mm Standard annual average rainfall

Area		WRAP Class (FSR, fig i 4.18(i))
0	km^2	1
3.789	km^2	2
0	km^2	3
0	km^2	4
0	km^2	5

Area check (sum) = 3.789 km^2

SOIL = 0.15 SOIL1 + 0.3 SOIL2 + 0.4 SOIL3 + 0.45 SOIL4 + 0.5 SOIL5

where SOILn is the fraction of the catchment in Wrap class n

SOIL = **0.30**

3.0 Mean Annual Flood (Rural)

Qbar (rural) = $0.00108 \times AREA^{0.89}\ SAAR^{1.17}\ SOIL^{2.17}$

IH124 Calcs

Qbar_rural = **1.50** m^3/s

4.0 Adjustment for Urbanisation

CWI = 123.70 Catchment Wetness Index (FSR, 1975)

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.36**

Urban Area 1.08 km^2

URBAN = **0.29** Fraction of urbanised area in the catcment

Qu bar/Qr bar = $(1 + URBAN)^{2NC}\ [1 + URBAN\{(21/CIND) - 0.3\}]$

Nc = 0.92-0.00024.SAAR for 500 ≤ SAAR ≤ 1100mm

or

Nc = 0.74-0.000082.SAAR for 1100 ≤ SAAR ≤ 3000mm

Nc = **0.64**

Qu bar/Qr bar = **1.18**

Qbar_urban = **1.77** m^3/s

5.0 Standard Error

Standard Factorial Error	1.65
$Qbar_{Urban}$ (68% Confidence)	**2.92**
$Qbar_{Urban}$ (95% Confidence)	**4.82**

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	235335-00		
	Member/Location Cork		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Institute of Hydrology Report No. 124	Made by	Date 07/03/2014	Chd.

Flood Studies Report Catchment Characteristics:

		HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09	HEP_09
AREA	km^2	22.03	13.53	7.45	7.13	3.5	3.63	1.34	9.89	3.789	3.789
SAAR	mm	1152	1174	1176	1187	1187	1169	1187	1176	1176	1176
WRAP Class		Area									
1	km^2	0	0	0	0	0	0	0	0	0	0
2	km^2	22.03	13.53	7.45	7.13	3.5	3.63	1.34	9.89	3.789	3.789
3	km^2	0	0	0	0	0	0	0	0	0	0
4	km^2	0	0	0	0	0	0	0	0	0	0
5	km^2	0	0	0	0	0	0	0	0	0	0
Area check (sum)	km^2	22.03	13.53	7.45	7.13	3.50	3.63	1.34	9.89	3.79	3.79
SOIL		0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30

Mean Annual Flood (Rural)

Qbar_rural	m^3/s	7.01	4.64	2.73	2.66	1.41	1.43	0.60	3.52	1.50	1.50

Adjustment for urbanisation

CWI		123.64	123.69	123.70	123.72	123.72	123.68	123.72	123.70	123.70	123.70
CIND		30.34	30.35	30.36	30.36	30.36	30.35	30.36	30.36	30.36	30.36
Urban Area	km^2	8.6	5.89	1.74	1.52	0.74	0.77	0.04	3.79	1.08	1.2
URBAN		0.39	0.44	0.23	0.21	0.21	0.21	0.03	0.38	0.29	0.32

Nc		0.65	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Qu bar/Qr bar		1.44	1.55	1.07	1.02	1.02	1.03	0.69	1.42	1.18	1.25
Qbar_urban	m^3/s	10.08	7.21	2.92	2.72	1.44	1.47	0.41	4.98	1.77	1.88

Standard Error

Standard Factorial Error		1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65
$Qbar_{Urban}$ (68% Confidence)	m^3/s	16.64	11.89	4.82	4.50	2.38	2.42	0.68	8.22	2.92	3.10
$Qbar_{Rural}$ (95% Confidence)	m^3/s	27.45	19.62	7.96	7.42	3.92	4.00	1.13	13.57	4.82	5.12

ARUP	Job No.	Sheet No.	Rev.
	234335-00		
	Member/Location		
Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: Rational Method	Made by	Date: 28/04/2014	Chd. AL

1.0 Catchment = HEP_03

2year Rainfall event (Qmed)

2.0 Rainfall

ARF	=	0.93		*From FSR table, based on time of concentration*
depth		15.65	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**14.55**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration 1.38 hrs

C	=	*Runoff Coefficient*		
$C_{(max)}$	=	0.50		*From NTF data analysis*
$C_{(ave)}$	=	0.37		*From NTF data analysis*
i	=	**10.55**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	198.11	ha	*Urban Area*
$A_{(rural)}$	=	547.36	ha	*Rural Area*
Q	=	**10928.58**	l/s	Using C_{max}
Q	=	**10.93**	m^3/s	Using C_{max}
Q	=	**8087.15**	l/s	Using C_{ave}
Q	=	**8.09**	m^3/s	Using C_{ave}

100 year Rainfall event

2.0 Rainfall

ARF	=	0.93		*From FSR table, based on time of concentration*
depth		35.2	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**32.74**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration 1.38 hrs

C	=	*Runoff Coefficient*		
$C_{(max)}$	=	0.50		*From NTF data analysis*
$C_{(ave)}$	=	0.37		*From NTF data analysis*
i	=	**23.72**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	198.11	ha	*Urban Area*
$A_{(rural)}$	=	547.36	ha	*Rural Area*
Q	=	**24580.57**	l/s	Using C_{max}
Q	=	**24.58**	m^3/s	Using C_{max}
Q	=	**18189.62**	l/s	Using C_{ave}
Q	=	**18.19**	m^3/s	Using C_{ave}

ARUP	Job No. 234335-00	Sheet No.	Rev.
	Member/Location		
Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: Rational Method	Made by	Date 28/04/2014	Chd.

1.0 Catchment = HEP_04

2year Rainfall event (Qmed)

2.0 Rainfall

ARF	=	0.94		*From FSR table, based on Critical storm duration*
depth		13.80	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**13.00**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.05	hrs	
C	=	*Runoff Coefficient*		
$C_{(max)}$	=	0.50		*From NTF data analysis*
$C_{(ave)}$	=	0.37		*From NTF data analysis*
i	=	**12.38**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	165.94	ha	*Urban Area*
$A_{(rural)}$	=	547.04	ha	*Rural Area*
Q	=	**12269.72**	l/s	Using C_{max}
Q	=	**12.27**	m^3/s	Using C_{max}
Q	=	**9079.59**	l/s	Using C_{ave}
Q	=	**9.08**	m^3/s	Using C_{ave}

100 year Rainfall event

2.0 Rainfall

ARF	=	0.94		*From FSR table, based on Critical storm duration*
depth		32.31	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**30.44**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.05	hrs	
Cv	=	*Runoff Coefficient*		
$C_{v\ (max)}$	=	0.51		*From NTF data analysis*
$C_{v\ (ave)}$	=	0.37		*From NTF data analysis*
i	=	**28.99**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	165.94	ha	*Urban Area*
$A_{(rural)}$	=	547.04	ha	*Rural Area*
Q	=	**29301.70**	l/s	Using C_{max}
Q	=	**29.30**	m^3/s	Using C_{max}
Q	=	**21258.09**	l/s	Using C_{ave}
Q	=	**21.26**	m^3/s	Using C_{ave}

ARUP	Job No.	Sheet No.	Rev.
	234335-00		
	Member/Location		
Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: Rational Method	Made by	Date 28/04/2014	Chd. AL

1.0 Catchment = HEP_05

2year Rainfall event (Qmed)

2.0 Rainfall

ARF	=	0.94		*From FSR table, based on Critical storm duration*
depth		13.80	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**13.00**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.12	hrs	
C	=	*Runoff Coefficient*		
$C_{(max)}$	=	0.49		*From NTF data analysis*
$C_{(ave)}$	=	0.36		*From NTF data analysis*
i	=	**11.61**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	77.87	ha	*Urban Area*
$A_{(rural)}$	=	272.48	ha	*Rural Area*
Q	=	**5539.35**	l/s	Using C_{max}
Q	=	**5.54**	m^3/s	Using C_{max}
Q	=	**4069.73**	l/s	Using C_{ave}
Q	=	**4.07**	m^3/s	Using C_{ave}

100 year Rainfall event

2.0 Rainfall

ARF	=	0.94		*From FSR table, based on Critical storm duration*
depth		32.31	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**30.44**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.12	hrs	
Cv	=	*Runoff Coefficient*		
$C_{v\,(max)}$	=	0.51		*From NTF data analysis*
$C_{v\,(ave)}$	=	0.36		*From NTF data analysis*
i	=	**27.18**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	77.87	ha	*Urban Area*
$A_{(rural)}$	=	272.48	ha	*Rural Area*
Q	=	**13498.67**	l/s	Using C_{max}
Q	=	**13.50**	m^3/s	Using C_{max}
Q	=	**9528.47**	l/s	Using C_{ave}
Q	=	**9.53**	m^3/s	Using C_{ave}

ARUP	Job No.	Sheet No.	Rev.
	234335-00		
	Member/Location		
Job Title: Douglas Flood Relief Scheme	Drg. Ref.		
Calculation: Rational Method	Made by	Date: 28/04/2014	Chd. AL

1.0 Catchment = HEP_06

2year Rainfall event (Qmed)

2.0 Rainfall

ARF	=	0.94		*From FSR table, based on Critical storm duration*
depth		13.03	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**12.30**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.01	hrs	
C	=	*Runoff Coefficient*		
$C_{(max)}$	=	0.51		*From NTF data analysis*
$C_{(ave)}$	=	0.38		*From NTF data analysis*
i	=	**12.18**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	87.46	ha	*Urban Area*
$A_{(rural)}$	=	275.24	ha	*Rural Area*
Q	=	**6262.75**		Using C_{max}
Q	=	**6.26**	m^3/s	Using C_{max}
Q	=	**4666.37**	l/s	Using C_{ave}
Q	=	**4.67**	m^3/s	Using C_{ave}

100 year Rainfall event

2.0 Rainfall

ARF	=	0.94		*From FSR table, based on Critical storm duration*
depth		32.31	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**30.50**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.01	hrs	
Cv	=	*Runoff Coefficient*		
$C_{v\ (max)}$	=	0.51		*From NTF data analysis*
$C_{v\ (ave)}$	=	0.38		*From NTF data analysis*
i	=	**30.20**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	87.46	ha	*Urban Area*
$A_{(rural)}$	=	275.24	ha	*Rural Area*
Q	=	**15529.51**	l/s	Using C_{max}
Q	=	**15.53**	m^3/s	Using C_{max}
Q	=	**11571.01**	l/s	Using C_{ave}
Q	=	**11.57**	m^3/s	Using C_{ave}

1.0 Catchment = HEP_09

2year Rainfall event (Qmed)

2.0 Rainfall

ARF	=	0.939		*From FSR table, based on Critical storm duration*
depth		12.89	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**12.10**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.24	hrs	
C	=	*Runoff Coefficient*		
$C_{(max)}$	=	0.53		*From NTF data analysis*
$C_{(ave)}$	=	0.40		*From NTF data analysis*
i	=	**9.76**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	108.00	ha	*Urban Area*
$A_{(rural)}$	=	270.90	ha	*Rural Area*
Q	=	**5449.32**	l/s	Using C_{max}
Q	=	**5.45**	m^3/s	Using C_{max}
Q	=	**4112.69**	l/s	Using C_{ave}
Q	=	**4.11**	m^3/s	Using C_{ave}

100 year Rainfall event

2.0 Rainfall

ARF	=	0.939		*From FSR table, based on Critical storm duration*
depth		32.31	mm	*Interpolation of DDF tables for time of concentration*
$Depth_{Reduced}$	=	**30.34**	mm	

3.0 Peak Flow

Q = 2.78 C i A

Time of concentration		1.24	hrs	
Cv	=	*Runoff Coefficient*		
$C_{v\ (max)}$	=	0.51		*From NTF data analysis*
$C_{v\ (ave)}$	=	0.40		*From NTF data analysis*
i	=	**24.47**	mm/hr	*average rainfall intensity*
$A_{(urban)}$	=	108.00	ha	*Urban Area*
$A_{(rural)}$	=	270.90	ha	*Rural Area*
Q	=	**13143.78**	l/s	Using C_{max}
Q	=	**13.14**	m^3/s	Using C_{max}
Q	=	**10308.85**	l/s	Using C_{ave}
Q	=	**10.31**	m^3/s	Using C_{ave}

ARUP	Job No.	Sheet No.	Rev.
	234335-00		
	Member/Location		
Job Title Douglas Flood Relief Scheme	Drg. Ref.		
Calculation Rational Method	Made by	Date 28/04/2014	Chd.

1.0 Rainfall

	HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09	
depth (2yr)			15.65	13.80	13.80	13.03			12.89	mm
$Depth_{Reduced}$			14.55	13.00	13.00	12.30			12.10	mm
depth (100yr)			35.20	31.10	31.10	32.31			31.42	mm
$Depth_{Reduced}$			32.74	29.30	29.30	30.50			29.50	mm

2.0 Peak Flow

	HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09	
Time of concentration			1.38	1.05	1.12	1.01			1.24	hrs
$C_{(max)}$			0.5	0.5	0.49	0.51			0.53	
$C_{(ave)}$			0.37	0.37	0.36	0.38			0.4	
i			25.20	29.61	27.76	32.38			25.41	mm/hr
i (2yr)			10.55	12.38	11.61	12.18			9.76	mm/hr
$AREA_{total}$			745.47	712.98	350.35	362.71			378.9	hectare
$AREA_{urban}$			198.11	165.94	77.87	87.46			108.0	hectare
$AREA_{rural}$			547.36	547.04	272.48	275.24			270.9	hectare

3.0 140yr rainfall

		HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09	
Q	using C max			26116.86	29340.64	13246.28	16649.41			5101.96	l/s
Q	using C max			26.12	29.34	13.25	16.65			5.10	m^3/s
Q	using C ave			19326.47	21712.07	9731.96	12405.44			3850.53	l/s
Q	using C ave			19.33	21.71	9.73	12.41			3.85	m^3/s

4.0 100yr rainfall

		HEP_01	HEP_02	HEP_03	HEP_04	HEP_05	HEP_06	HEP_07	HEP_08	HEP_09	
Q	using C max			24580.57	27651.33	12483.61	15529.51			4778.05	l/s
Q	using C max			24.58	27.65	12.48	15.53			4.78	m^3/s
Q	using C ave			18189.62	20461.98	9171.63	11571.01			3606.07	l/s
Q	using C ave			18.19	20.46	9.17	11.57			3.61	m^3/s

Job title	Douglas	Job number	Sheet number	Revision
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Calc title	Choice of pooling group	Member/Location	0-12-7	
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		Made by LRJB	Date 05/06/14	Chd.

1 Pooling Group Derivation

1.1 Subject Site

Flow Estimation Points: HEP 001, HEP 003

	HEP_01	HEP_03
NODE_EAST	169940	169815
NODE_NORTH	69612	69503
CENTROID Easting	168080	169560
CENTROID Northing	68480	67840
AREA	22.03	7.45
ALTBAR	77.9	97.4
SAAR	1152	1176
FARL	1	1
URBEXT	0.43	0.222
BFISOIL	0.5867303	0.61554938
FPEXT	0.01	0.00

1.2 Methodology

Improved FEH pooling group	Method	Used (Y/N)
	No review of pooling group	N
	Minimal review of pooling group (based on HiFlows-UK suitability indication)	Y
	Detailed review of pooling group (beyond HiFlows-UK suitability indication)	N

Flow Estimation Points are located in Ireland, and selected by Flood Studies Update (FSU) methodology. WINFAP analysis is required because of lack of confidence in FSU online tools (still currently at “beta”stage). Some modifications to approach are required.

For instance, while it is Flood Estimation Handbook (FEH) procedure to reject sites that have URBEXT >0.05, and it remains logical that this should be the case in the FSU process, there is no reference to such a procedure in the FSU guidance. To address this particular point, sensitivity analyses have been carried out for the growth curve with, and without the urbanised sites.

1.3 Pooling group derivation

The pooling groups have been created by the development of WINFAP compatible data files for Irish gauge data. The pooling groups have been drawn exclusively from this gauge set. Some review of gauges was carried out, and two were rejected due to heavy influence of arterial drainage schemes apparently causing what appeared to be an apparently artificial influence in their AMAX record

Versions of FEH software and databases used in this study:

Job title	Douglas	Job number	Sheet number	Revision
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Calc title	Choice of pooling group	Member/Location	0-12-7	
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FEH CD-ROM Not applicable
Winfap FEH V 3.0.003 (2009)
HiFlows UK database Not applicable

Initial pooling groups provided:

HEP_01 Pooling group	
STATIONNR	**LOCATION**
6031	CURRALHIR
19020	BALLYEDMOND
16005	AUGHNAGROSS
25044	COOLE
26022	KILMORE
29001	RATHGORGIN
26009	BELLANTRA BR.
9010	WALDRONS BRIDGE
29071	CUTRA
29004	CLARINBRIDGE
25158	CAPPAMORE
25027	GOURDEEN BRIDGE
34024	KILTIMAGH
26020	ARGAR
34011	GNEEVE BRIDGE

HEP_03 Pooling group	
STATIONNR	**LOCATION**
25040	ROSCREA
10022	CARRICKMINES
6031	CURRALHIR
19020	BALLYEDMOND
16005	AUGHNAGROSS
10021	COMMONS ROAD
26022	KILMORE
25044	COOLE
8002	NAUL
31002	CASHLA
8005	KINSALEY HALL
26009	BELLANTRA BR.
29001	RATHGORGIN
33070	CARROWMORE
9010	WALDRONS BRIDGE
9002	LUCAN
29071	CUTRA
29004	CLARINBRIDGE

Sites of potential concern:

9010	URBEXT = 0.24
25027	Potential artificial influence
34024	Strongly influenced by arterial drainage schemes
26020	
34011	
29071	FARL = 0.804
34011	FARL = 0.867

8005	URBEXT = 0.25
9002	URBEXT = 0.21
9010	URBEXT = 0.24
10021	URBEXT = 0.24
10022	URBEXT = 0.30
25040	URBEXT = 0.06
29071	FARL = 0.804
31002	FARL = 0.632
33070	FARL = 0.677

Additional sites provided:

Job title	Douglas	Job number	Sheet number	Revision
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HEP_01 Pooling group	
Sites added	
STATIONNR	LOCATION
8002	NAUL
35004	BIG BRIDGE
36031	LISDARN

HEP_03 Pooling group	
Sites added	
STATIONNR	LOCATION
25158	CAPPAMORE
26018	BELLAVAHAN
36031	LISDARN

These were in turn reviewed

Sites of potential concern:

36031	URBEXT =0.06

26018	FARL = 0.76
36031	URBEXT =0.06

Sites with low values of FARL, or high arterial drainage influence were removed entirely from the pooling groups. Station 25027 was retained after examination of the physical characteristics of the system determined that there was no good reason not to include it in the pooling groups. Sites with high urbanisation were retained and used in a sensitivity analysis.

The final pooling groups for assessment were:

HEP_01A Pooling group – URBAN SITES REMOVED	
STATIONNR	LOCATION
6031	CURRALHIR
19020	BALLYEDMOND
16005	AUGHNAGROSS
25044	COOLE
26022	KILMORE
29001	RATHGORGIN
26009	BELLANTRA BR.
29004	CLARINBRIDGE
25158	CAPPAMORE
8002	NAUL
35004	BIG BRIDGE

HEP_03A Pooling group– URBAN SITES REMOVED	
STATIONNR	LOCATION
6031	CURRALHIR
19020	BALLYEDMOND
16005	AUGHNAGROSS
26022	KILMORE
25044	COOLE
8002	NAUL
26009	BELLANTRA BR.
29001	RATHGORGIN
29004	CLARINBRIDGE
25158	CAPPAMORE

Sensitivity testing: Urban sites retained

HEP_01B Pooling group – SENSITIVITY - URBAN SITES RETAINED	
STATIONNR	LOCATION

HEP_03B Pooling group – SENSITIVITY - URBAN SITES RETAINED	
STATIONNR	LOCATION

Job title	Douglas	Job number	Sheet number	Revision
		234335-02		
Calc title	Choice of pooling group	Member/Location	0-12-7	
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6031	CURRALHIR
19020	BALLYEDMOND
16005	AUGHNAGROSS
25044	COOLE
26022	KILMORE
29001	RATHGORGIN
26009	BELLANTRA BR.
9010	WALDRONS BRIDGE
29004	CLARINBRIDGE
25158	CAPPAMORE
25027	GOURDEEN BRIDGE
8002	NAUL
35004	BIG BRIDGE
36031	LISDARN

25040	ROSCREA
10022	CARRICKMINES
6031	CURRALHIR
19020	BALLYEDMOND
16005	AUGHNAGROSS
10021	COMMONS ROAD
26022	KILMORE
25044	COOLE
8002	NAUL
8005	KINSALEY HALL
26009	BELLANTRA BR.
29001	RATHGORGIN
9010	WALDRONS BRIDGE
9002	LUCAN
29004	CLARINBRIDGE
25158	CAPPAMORE
36031	LISDARN

Job title	Douglas	Job number	Sheet number	Revision
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		Made by LRJB	Date 05/06/14	Chd.

HEP01A:

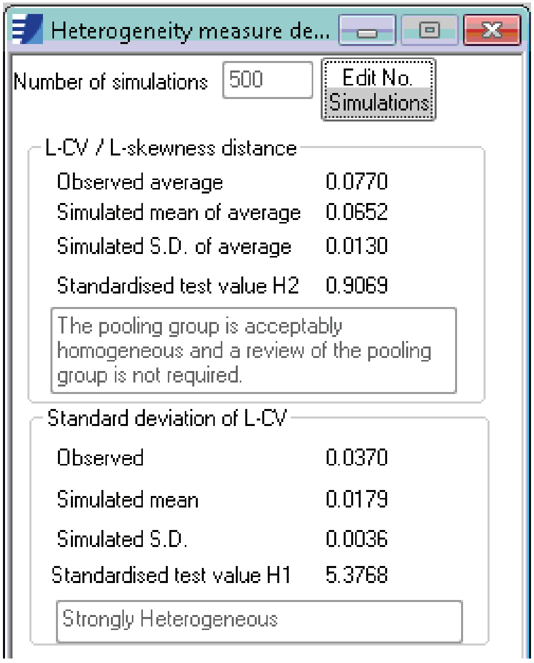
	HEP_01A Pooling group – URBAN SITES REMOVED		
Rank in FSU	**Rank in FEH**	**STATIONNR**	**LOCATION**
1	1	6031	CURRALHIR
2	4	19020	BALLYEDMOND
3	5	16005	AUGHNAGROSS
4	7	25044	COOLE
5	3	26022	KILMORE
6	9	29001	RATHGORGIN
7	6	26009	BELLANTRA BR.
8	12	29004	CLARINBRIDGE
9	8	25158	CAPPAMORE
10	13	25027	GOURDEEN BRIDGE
11	2	8002	NAUL
12	10	35004	BIG BRIDGE
12	13	Sites in group	
392	451	Years of record	

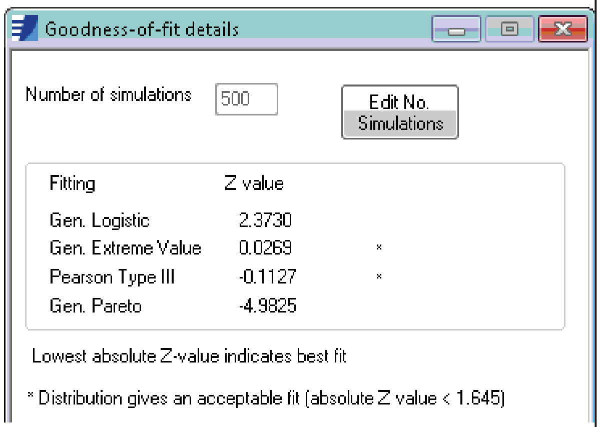
WINFAP's initial selection, with above sites removed.

	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
1	6031 (Flurry @ Curralhir)	1.113	14	12.576	0.248	0.407	2.655
2	8002 (Delvin @ Naul)	1.185	21	3.428	0.153	0.273	0.552
3	26022 (Fallan @ Kilmore)	1.553	41	6.300	0.175	0.137	0.820
4	19020 (Owennacurra @ Ballyedı	1.701	23	21.073	0.205	0.091	1.096
5	16005 (Multeen @ Aughnagross	1.956	33	6.700	0.137	0.135	0.221
6	26009 (Black @ Bellantra br)	2.163	43	13.400	0.092	0.188	1.641
7	25044 (Kilmastulla @ Coole)	2.242	39	20.148	0.176	0.276	0.604
8	25158 (Bilboa @ Cappamore)	2.299	16	47.333	0.121	-0.021	1.826
9	29001 (Raford @ Rathgorgin)	2.368	48	14.000	0.122	0.111	0.287
10	35004 (Big Bridge @ Owenmore	2.385	14	19.435	0.130	0.242	1.766
11	25023 (Little Brosna @ Milltown)	2.392	59	12.000	0.165	0.045	0.736
12	29004 (Clarinbridge @ Clarinbrid	2.402	40	11.150	0.110	0.159	0.488
13	25027 (Ollatrim @ Gourdeen Bric	2.413	60	12.200	0.186	0.151	0.306
14							
15	Total		451				
16	Weighted means		451		0.157	0.163	

Note: FEH initially imported additional sites to make up 500 years of record, some of these have been removed, leaving the pooling group with 451years of record.After this process, the only additional site is 25023, Little Brosna. Also note that the order of sites differs slightly from those provided due to differences in the distance measures embedded in the FEH, versus those used in the FSU. The relative variances and weightings of the parameters used in the distance measure also have a slight impact on the order.

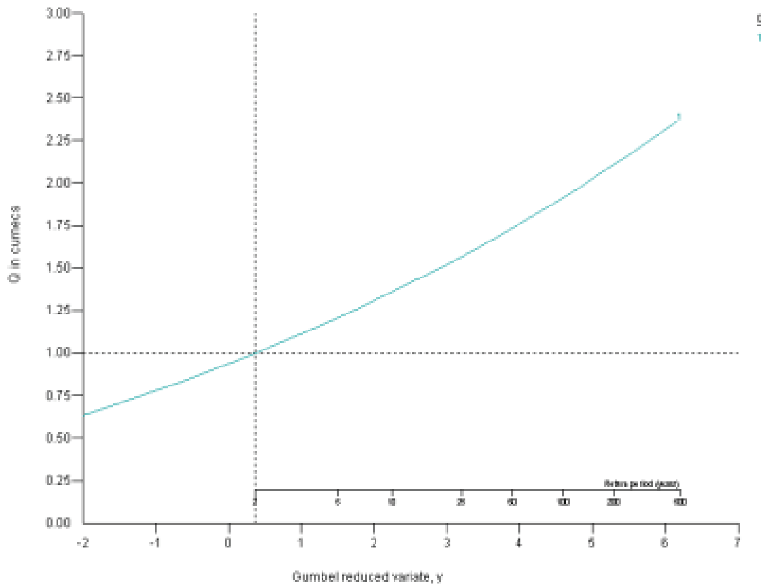
Testing of the heterogeneity of the pooling group indicates that there is no need to review and refine it. Goodness of fit measures suggest that the Generalised Extreme Variable (GEV) and Pearson Type III distributions give the best fit to the data; of these, FSU recommends use of the GEV.





The resulting growth curve fittings are as follows:

HEP001A Growth Curve	
Return period (years)	**Growth factor**
2	1
5	1.21
10	1.36
25	1.57
50	1.74
100	1.92
200	2.11
500	2.38



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HEP03A:

	HEP_03A Pooling group – URBAN SITES REMOVED		
Rank in FSU	**Rank in FEH**	**STATIONNR**	**LOCATION**
1	2	6031	CURRALHIR
2	4	19020	BALLYEDMOND
3	5	16005	AUGHNAGROSS
4	3	26022	KILMORE
5	7	25044	COOLE
6	1	8002	NAUL
7	6	26009	BELLANTRA BR.
8	9	29001	RATHGORGIN
9	12	29004	CLARINBRIDGE
10	8	25158	CAPPAMORE
10	12	Sites in group	
318	391	Years of record	

WINFAP's initial selection, with above sites removed.

	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordanc
1	8002 (Delvin @ Naul)	2.388	21	3.428	0.153	0.273	0.493
2	6031 (Flurry @ Curralhir)	2.589	14	12.576	0.248	0.407	2.502
3	26022 (Fallan @ Kilmore)	3.035	41	6.300	0.175	0.137	0.844
4	19020 (Owennacurra @ Ballyedı	3.220	23	21.073	0.205	0.091	1.177
5	16005 (Multeen @ Aughnagross	3.454	33	6.700	0.137	0.135	0.187
6	26009 (Black @ Bellantra br)	3.662	43	13.400	0.092	0.188	1.491
7	25044 (Kilmastulla @ Coole)	3.693	39	20.148	0.176	0.276	0.569
8	25158 (Bilboa @ Cappamore)	3.801	16	47.333	0.121	-0.021	1.678
9	29001 (Raford @ Rathgorgin)	3.880	48	14.000	0.122	0.111	0.251
10	25023 (Little Brosna @ Milltown)	3.891	59	12.000	0.165	0.045	0.770
11	35004 (Big Bridge @ Owenmore	3.897	14	19.435	0.130	0.242	1.613
12	29004 (Clarinbridge @ Clarinbrid	3.921	40	11.150	0.110	0.159	0.425
13							
14	Total		391				
15	Weighted means		391		0.154	0.164	

Note: FEH initially imported additional sites to make up 500 years of record, some of these have been removed, leaving the pooling group with 391years of record. After this process, the additional sites are 25023, 35004.

Testing of the heterogeneity of the pooling group indicates that the need to review the pooling group is optional. The limited quality of the available gauges of hydrological similarity suggests that further refinement of the pooling group will not improve the estimate of the growth curve. Goodness of fit measures suggest that the Generalised Extreme Variable (GEV) and Pearson Type III distributions give the best fit to the data; of these, FSU recommends use of the GEV.

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Heterogeneity measure de...

Number of simulations: 500 [Edit No. Simulations]

L-CV / L-skewness distance

Observed average	0.0829
Simulated mean of average	0.0671
Simulated S.D. of average	0.0147
Standardised test value H2	1.0709

The pooling group is possibly heterogeneous and a review of the pooling group is optional.

Standard deviation of L-CV

Observed	0.0371
Simulated mean	0.0179
Simulated S.D.	0.0038
Standardised test value H1	5.0197

Strongly Heterogeneous

Goodness-of-fit details

Number of simulations: 500 [Edit No. Simulations]

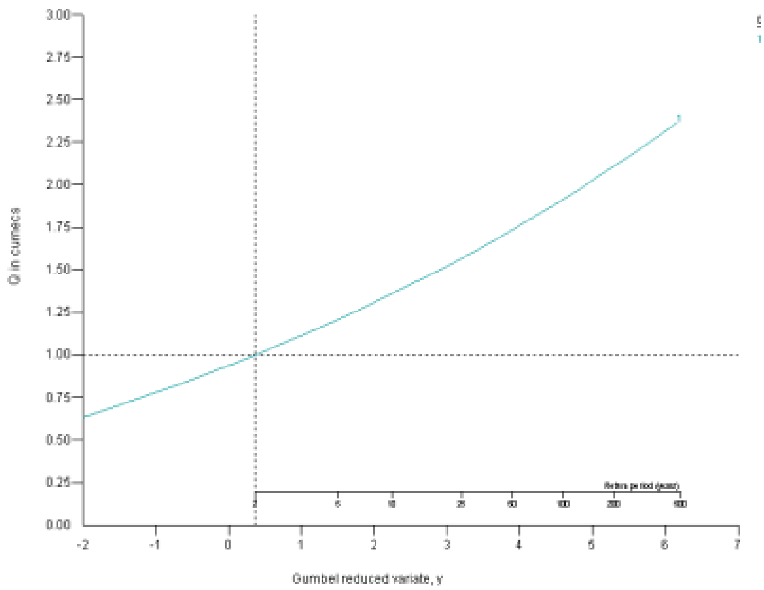
Fitting	Z value	
Gen. Logistic	2.2183	
Gen. Extreme Value	-0.0088	*
Pearson Type III	-0.1431	*
Gen. Pareto	-4.7655	

Lowest absolute Z-value indicates best fit

* Distribution gives an acceptable fit (absolute Z value < 1.645)

The resulting growth curve fittings are as follows:

HEP003A Growth Curve	
Return period (years)	**Growth factor**
2	1
5	1.23
10	1.39
25	1.60
50	1.77
100	1.93
200	2.11
500	2.34



HEP01B: SENSITIVITY ANALYSIS: URBAN SITES RETAINED

	HEP_01B Pooling group – URBAN SITES RETAINED		
Rank in FSU	Rank in WINFAP	STATIONNR	LOCATION
1	3	6031	CURRALHIR
2	10	19020	BALLYEDMOND
3	11	16005	AUGHNAGROSS
4	14	25044	COOLE
5	8	26022	KILMORE
6	16	29001	RATHGORGIN
7	13	26009	BELLANTRA BR.
8	12	9010	WALDRONS BRIDGE
9	19	29004	CLARINBRIDGE
10	15	25158	CAPPAMORE
11	20	25027	GOURDEEN BRIDGE
12	6	8002	NAUL
13	17	35004	BIG BRIDGE
14	9	36031	LISDARN
14	20	Sites in group	
	631	Years of record	

	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordanc
1	25040 (Bunow @ Roscrea)	0.618	26	4.028	0.145	0.224	0.455
2	10021 (Shanganagh @ Commor	0.996	29	8.532	0.245	0.219	0.548
3	6031 (Flurry @ Curralhir)	1.113	14	12.576	0.248	0.407	1.650
4	10022 (Cabinteely @ Carrickmin	1.162	17	3.853	0.232	0.085	0.748
5	9002 (Griffeen @ Lucan)	1.164	21	5.766	0.413	0.336	1.969
6	8002 (Delvin @ Naul)	1.185	21	3.428	0.153	0.273	0.458
7	8005 (Sluice @ Kinsaley Hall)	1.548	22	2.750	0.367	0.316	1.141
8	26022 (Fallan @ Kilmore)	1.553	41	6.300	0.175	0.137	0.740
9	36031 (Cavan @ Lisdarn)	1.613	37	5.939	0.197	0.482	2.125
10	19020 (Owennacurra @ Ballyedi	1.701	23	21.073	0.205	0.091	0.483
11	16005 (Multeen @ Aughnagross	1.956	33	6.700	0.137	0.135	0.402
12	9010 (Dodder @ Waldrons Bridg	2.112	28	46.877	0.424	0.450	1.999
13	26009 (Black @ Bellantra br)	2.163	43	13.400	0.092	0.188	1.316
14	25044 (Kilmastulla @ Coole)	2.242	39	20.148	0.176	0.276	0.392
15	25158 (Bilboa @ Cappamore)	2.299	16	47.333	0.121	-0.021	1.976
16	29001 (Raford @ Rathgorgin)	2.368	48	14.000	0.122	0.111	0.353
17	35004 (Big Bridge @ Owenmore	2.385	14	19.435	0.130	0.242	2.110
18	25023 (Little Brosna @ Milltown)	2.392	59	12.000	0.165	0.045	0.679
19	29004 (Clarinbridge @ Clarinbrid	2.402	40	11.150	0.110	0.159	0.368
20	25027 (Ollatrim @ Gourdeen Bric	2.413	60	12.200	0.186	0.151	0.088
21							
22	Total		631				

WINFAP's initial selection did not require any of the rejected sites above to be removed. It is however notably different from that of the FSU, as the inclusion of the urbanised sites brings in

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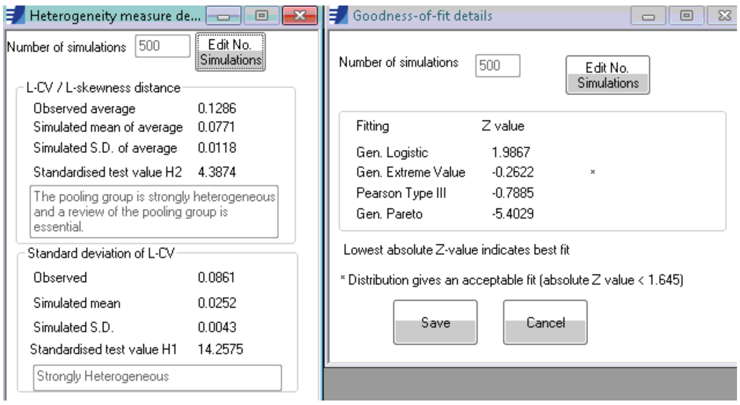
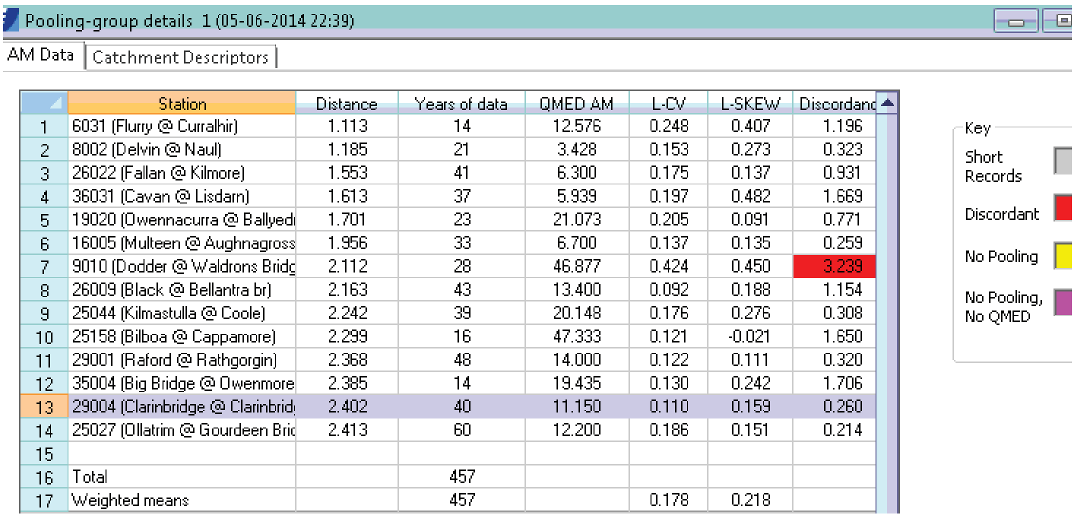
many more sites that are closer to the subject site in terms of their Area, annual average rainfall and floodplain extent. This resulted in two sites (29004, 25027) from the FSU selection not being included in the initial WINFAP pooling group – where this occurred, the FSU sites were added manually.

Note: FEH initially imported additional sites to make up 500 years of record, some of these have been removed, leaving the pooling group with 451years of record.After this process, the only additional site is 25023, Little Brosna. Also note that the order of sites differs slightly from those provided due to differences in the distance measures embedded in the FEH, versus those used in the FSU. The relative variances and weightings of the parameters used in the distance measure also have a slight impact on the order.

Testing of the heterogeneity of the pooling group indicates that there is a strong need to review and refine it.



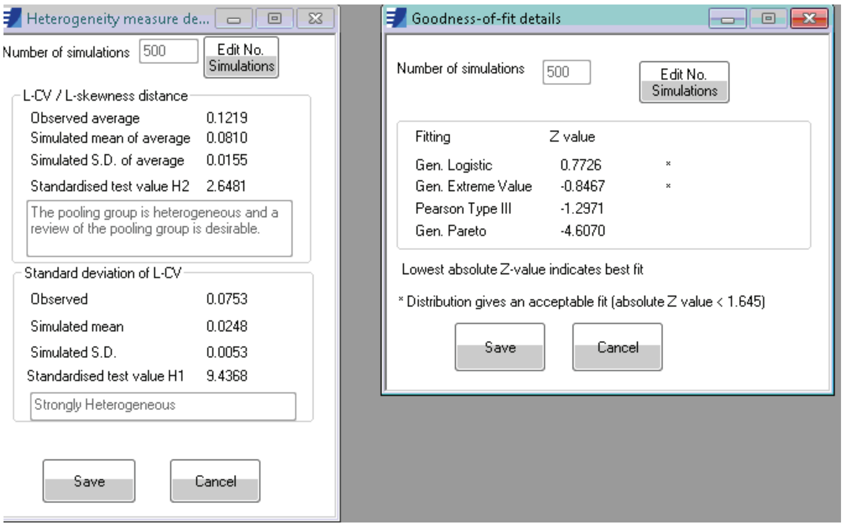
While few of the sites are obviously different from the main site, it is attempted to attain greater homogeneity by removing those sites not in the original FSU selection: 25040,10021,10022, 9002, 8005 and 25023. This reduces the record to 457yrs of record. The revised pooling group is shown below. While the discordancy of 9010 is notable, this is due to a genuine extreme event (Hurricane Charlie on the Dodder), and is retained.


Pooling-group details 1 (05-06-2014 22:39)

AM Data | Catchment Descriptors

	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordanc
1	6031 (Flurry @ Curralhir)	1.113	14	12.576	0.248	0.407	1.196
2	8002 (Delvin @ Naul)	1.185	21	3.428	0.153	0.273	0.323
3	26022 (Fallan @ Kilmore)	1.553	41	6.300	0.175	0.137	0.931
4	36031 (Cavan @ Lisdarn)	1.613	37	5.939	0.197	0.482	1.669
5	19020 (Owennacurra @ Ballyed	1.701	23	21.073	0.205	0.091	0.771
6	16005 (Multeen @ Aughnagross	1.956	33	6.700	0.137	0.135	0.259
7	9010 (Dodder @ Waldrons Bridg	2.112	28	46.877	0.424	0.450	3.239
8	26009 (Black @ Bellantra br)	2.163	43	13.400	0.092	0.188	1.154
9	25044 (Kilmastulla @ Coole)	2.242	39	20.148	0.176	0.276	0.308
10	25158 (Bilboa @ Cappamore)	2.299	16	47.333	0.121	-0.021	1.650
11	29001 (Raford @ Rathgorgin)	2.368	48	14.000	0.122	0.111	0.320
12	35004 (Big Bridge @ Owenmore	2.385	14	19.435	0.130	0.242	1.706
13	29004 (Clarinbridge @ Clarinbri	2.402	40	11.150	0.110	0.159	0.260
14	25027 (Ollatrim @ Gourdeen Bri	2.413	60	12.200	0.186	0.151	0.214
15							
16	Total		457				
17	Weighted means		457		0.178	0.218	

Key: Short Records; Discordant; No Pooling; No Pooling, No QMED



The remaining heterogeneity of the pooling group is thought to be because of the contrast between urbanised and rural sites. Goodness of fit measures suggest that the Generalised Extreme Variable (GEV) and Generalised Logistic distributions give the best fit to the data; of these, FSU recommends use of the GEV

The resulting growth curve fittings are as follows:

Return period (years)	GEV Growth factor
2	1.00
5	1.24
10	1.42
25	1.70
50	1.94
100	2.21
200	2.51
500	2.98

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HEP03B:

	HEP_03B Pooling group – URBAN SITES RETAINED		
Rank in FSU	Rank in FEH	STATIONNR	LOCATION
1	3	25040	ROSCREA
2	2	10022	CARRICKMINES
3	7	6031	CURRALHIR
4	10	19020	BALLYEDMOND
5	11	16005	AUGHNAGROSS
6	4	10021	COMMONS ROAD
7	8	26022	KILMORE
8	14	25044	COOLE
9	5	8002	NAUL
10	1	8005	KINSALEY HALL
11	13	26009	BELLANTRA BR.
12	16	29001	RATHGORGIN
13	12	9010	WALDRONS BRIDGE
14	6	9002	LUCAN
15	-	29004	CLARINBRIDGE
16	15	25158	CAPPAMORE
17	9	36031	LISDARN

WINFAP's initial selection

Pooling-group details 3 (05-06-2014 23:10)

AM Data | Catchment Descriptors

	Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordanc
1	8005 (Sluice @ Kinsaley Hall)	1.055	22	2.750	0.367	0.316	0.942
2	10022 (Cabinteely @ Carrickmin	1.264	17	3.853	0.232	0.085	0.638
3	25040 (Bunow @ Roscrea)	1.957	26	4.028	0.145	0.224	0.382
4	10021 (Shanganagh @ Commor	2.260	29	8.532	0.245	0.219	0.542
5	8002 (Delvin @ Naul)	2.388	21	3.428	0.153	0.273	0.409
6	9002 (Griffeen @ Lucan)	2.409	21	5.766	0.413	0.336	1.906
7	6031 (Flurry @ Curralhir)	2.589	14	12.576	0.248	0.407	2.114
8	26022 (Fallan @ Kilmore)	3.035	41	6.300	0.175	0.137	0.721
9	36031 (Cavan @ Lisdarn)	3.087	37	5.939	0.197	0.482	1.963
10	19020 (Owennacurra @ Ballyedi	3.220	23	21.073	0.205	0.091	0.427
11	16005 (Multeen @ Aughnagross	3.454	33	6.700	0.137	0.135	0.658
12	9010 (Dodder @ Waldrons Bridg	3.611	28	46.877	0.424	0.450	1.671
13	26009 (Black @ Bellantra br)	3.662	43	13.400	0.092	0.188	1.147
14	25044 (Kilmastulla @ Coole)	3.693	39	20.148	0.176	0.276	0.317
15	25158 (Bilboa @ Cappamore)	3.801	16	47.333	0.121	-0.021	2.231
16	29001 (Raford @ Rathgorgin)	3.880	48	14.000	0.122	0.111	0.333
17	25023 (Little Brosna @ Milltown)	3.891	59	12.000	0.165	0.045	0.597
18							
19	Total		517				
20	Weighted means				0.218	0.219	

This selection is much closer to the FSU Pooling Group, in terms of both ranking, and members. The main difference is the use of 25023 instead of 29004, although as both are low ranking sites, the influence of this would be low.

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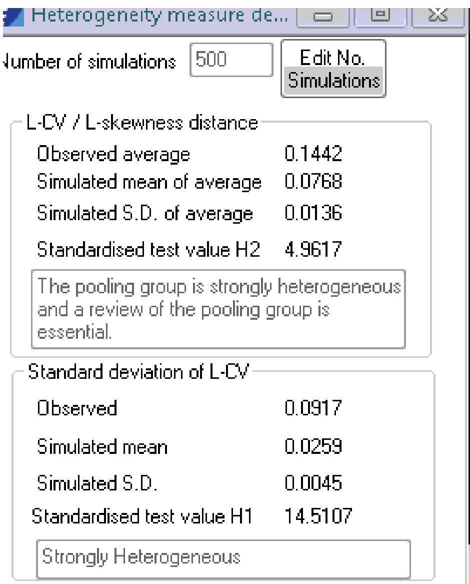

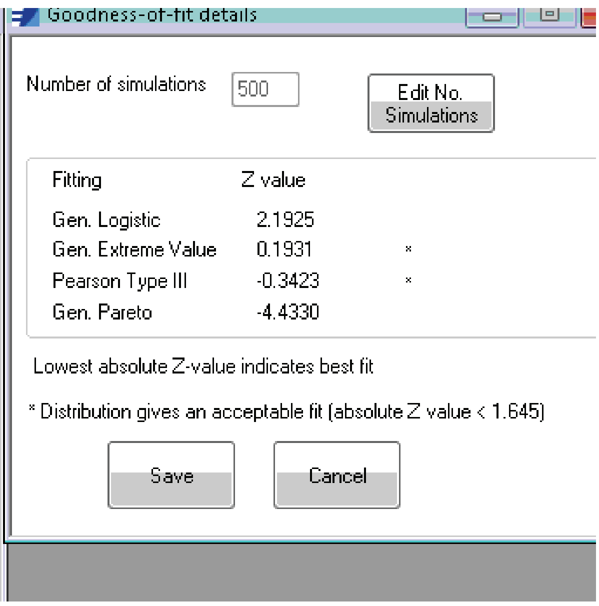

Testing of the heterogeneity of the pooling group indicates that the need to review the pooling group is essential, however the limited quality of the available gauges of hydrological similarity suggests that further refinement of the pooling group will not improve the estimate of the growth curve. Goodness of fit measures suggest that the Generalised Extreme Variable (GEV) and Pearson Type III distributions give the best fit to the data; of these, FSU recommends use of the GEV.

The resulting growth curve fittings are as follows:

HEP003B Growth Curve	
Return period (years)	**Growth factor**
2	1
5	1.34
10	1.59
25	1.95
50	2.24
100	2.56
200	2.92
500	3.43

Job title	Douglas	Job number	Sheet number	Revision
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Summary of growth curves

	Growth factors			
Return period (years)	**001A**	**001B**	**003A**	**003B**
2	1	1	1.00	1
5	1.21	1.23	1.24	1.34
10	1.36	1.39	1.42	1.59
25	1.57	1.60	1.70	1.95
50	1.74	1.77	1.94	2.24
100	1.92	1.93	2.21	2.56
200	2.11	2.11	2.51	2.92
500	2.38	2.34	2.98	3.43

It can be seen that, while 1A and 1B exhibit markedly similar growth curves when only rural sites are used in the growth curve, the influence of urbanised sites within the growth curve can be to increase floods by a factor of 1.15-1.33 in the 100yr event. This is contrary to the conventionally predicted influence of urbanisation, which is that it should flatten the growth curve, not steepen it (this is due to the lack of storage in the system,so the growth curve is much closer related to the rainfall DDF) .

Given the magnitude of the difference, clarity should be sought from the OPW re the applicability of using urbanised sites within pooling groups. If no further clarity can be obtained, the more conservative result should be adopted.