ARUP

Cork County Council

Midleton Flood Relief Scheme

Hydrology Report

Reference: REP/1

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Contents

Tables

Figures

Appendices

1. Introduction

1.1 Context

Midleton has a long history of flooding. In recent years, the most notable flood events occurred in November 2000, October 2004, June 2012, July 2013, January 2014, February 2014, October 2014, December 2015, January 2016 and December 2018.

Following recommendations contained within the Lee Catchment Flood Risk Assessment and Management (CFRAM) Study and following the December 2015 flood event which had a significant impact on the town, Arup was commissioned by Cork County Council (CCC) to assess the flood risk within the Owenacurra River Catchment and to develop a flood relief scheme to manage the risk.

The project consists of five stages:

- Stage 1 – Development of a number of flood defence options and the identification of a preferred Scheme;
- Stage 2 – Outline Design and Public Exhibition, or Planning, including an Appropriate Assessment (AA), Environmental Impact Statement (EIS) and Final Flood Risk Management Plan;
- Stage 3 – Detailed design, confirmation and tender;
- Stage 4 – Construction;
- Stage 5 – Handover of works.

This report presents the hydrological analysis undertaken as part of the study. The report is to be read in parallel with the other key reports produced as part of Stage I of the project:

- Midleton FRS Hydraulics Report, Arup (October 2022)
- Summary of Hydrogeological Assessment of Flood Cells, 1, 5, 6 & 7, Arup (February 2019)
- Midleton FRS Constraints Report, Arup (August 2017)

1.2 Scope

The scope of the hydrological study is as follows:

- Review the hydrological analysis undertaken for the Lee CFRAM Study;
- Review the available records of historic flooding in the study area in order to inform the selection of design flows;
- Review and update the stage-discharge relationship at Ballyedmond station (19020);
- Review data recordings of IDL gauges at Pitch & Putt and Shanty Bridge;
- Estimate flood flows and hydrograph shapes at key locations in the study area for the design flood events using a range of methodologies including the Flood Studies Report, Flood Studies Update etc.;
- Produce a hydrology report which presents the key findings of the study.

1.3 Overview of the Report

An overview of the report is presented in the following table.

Table 1.1: Report overview

Chapter Number	Chapter Title	Description
1	Introduction	Provides an introduction to the study
2	Catchment Description	Provides an overview of the Owenacurra and Dungourney catchments
3	Data Review	Reviews the various datasets used to inform the hydrological analysis
4	Analysis of Hydrometric Data	Details the analysis undertaken on the hydrometric data
5	Ballyedmond Gauge (19020) Rating Review	Presents the findings of the hydrometric review of the Ballyedmond gauge
6	Estimation of the Index Flood	Details the index flood calculations
7	Flood Frequency Analysis	Details the singe site and pooling group analysis calculations
8	Flow Hydrograph Analysis	Outlines the methodology used to derive the hydrograph shapes
9	Design Tidal Water Levels	Presents the tidal water levels for the study. Both calibration and design levels are considered.
10	Fluvial and Tidal Joint Probability	Presents the fluvial/tidal joint probability analysis.
11	Climate Change	Details the climate change allowance uplifts used as part of the study
12	Conclusion	Provides an overall conclusion to the study
Appendix A	National Flood Hazard Mapping report	Presents output from the OPW's historic flooding database for Midleton
Appendix B	Hydrology calculations	Presents the detailed hydrological estimation calculations for the study

2. Catchment Description

2.1 General

Midleton is located at the downstream end of the Owenacurra catchment in East Cork (Figure 2-1). The catchment has a total area of circa 158km^2 and is drained by two primary watercourses:

- Owenacurra River (catchment area of circa 106km^2);
- Dungourney River (catchment area of circa 53km^2).

The Dungourney meets with the Owenacurra at The Baby's Walk public park which is situated at the lower end of Main Street. Both the Owenacurra and the Dungourney are tidally influenced at their downstream end due to their connectivity and proximity to Cork Harbour as shown in Figure 2-2.

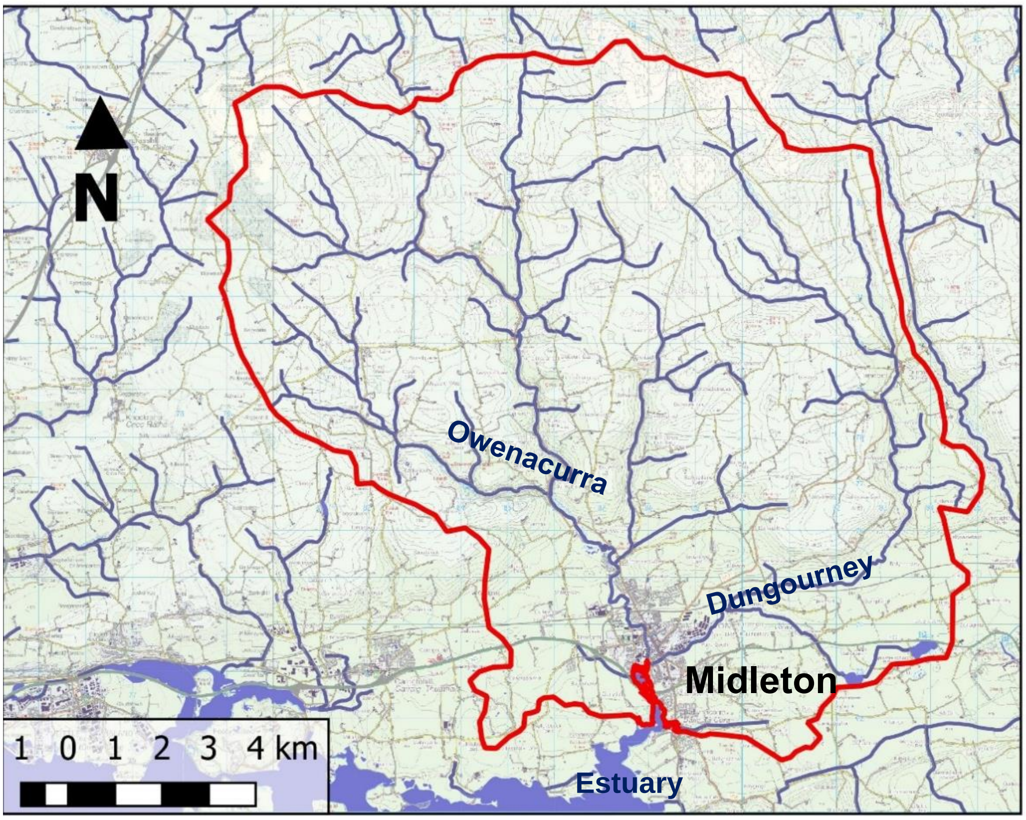

Figure 2-1: Owenacurra River Catchment

Two other minor watercourses are also relevant to the study:

- Water Rock Stream (catchment area of circa 6.23km^2);
- Ballinacurra River (catchment area of circa 2.75km^2).

The alignment of all the primary watercourses within the scheme area is presented in Figure 2-2.

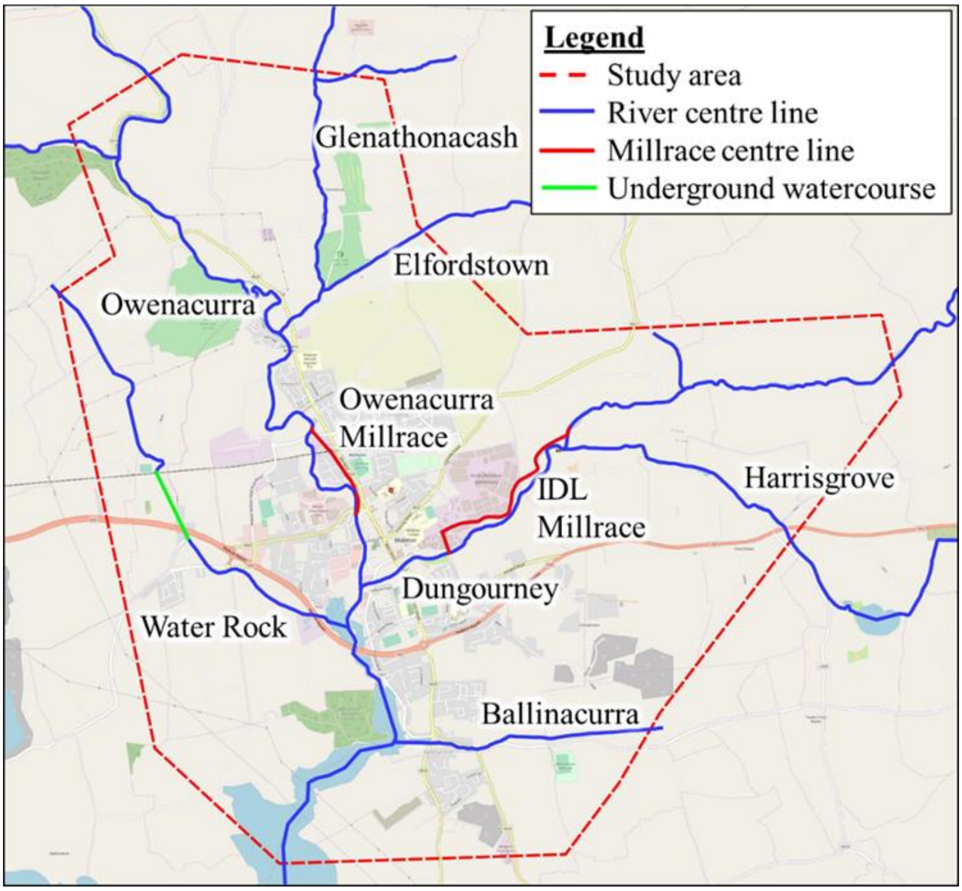

Figure 2-2: Scheme Area showing water courses (© Open Street Map)

2.2 Topography

Midleton lies in a circa 6km wide valley that runs in an East to West direction as shown in Figure 2-3.

Ground levels within the scheme area vary from circa 2mOD/2.5mOD in the town centre to circa 12mOD/13mOD in the Tir Cluain housing estate which is situated at the North of the town adjacent to the Owenacurra. The elevations of the upper reaches of the Dungourney and Owenacurra River catchments vary quite considerably from circa 30mOD to circa 200mOD.

Figure 2-3 presents a schematic of the topography of the Owenacurra Catchment.

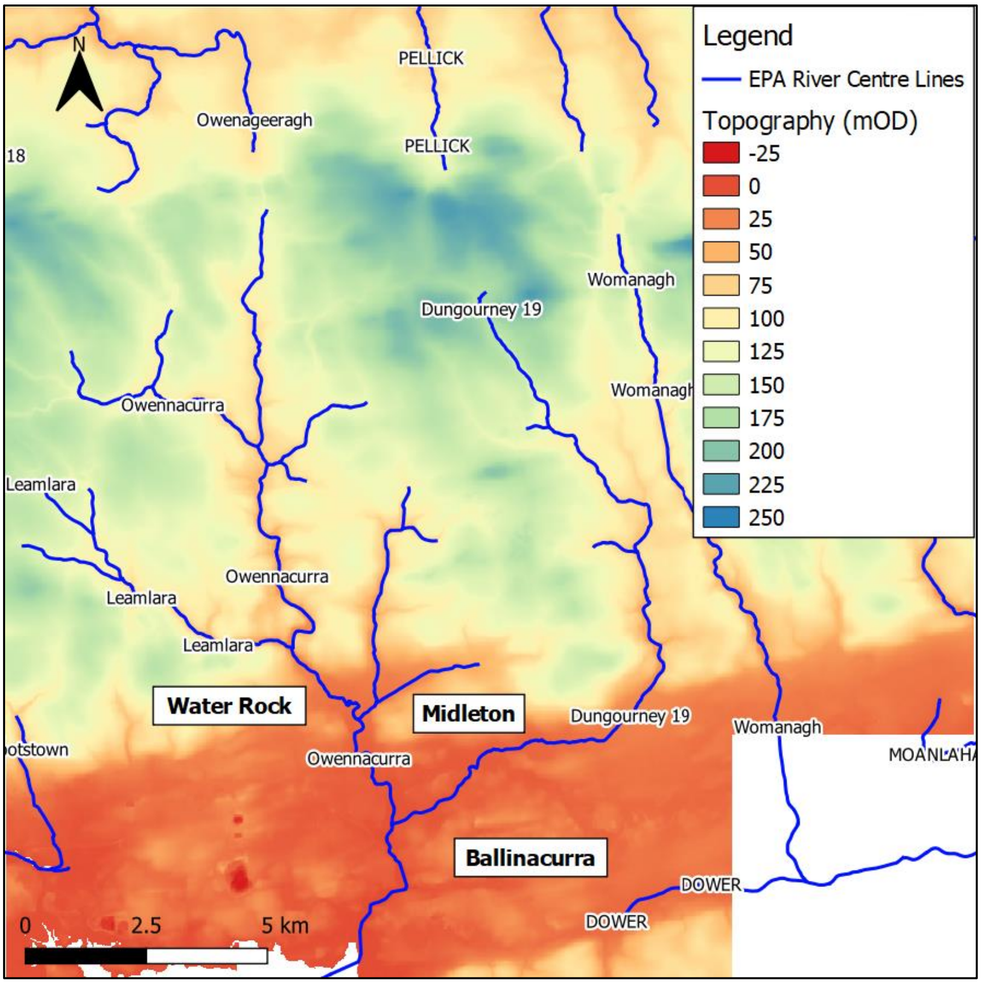

Figure 2-3: Topography of the Owenacurra River Catchment

2.3 Land Use

The majority of the Owenacurra River Catchment consists of rural and pasture land. The primary urbanised centre is Midleton. There are also a number of small villages located throughout the catchment such as Lisgoold, Dungourney Village and Leamlara. Figure 2-4 presents the location of each of the key urban areas.

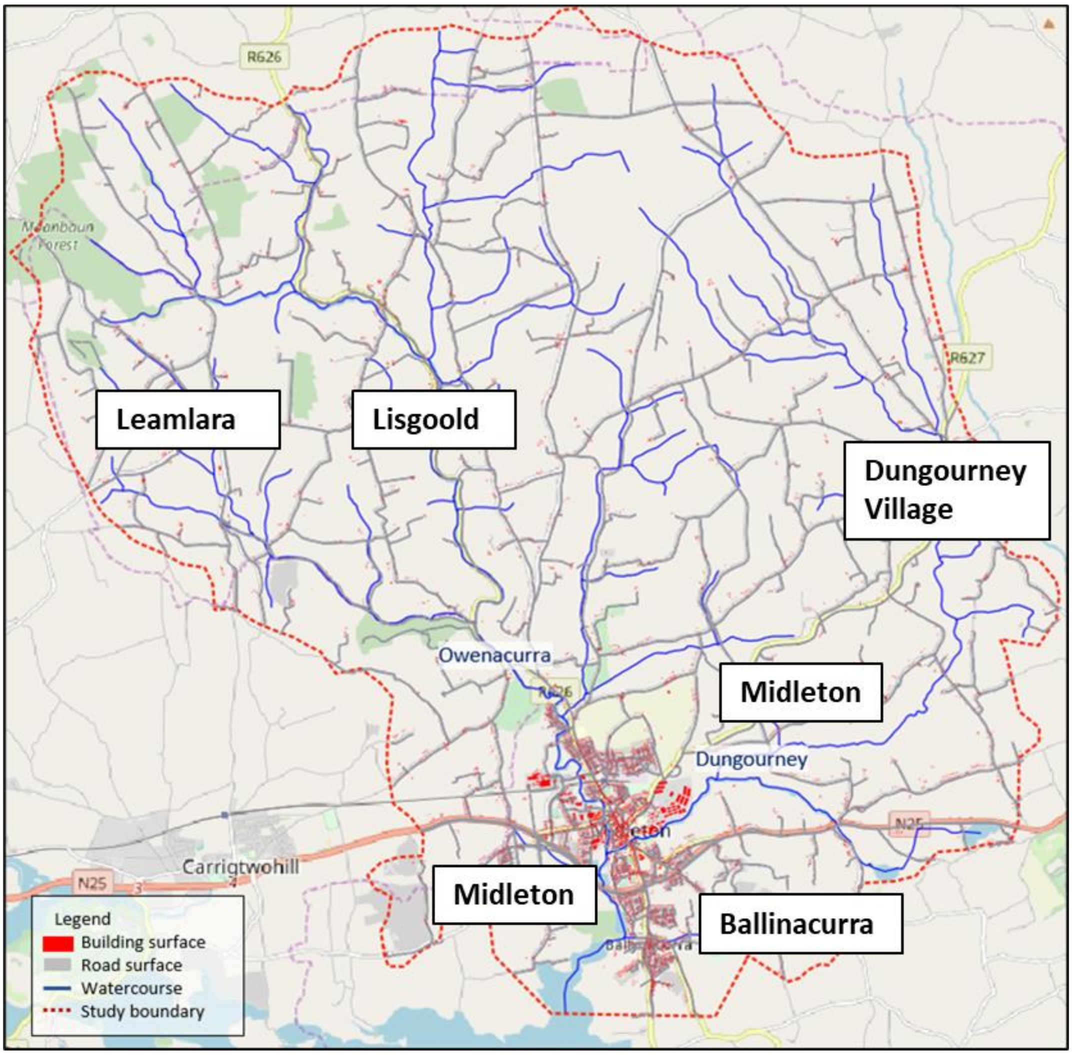

Figure 2-4: Urbanised Catchment Area (© Open Street Map)

2.4 Geology and Soils

The Geological Survey of Ireland (GSI) mapping for the catchment is presented in Figure 2-5. It can be seen from the map that the dominant rock types in the Owenacurra catchment consist of Sandstone and Limestone (Ballytrasna Formation), which covers most of the upper reaches of the Dungourney and Owenacurra River. The rock types of the lower reaches are also dominated by Sandstone and Limestone from a number of formations.

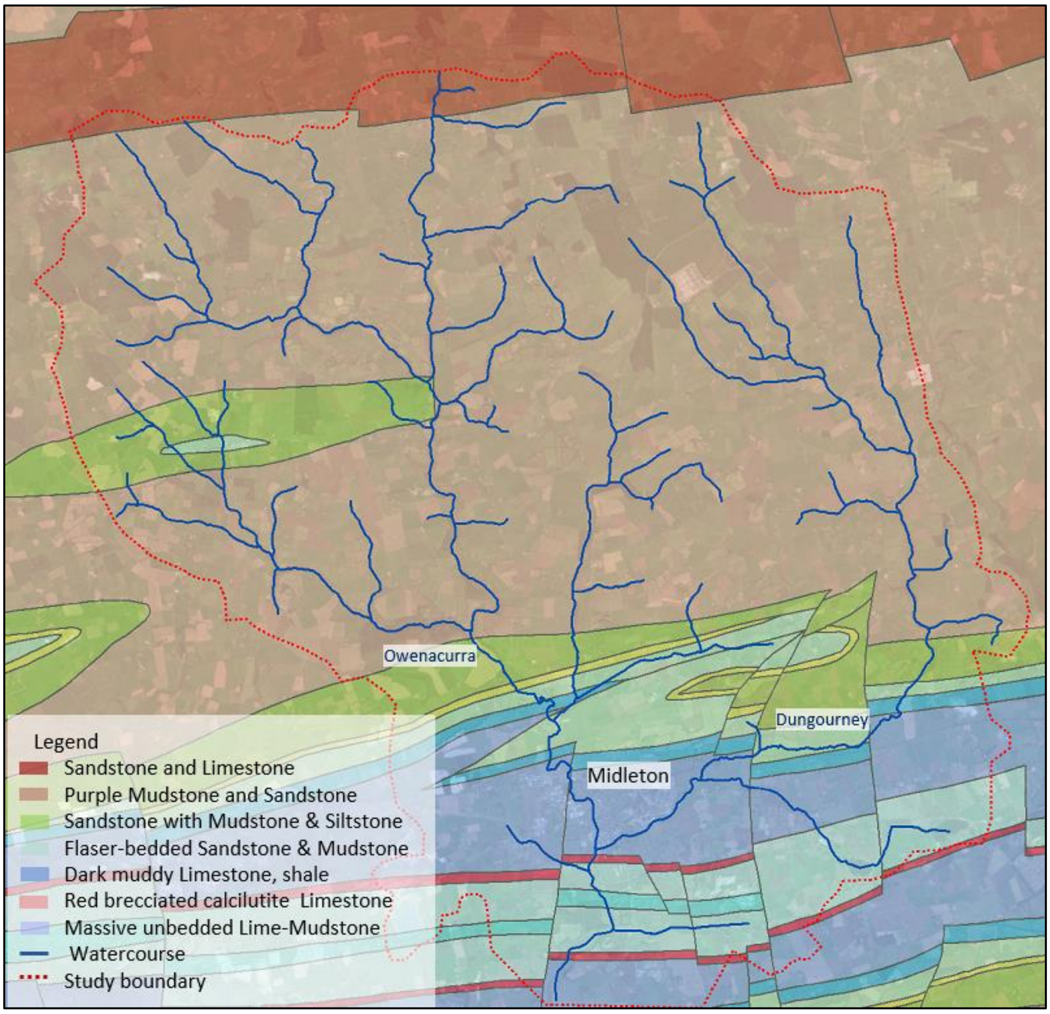

Figure 2-5: Bedrock Map (GSI)

The EPA/Teagasc Subsoils map classifies the subsoils of Ireland into 16 themes which has been derived using digital stereo photogrammetry supported by field work. The soil mapping for the catchment is presented in Figure 2-6 and indicates that the dominant soil type consists of Sandstone till. The dominant soil types in the vicinity of Midleton are made ground and Alluvium gravel.

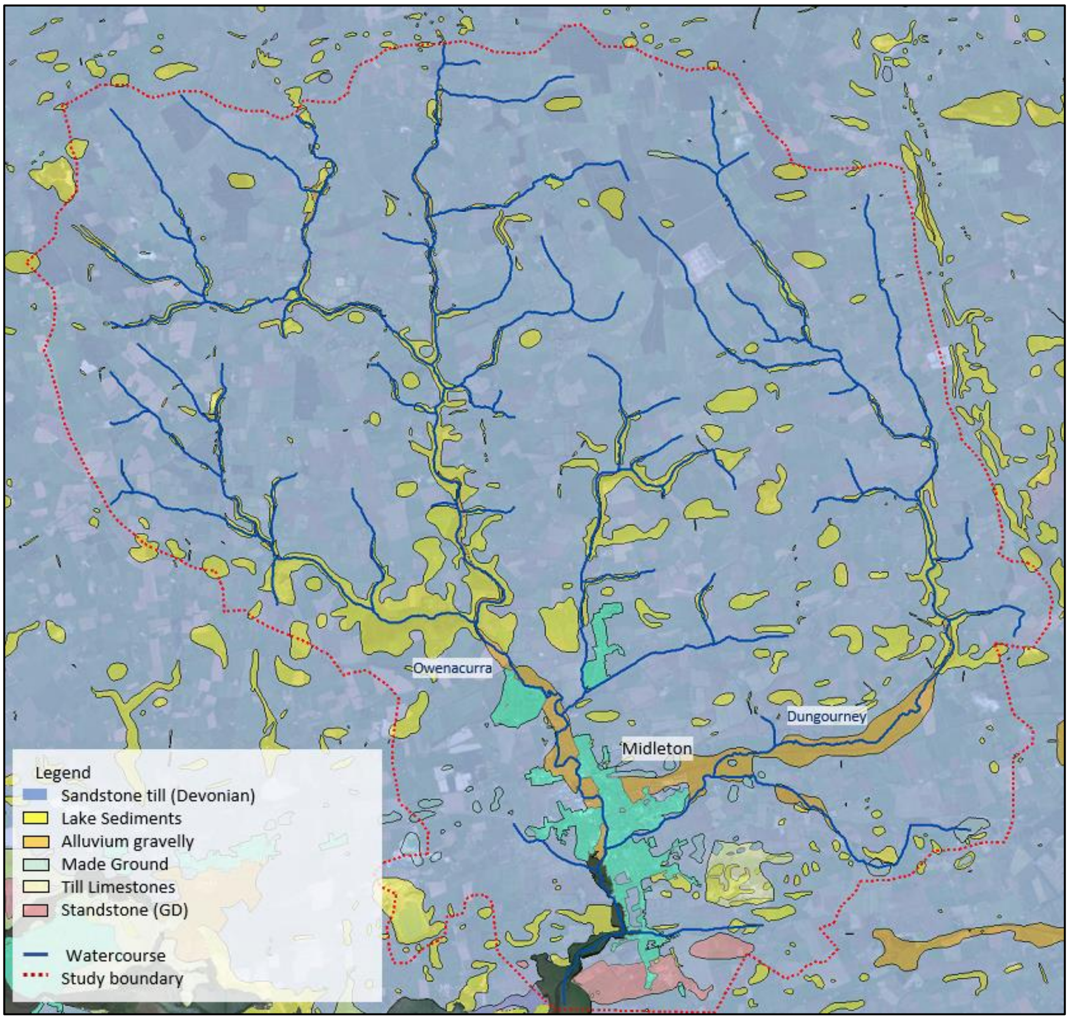

Figure 2-6: Soil Map (EPA/Teagasc)

2.5 Designated Sites

There are 42 designated areas, or areas proposed to be designated, for nature conservation within 15 km of the scheme Study area. These consist of:

- Three Special Areas of Conservation (SACs);
- Five Special Protection Areas (SPAs); and
- 34 proposed Natural Heritage Areas (pNHAs).

There are no Natural Heritage Areas located within 15 km of the study area.

3. Data Review

3.1 Review of Historical Events

3.1.1 National Flood Hazard Mapping Website

The OPW's national flood information portal (https://www.floodinfo.ie/) has collated records of historic flooding events throughout Ireland. Inspection of the website confirms that numerous flood events have occurred in Midleton in the past. A summary report is provided in Appendix A and a screengrab from the portal is presented in Figure 3-1.

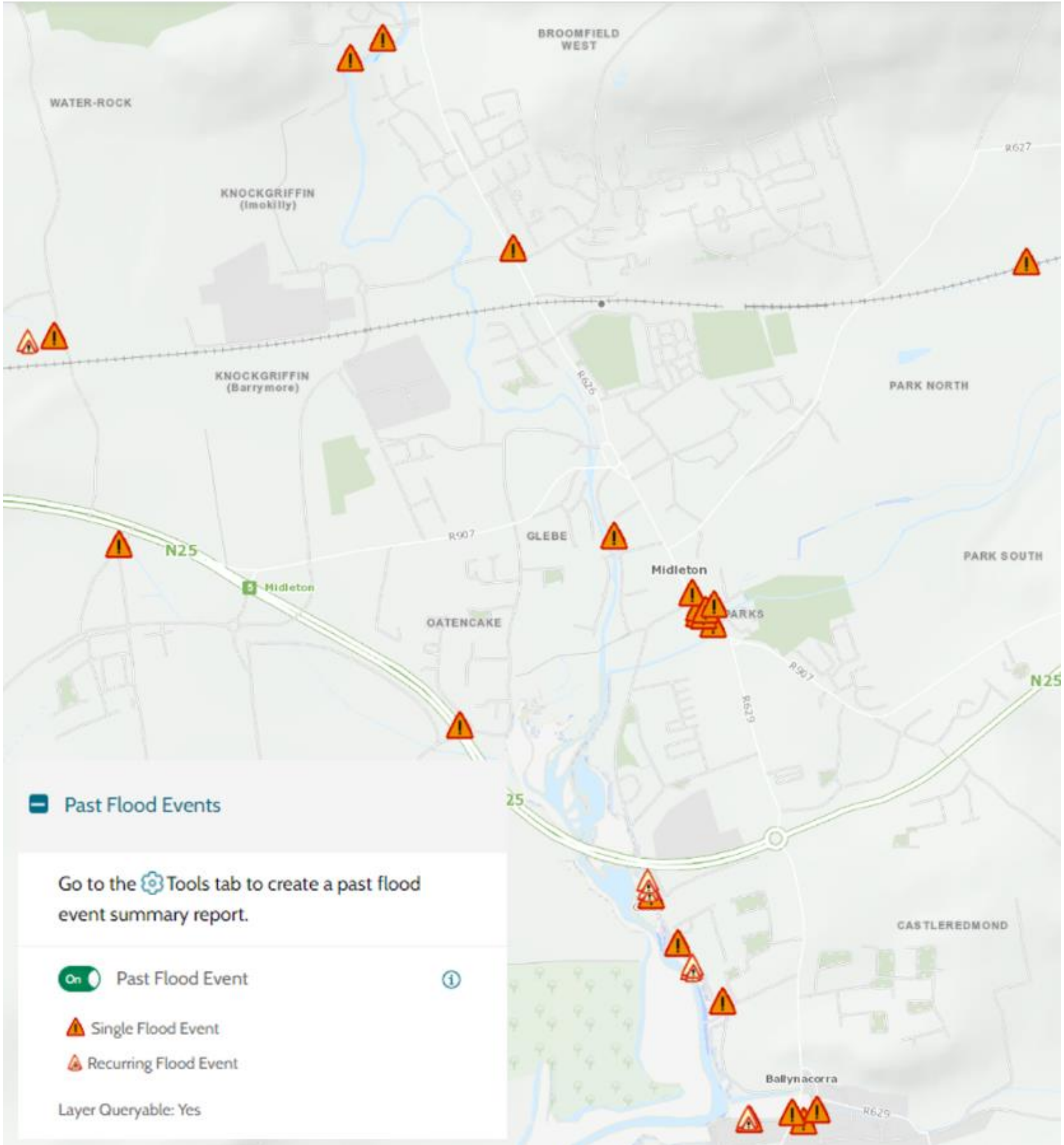

Figure 3-1: Extract from floodinfo.ie

3.1.2 Information Provided by CCC and OPW

Reports and other information on past flood events in the study area were supplied by CCC and the OPW and have also been considered as part of the study.

Further it is noted that anecdotal evidence from CCC staff suggests that the town centre of Midleton has experienced infrequent minor flooding in the past from backing-up/blockage of the drainage system at Lower Main Street, Youghal Road and St. Mary's Road.

3.1.3 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.

3.1.4 Summary of historic flooding

Table 3.1 presents a summary of the historic flood records at Midleton.

Table 3.1: Timeline of major flood events in the study area

Date of Flood Event	Mechanism	Areas Affected
February 1993	Fluvial	Water Rock
March 1995	Fluvial	Water Rock
November 2000	Fluvial	Water Rock, Bilburry Road, Bloomfield West
October 2004	Tidal	Bailick Road
May 2005	Tidal	Bailick Road
June 2012	Pluvial/ Tidal	14 residential and 14 commercial in areas of: Distillery Walk/Lower Main Street/Woodlands
July 2013	Pluvial	8 residential, 10 commercials in areas of: New Cork Road, Mill Road, Beechwood Estate, Youghal Road
Jan and Feb 2014	Tidal	Lower Main Street and Bailick Road
Oct 2014	Tidal	Bailick Road
Dec 2015-Jan 2016	Fluvial/ Groundwater	50 businesses and 20 houses in areas of Tir Cluain/ Willow Bank/ Mill Road/ Woodlands/ Riverside Walk /Lower Main Street/ Broderick Street/ Distillery Walk/ Coolbawn/ Riversfield Estate/ Lauriston/ Midleton Rugby Club/ IDL/ Water Rock
Dec 2018	Fluvial	Flooding of agricultural lands and local roads. No property flooding.

The following section of the report considers the key historic flood events in further detail.

November 2000

The CCC record of flooding from the event listed the inundated areas as Water Rock, Bilburry, and Bloomfield West.

October 2004

The Area Engineer outlined the areas impacted by the October 2004 event and noted that a number of these locations are at regular risk of flooding:

- Bailick Road, Midleton – Regular flooding resulting from periods of heavy rainfall. Flood ID 5193.
- The 96303 road floods on a regular basis which included October 2004. Flood ID 5194 & 5195.
- The Rostellan road flooded on October 2004 due to the extreme tides and wind direction. This mechanism occurs relatively infrequently. Flood ID 5196 & 5197.
- R630 at Whitegate was inundated during the October 2004. This is an infrequent mechanism of flooding. Flood ID 5199.

- Ballycotton pier flooded during the October 2004 event and is also at risk from regular high tides/wave overtopping. Flood ID 5200 & 5201.
- The East Ferry road (L3629) was also inundated during the event. Flood ID 5203.

June 2012

The flood event that occurred on 5th June 2012 impacted the Distillery Walk/Lower Main Street area of the town. The source of the flooding was described in the OPW Flood Event Report as "unusually heavy rainfall coinciding with high tide levels which would have prevented discharge from the surface water drainage system in some parts of the town."

The event report also states that the flooding *"was due to a very significant rainfall event which may have been exacerbated by the combined stormwater system being blocked or at capacity. Spring high tides may also have affected capacity of the stormwater system."*

14 residential and 14 commercial properties were impacted by the event.

The report also mentions that *"after discussions with residents, wave action caused by vehicles continuing to drive through flood may have increased severity of flooding in properties."*

The maximum flood depth was recorded as 350mm.

July 2013

Surface water sewers became overwhelmed during this event due to the intense rainfall. Combined sewers were also surcharged in the same area. The maximum flood depth was recorded as 150mm. 8 residential and 10 commercial properties in the town centre were impacted.

January 2014

The January 2014 tidal flood event impacted Bailick Road, The Baby's Walk and the junction of Distillery Road and Main Street. No properties were impacted by this flooding event.

Bailick Road was closed to traffic during the event. The OPW Flood Event Report stated that "*the river was at street level therefore there was no positive outfall from storm water drainage system*."

The maximum flood depth was recorded as 450mm at Bailick Road.

February 2014

The tidal flood event of February 2014 event occurred at high tide on the 3rd and 5th February 2014. The areas affected were Lower Main Street and Bailick Road. No properties were impacted.

The OPW Flood Event Report stated that the tidal event was caused *"by a combination of south-easterly winds and high tides."* As a result, the drains from Distillery Walk were backed up from the Dungourney River and water came out of manholes causing water to flow towards Main Street.

The Owenacurra also burst its banks at Kennedy Park and flowed onto Broderick Street and onto Main Street. Bailick Road was closed to traffic during the event. The report states that *"Access was prevented to Ballinacurra No.1 Pumping Station during the flooding event."*

The maximum flood depth was recorded as 450mm at Bailick Road.

October 2014

The tidal flood event of October 2014 impacted Bailick Road.

Winter 2015/2016

A detailed Flood Review of the Winter 2015-2016 flood event was undertaken by Arup in the immediate aftermath of the event. The report states that the *"two areas worst affected in Cork were Midleton and Bandon with flooding to a significant number of properties.*

Heavy rainfall in the days leading up to the event elevated the groundwater levels across the catchment until the system became saturated in some areas. The high groundwater levels resulted in a higher rate of runoff from the surrounding lands in the lead up to the event. Analysis of the cumulative rainfall suggests that monthly rainfall was equivalent to a return period of circa 1 in 200 years. The flood event commenced at the end of December and lasted until the 2nd January 2016.

The reader is referred to the hydraulics report for a detailed description of the event and its impact on Midleton.

December 2018

The December 2018 event was a fluvial event that impacted a number of agricultural lands and local roads. No properties were inundated during the event. The peak flow recorded at the Ballyedmond was circa 27.5m^3/s, which is marginally above the Qmed.

3.2 Review of Previous Studies

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 Owenacurra and Dungourney River catchments.

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 https://www.floodinfo.ie/.

Of particular importance in the context of this study is the analysis of the flood risk and possible options in Midleton. The CFRAM recommended the following options:

- Fluvial and tidal forecasting system, combined with a targeted public awareness and education campaign and individual property protection/flood proofing; and
- Permanent flood walls/sea walls/revetments/embankments (to manage both tidal and fluvial risk).

These options will be reviewed as part of the Optioneering which is to be undertaken as part of Stage I of the study.

3.3 Groundwater Assessment

Groundwater flooding was a known mechanism of flooding during the Winter 2015/2016 event and affected a number of areas in Midleton. The scope of the Midleton FRS therefore requires a detailed assessment of groundwater flood risk to be undertaken out. The interaction of the groundwater with the river flow is therefore an important consideration.

As part of the study Arup therefore arranged for extensive site investigation to be carried out in order to support the hydrogeological analysis. This work consisted of geophysical investigation, intrusive ground investigation combined, water level monitoring and tracer testing. This data collection is outlined in the following section of the report.

3.3.1 Overview of Site Investigation

This investigation was carried out in five phases:

Phase 1: Geophysical investigation comprised seismic survey along seven survey lines of 4,200m in total length and electrical resistivity tomography (ERT) along sections of the seven survey lines covering a total length of 2,100m (Apex, 2017). The purpose of this investigation was to establish the width, depth and extent of the paleochannel between rock valleys, depth to rock head, type and thickness of overburden, weathered and fractured zone and the presence of any voids or cavities.

Phase 2-5: Intrusive ground investigation (PGL, 2018). This works comprised cable percussion and rotary boreholes (24 boreholes), the installation of river water and groundwater monitoring installations (4 and 13 installations respectively). Long term digital data loggers fitted in 4 of the river monitoring installations and 9 of the groundwater monitoring installations.

Permeability testing of the sand and gravel aquifer was completed with rising and falling head tests and one pumping test. Groundwater level monitoring continued until January 2019.

Separate to the Hydrogeological Site Investigation, a LiDAR survey was completed for the Midleton Flood Relief Scheme and the Digital Terrain Model (DTM) created informed the hydrogeological assessments.

3.3.2 Findings of the hydrogeological assessment

This section presents a summary of the findings of the hydrogeological assessment. The study divided Midleton into different flood cells as indicated in on the following map.

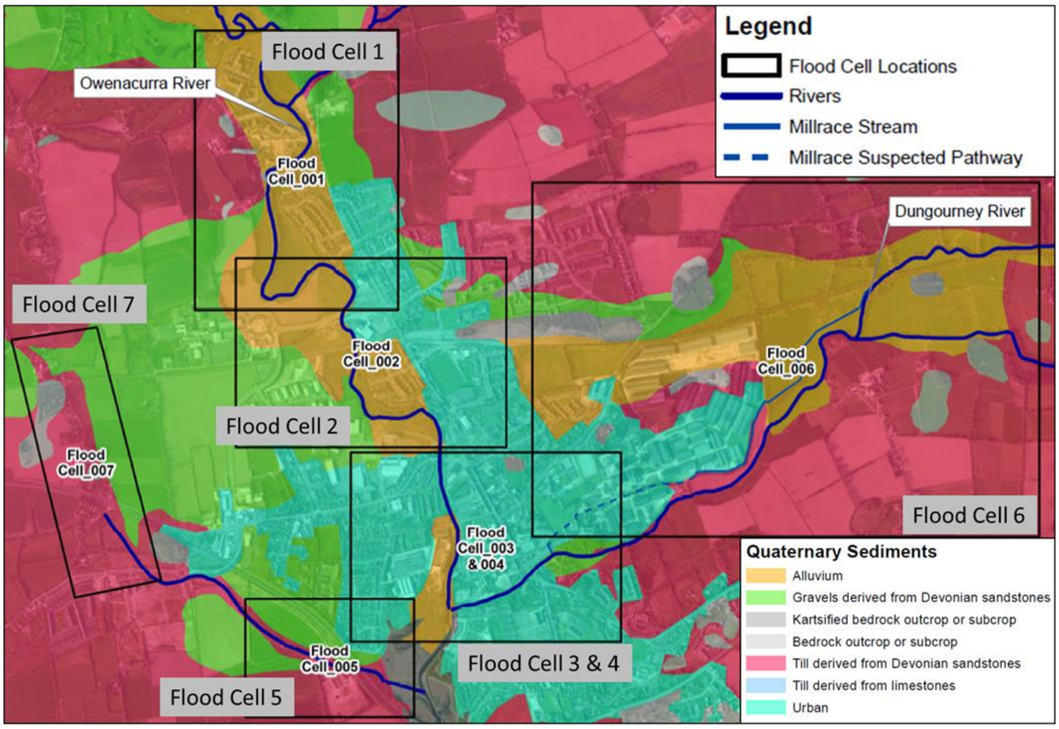

Figure 3-2: Flood cells

The conclusions of the assessment for the individual flood cells is summarised as:

3.3.3 Flood Cell 2, 3 and 4

There is a negligible contribution from groundwater flooding in these three flood cells due to the absence of any historic record of groundwater flooding in these areas.

3.3.4 Flood Cell 1

The results of this assessment concluded that the groundwater contribution to the Owenacurra River is negligible. Additional inflows to the river from groundwater sources is therefore not required.

3.3.5 Flood Cell 5 and 7

The results of this assessment concluded that the groundwater contribution to both the Owenacurra River and the Water Rock Stream is negligible. Additional inflows to the river from groundwater sources is therefore not required.

3.3.6 Flood Cell 6

Analysis of the river water level and groundwater monitoring data collected in Flood Cell 6 indicate that the Dungourney River loses water to the gravel and limestone aquifers in this area. The follow key points highlight the groundwater-surface water interactions:

The hydrogeological conceptual model highlights that river is in hydraulic connection with the gravel aquifer and discharges water into the aquifer during peak flow conditions. The limestone aquifer is semi-confined with groundwater levels that are lower than in the overlying gravel aquifer and the river.

The groundwater elevation in both the gravels and limestone aquifers are consistently below that of the river water level, indicating that the river is losing flow to the gravel aquifer, rather than the reverse.

There is a time lag from when the maximum water level occurs in the river, followed by the maximum that occurs in the gravels or limestone demonstrating the aquifer responding recharge which may be from the river.

The response in groundwater level in the gravel aquifer dampens with distance from the river and also vertically which demonstrates the influence of aquifer storage effects as water travels from the river through the aquifer.

These factors are of importance as they indicate that the groundwater is not a contributing factor to high water levels seen in the river, but rather the Dungourney River is losing water to the aquifer, even during high rainfall events.

The groundwater is flowing from east to west through the Lauriston Mews/Midleton Rugby Club study area, as is demonstrated by the ripple effect of peak water levels emanating from the Dungourney River towards the Owenacurra River and the gradient observed across groundwater level monitoring wells.

As groundwater does not contribute to high water levels in the Dungourney River in this area the hydraulic model has not included any groundwater source discharges. Neither has the model included hydraulic sinks to account for the impact of the Dungourney River losing water to the aquifer. Our approach is therefore conservative as the volume of water that is lost during extreme events is assumed to be contained within the watercourse and floodplain.

For further information and detailed findings of, please refer to the GW Assessment Report (Arup, January 2019).

4. Analysis of Hydrometric Data

4.1 Rainfall Data

The Met Éireann rain gauges most relevant to the study are at Roches Point, Cork Airport and Moore Park as shown in Figure 4-1 below. It is noted that each of these gauges are located circa 20km/30km from Midleton.

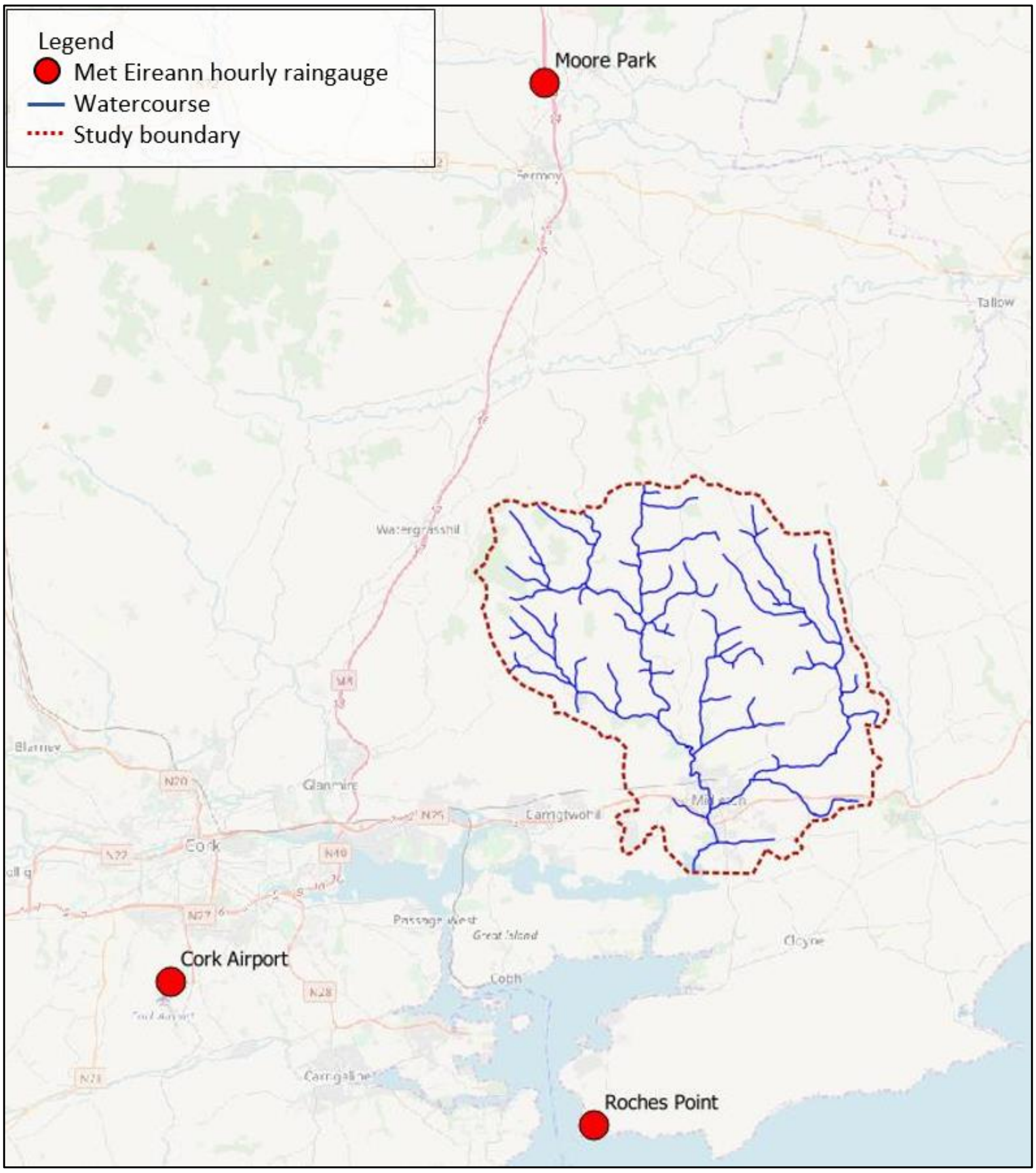

Figure 4-1: Met Eireann Rain Gauge Locations

CCC also installed a tipping bucket rain gauge at the site of the WwTP pumping station in February 2018. Data from the gauge has not however been used as part of the analysis due the short length of record available when the hydrological assessment was being undertaken.

Data from the gauge will however be used for future hydrological analysis including the assessment of any significant flood events that may occur over the duration of the project. Data from the gauge will also inform the Flood Studies Update (FSU) national rainfall datasets.

4.2 River Gauge Data

There are a number of active/historic hydrometric gauges in the scheme area:

- Ballyedmond Gauge (19020) – operated by the EPA;

- Dungourney River gauge (19038) – operated by the EPA;
- Three unnumbered gauges on the Dungourney River operated by Irish Distillers Ltd (IDL).

The locations of the Hydrometric Stations are indicated on Figure 4-2 and are listed in Table 4.1.

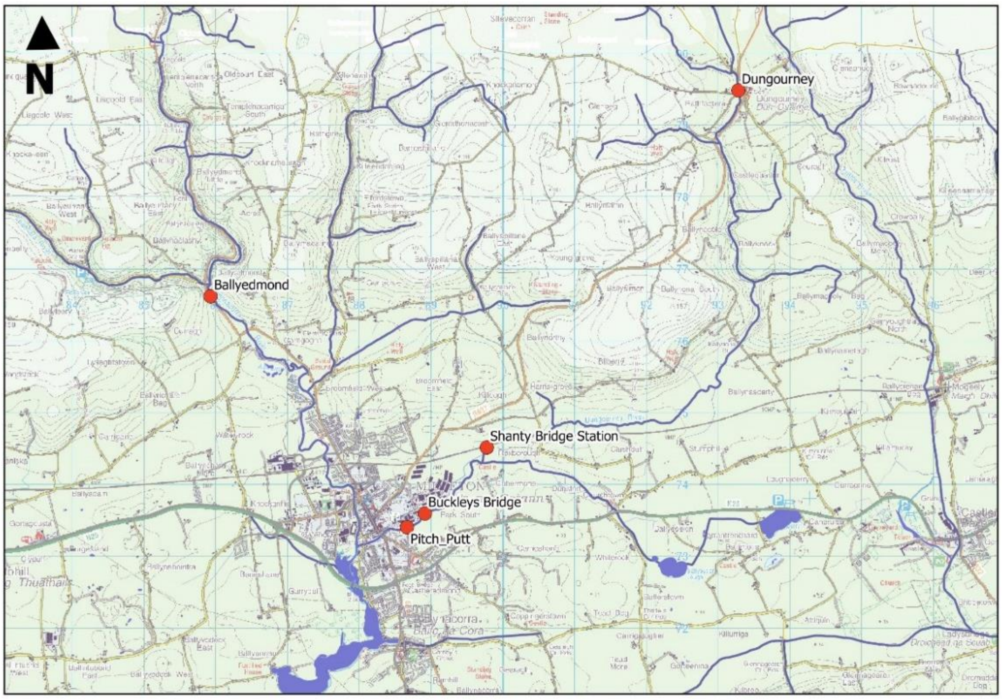

Figure 4-2: Location plan of river gauges

Table 4.1: Details of Hydrometric Stations

Station	Ref	Type	Easting	Northing	Waterbody	Responsible Authority	Active
Ballyedmond	19020	Recorder	185923	76618	Owenacurra	EPA	Yes
Dungourney	19038	Staff Only	193284	79487	Dungourney	EPA	No
Shanty Bridge	NA	Recorder	189766	74512	Dungourney	IDL	No
Buckley's Bridge	NA	Recorder	188912	73588	Dungourney	IDL	No
Pitch & Putt	NA	Recorder	188662	73398	Dungourney	IDL	No

The following table presents the details on the gauges.

Table 4.2: Summary of Gauging Stations

Gauge No.	Gauge Name	Time Period	Significant Gaps (>30 days)	Comments
19020	Ballyedmond	Jun 1977 – Present	Dec 2004 - Apr 2005 July 2005 - Sep 2005 Mar 2009 - Apr 2009 Apr 2010 - July 2010	37 years of data record
19038	Dungourney	Mar 1991 - Jul 2011	N/s	Staff only gauge

Gauge No.	Gauge Name	Time Period	Significant Gaps (>30 days)	Comments
19005	Buckley's Bridge	Sept 1980 - Apr 1986	None	6 years data record
N/A	IDL - Pitch and Putt	Jan 2014 - Jan 2017	Jan 2014 - Dec 2014	2 years data record
N/A	IDL – Shanty Bridge	Aug 2015 – Jan 2016	None	Only 4 months of data available

4.2.1 River Gauge Data Review

Dungourney Gauge

The Dungourney gauge is a staff-only gauge and is remote from Midleton Town. It has therefore not been considered as part of the hydrological flow estimation in the study.

IDL/Buckley's Bridge

There is six years of Amax data available for the Buckley's Bridge gauge which was operational from September 1980 to April 1986. This gauge was located circa 300m upstream from the Pitch & Putt gauges which were operated by the IDL from 2014 - 2017. Data from the IDL and Buckley's Bridge do not therefore overlap in time.

Data from the three gauges was investigated in order to determine if it was suitable for use as part of the Qmed estimation for the Dungourney River. Following this review the data was not deemed to be suitable and was therefore discarded. The justification for this approach is given as:

- There is a large variability in the flow estimates from both of the IDL gauges for the overlapping period and the quality of the data from both gauges is questionable;
- Only four months of data is available from the Shanty Bridge which is too short to assist in the hydrological flow estimation;
- The Buckley's Bridge gauge was decommissioned over 30 year ago and changes local to the gauge have occurred which impact on the hydraulics and hence the QH relationship.

Ballyedmond Gauge

The Ballyedmond gauge was installed in June 1977 and is currently active. Data from the gauge has been deemed suitable for use in the study.

The gauge was offline for a number of periods as listed in Table 4.2. The most significant of these periods was from 2014 to April 2017 which includes the December 2015 event. The Annual Maximum data for these missing years has therefore been derived as part of the study using the FSSR16 methodology (refer to Section 6.3.1).

Conclusions

Having reviewed the various gauged data in detail, only data from the Ballyedmond gauge is found to be of sufficient length and quality to inform the hydrological flow estimation for this study. A detailed rating review of this gauge has therefore been undertaken and the findings of the analysis are presented in the next Section of the report.

4.3 Tidal Gauges

Two water level recorded gauges were installed by the OPW in the Ballinacurra estuary in March 2022 in order to record tidal water levels. The gauges are referred to as Bailick Road U/S (19165) and Bailick Road D/S (19166). The location of both gauges is indicated in Figure 4-3.

Data from the tidal gauges has been used to inform on the optioneering for the tidally dominated reach and is discussed in the Options Report.

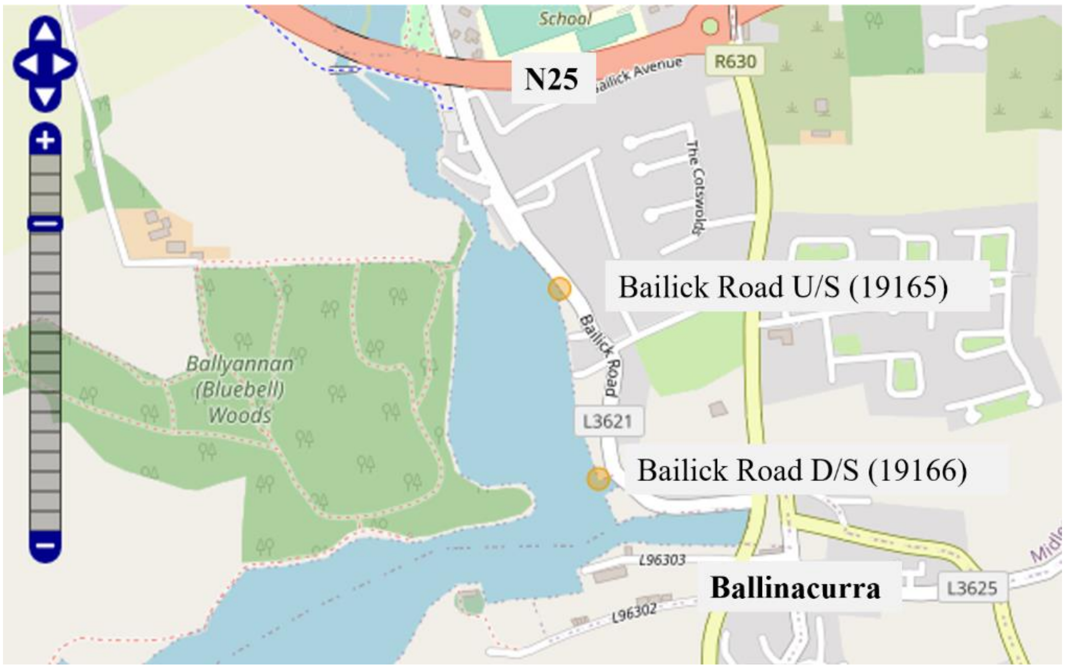

Figure 4-3: Tidal Gauge Locations (orange circles)

5. Ballyedmond Gauge (19020) Rating Review

5.1 Introduction

A rating review of the Ballyedmond gauge (Station No: 19020) has been undertaken as part of the study. The objective of the review was to revise and update the existing rating curve and to extend it to the highest recorded water level at the gauge. The revised rating curve will then be used to calculate the Qmed value for the gauge with an improved level of confidence.

The following steps were undertaken as part of the review:

- Collate and review the spot gaugings collected at the gauge;
- Development of a detailed hydraulic model in order to simulate high flows through the reach (i.e. flow in excess of the highest spot gauging);
- Revise the rating curve based on the spot gaugings and the results of the hydraulic model;
- Comparison of the revised rating against the previous rating curves (i.e. Lee CFRAM, EPA) for the gauge.

5.2 Ballyedmond Gauge

The Ballyedmond gauge is located circa 2.8km upstream of Midleton on the Owenacurra River and circa 50m downstream of the confluence of the Leamlara River and Owenacurra River (coordinates 185923E 76618N). Figure 5-1 presents an image of the gauge which was taken as part of our site visit to the gauge.

Figure 5-1: Gauge at Ballyedmond

Figure 5-2 presents a plot of the water level recordings for the gauge from 1977 to the end of 2017. As discussed in the previous section, the gauge record has a number of gaps which are evident from the plot.

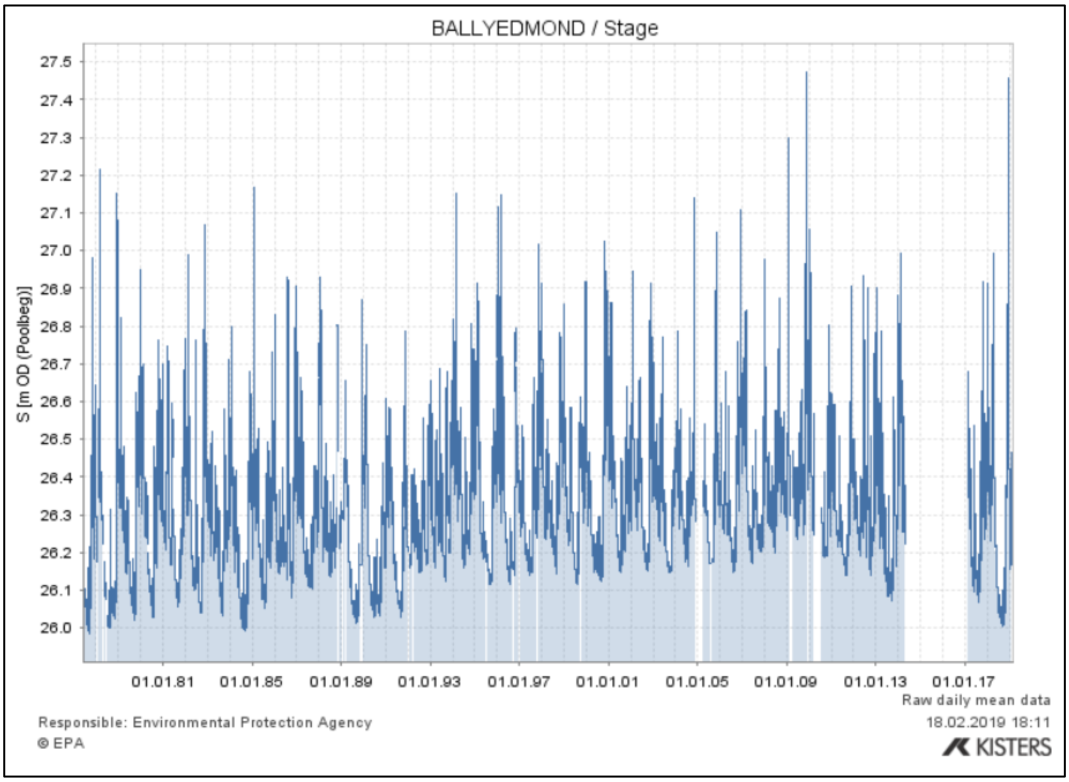

Figure 5-2: Water level recordings at Ballyedmond

Water levels at the gauge are subject to open channel control as there is no structure (such as a weir) in the vicinity of the gauge that acts as a control. Figure 5-3 presents the gauge characteristics as presented on the EPA datasheet. It can be seen that control at the gauge is unstable and that the rating is subject to change.

Station No.	19020	Catchment Area (km²):	75.0
Location:	BALLYEDMOND	Long Average Rainfall(mm/annum): Estimated losses (mm/annum): Long average runoff (mm/annum): Long average runoff expressed in m³/s:	1224 486 738 1.76
River:	OWENNACURRA		
Body responsible:	COR		
NGR:	W859766	Estimated dry weather flow (m³/s): Estimated 95 percentile flow(m³/s):	--- ---
Type:	Velocity-area station with natural control.	Staff gauge readings available for the years:	---
		Continuous water level records commenced:	APR 1977
Comment:	Unstable control. Rating subject to change, although can be stable for a number of years.	Period for which records are digitised: Period for which records are processed: Average flow (m³/s) in this period: 95 percentile flow (m³/s) in this period:	1977-93 1978-93 1.82 0.20

Figure 5-3: Gauge characteristics (from EPA datasheet)

The floodplain is relatively well contained at the location of the gauge but opens up into a wide and expansive floodplain circa 20m downstream along the left bank of the river. There are a number of mature trees and thick side vegetation on both sides of the watercourse immediately upstream of the gauge. The topography in the immediate vicinity of the gauge (taken from the study lidar dataset) is presented in Figure 5-4.

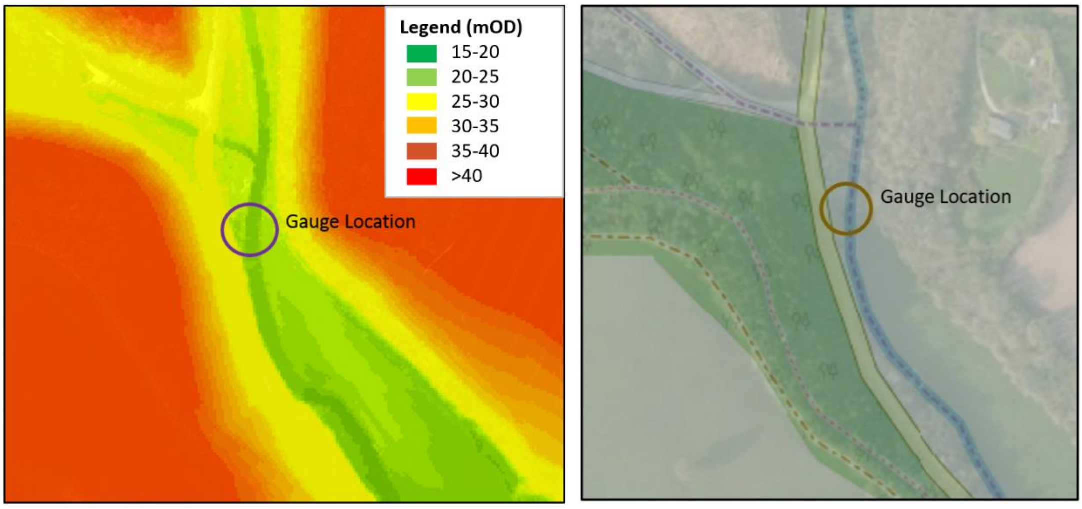

Figure 5-4: Topography data in the vicinity of the gauge(left), with Bing Maps(right)

5.3 Spot Gauging

The EPA provided Arup with the complete set of spot gauging for the station. The data consists of 229 concurrent measurements of flow and water level. The first spot gauging was taken in August 1976 and the most recent gauging was taken in August 2022.

As the gauge review work was undertaken in October/November 2018, spot gauging taken after this data were not available to the analysis. This is considered further in the final section of the chapter when the findings of the gauge review are considered in light of the more recently collected gauging (i.e. the data collected after the analysis was completed at the end of 2018).

While the dataset provided by the EPA states that gauge zero is set at 25.887m OD Poolbeg (23.187m OD Malin) subsequent communication with the EPA has established that this datum only refers to the period since 2002 and that the gauge zero has changed historically. The correct gauge zero for each historic period (supplied by the EPA) was subsequently applied to the spot gauging record.

Additionally, there were a number of points in the spot gauging dataset that on inspection appeared to be erroneous. An investigation of the dataset discovered a text formatting error in the file supplied by the EPA which caused these points to be incorrectly represented. The points were subsequently adjusted and the gauge record was corrected.

The corrected spot gauging and cross section at the gauge are plotted in Figure 5-5.

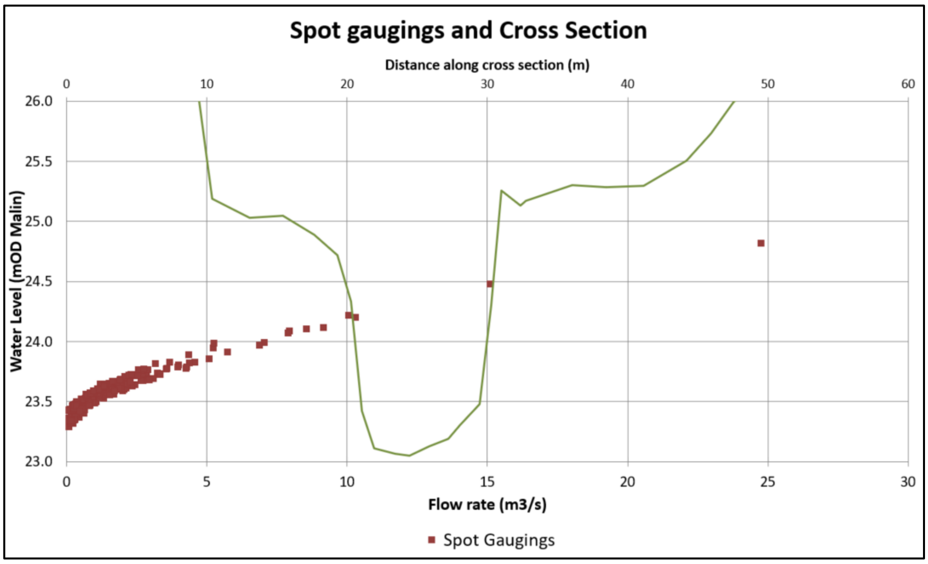

Figure 5-5: Spot Gauging and Cross Section

It can be seen from Figure 5-5 that there is a reasonably consistent trend over the full range of flows. It can also be seen that the majority of spot gaugings are for reasonably low flows ($Q<5m^3/s$) – only two points exceed $15m^3/s$.

5.4 Previous EPA Rating Curves

Nine separate rating curves have been developed by the EPA since the gauge was commissioned in 1977. Each curve corresponds to a particular historic period as indicated in Table 5.1.

Table 5.1: Historic periods for which the EPA developed a rating curve for the gauge

Period	From	To
1	08/1976	08/1977
2	01/1978	07/1980
3	10/1980	11/1996
4	05/1987	11/1987
5	04/1988	10/1991
6	03/1992	11/1994
7	03/1995	10/1995
8	02/1996	07/2012
9	08/2012	03/2014
10	02/2017	07/2018

Figure 5-6 presents the spot gaugings for each of the different historic periods highlighted in Table 5.1. Figure 5-7 presents the same dataset but with the scales of the graph altered to highlight flow rates less than $10m^3/s$.

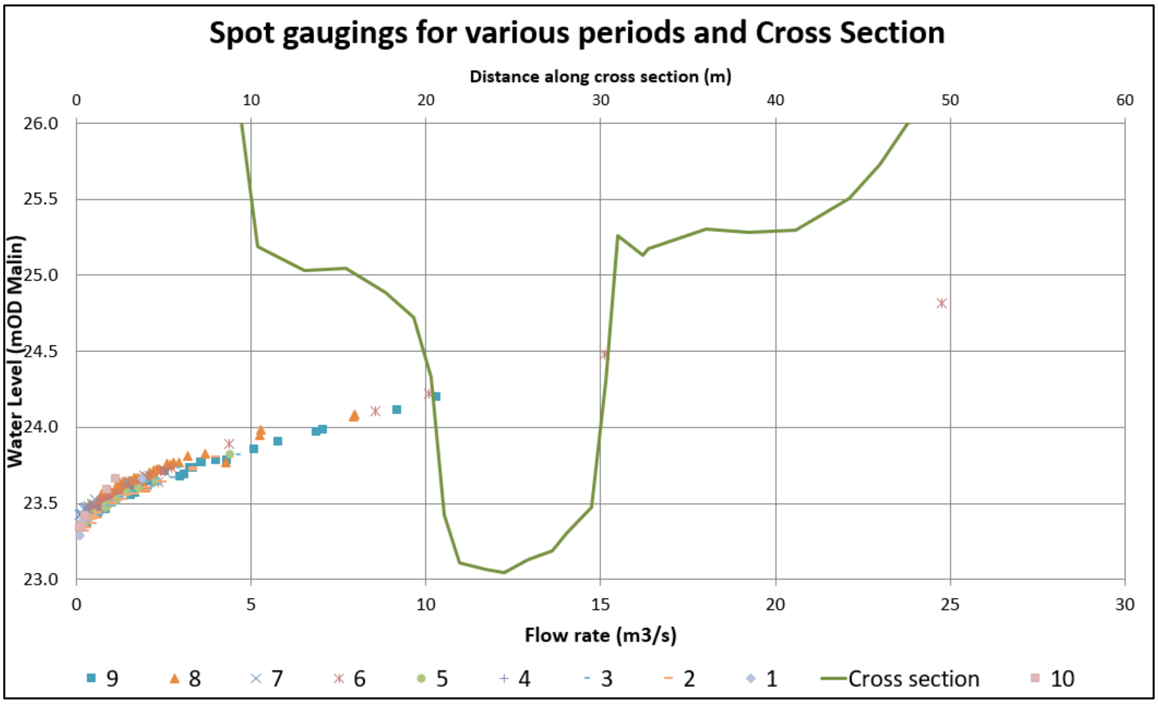

Figure 5-6: Historic Period Ratings

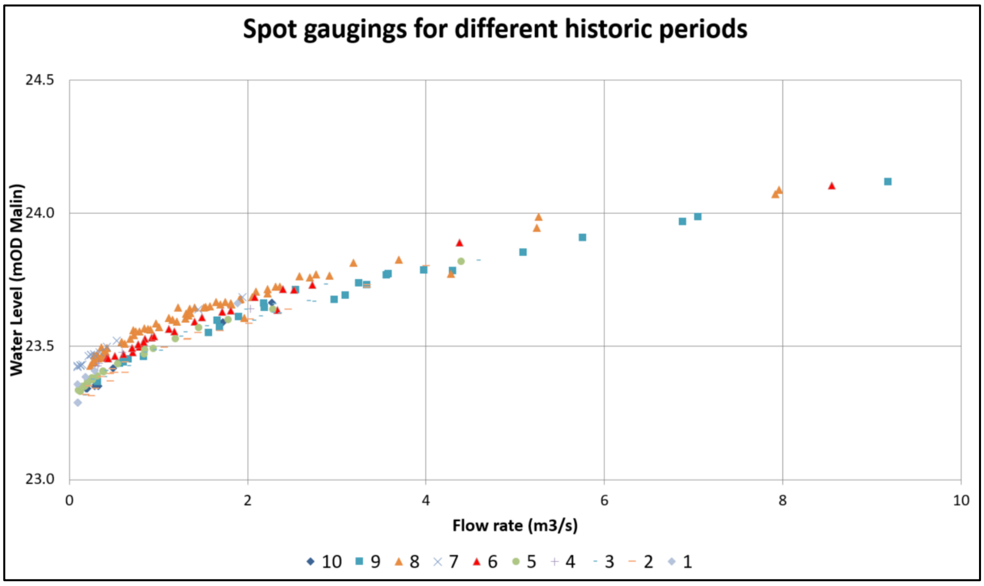

Figure 5-7: Historic Period Ratings (zoomed in view)

It can be seen from Figure 5-7 that there are two general trends for flow less than 5m^3/s:

- Spot gaugings for periods 1, 7 and 8 all show a consistent trend;
- Spot gaugings for periods 2, 3, 5, 9 and 10 all show a consistent trend.

The spot gaugings for period 6 lie in between these two different groupings.

Above 5m^3/s however all the data points demonstrate a reasonably consistent trend.

It is evident therefore that the rating for low flows varies historically - it can be seen for instance that for a level of 23.6mOD the flows range from circa 1.1m^3/s to circa 2m^3/s.

Since the gauge cross section is natural and not fixed, it is reasonable to assume that the riverbed at the gauge location changes with time. The datum at the station is likely therefore to have been correct at the time at which the gauging's were taken. The spot gauges are also therefore likely to be accurate relative to the time at which they were taken. As the river geometry changes over time, new flow conditions appear which is particularly evident for low flows.

We have investigated if seasonal changes along the channel (i.e. higher vegetation in summer that in winter) may also contribute to the historic variation in rating. Figure 5-8 presents the spot gauging's grouped into summer and winter months.[1] It is evident from the plot that there is no clear pattern or trend in the summer/winter groupings. Seasonal changes in vegetation along the channel is therefore not likely to have any significant impact on the rating.

[1] Winter defined as: Oct, Nov, Dec, Jan, Feb, Mar. Summer defined as: Apr, May, Jun, July, Aug, Sept

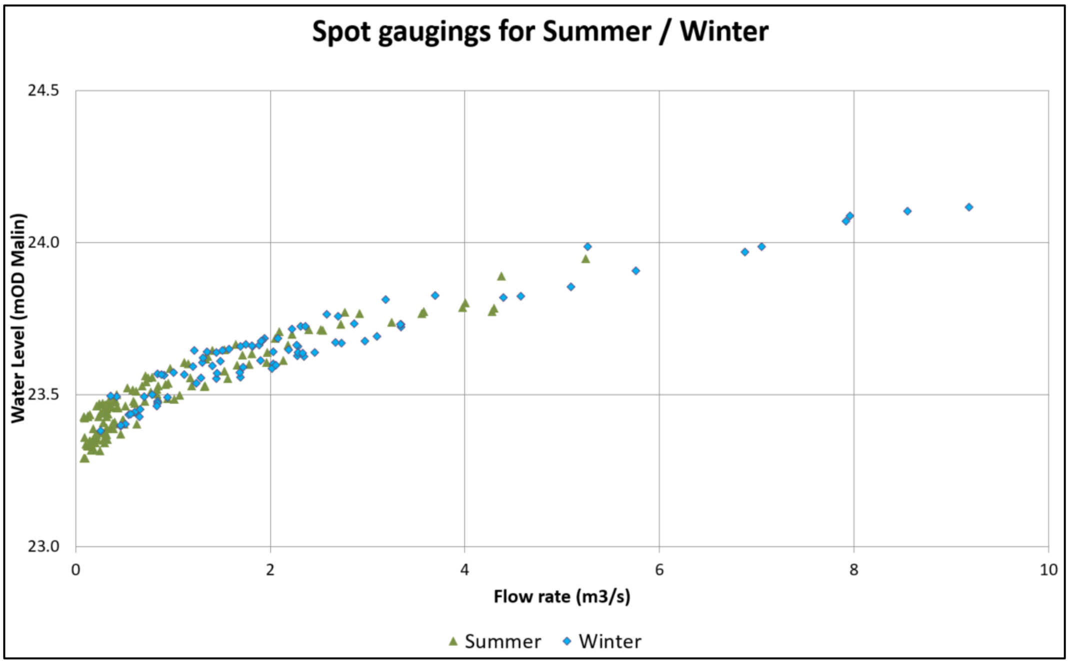

Figure 5-8: Summer/Winter Spot Gauging

5.5 Annual maximum water levels at the gauge

Figure 5-9 presents the annual maximum water levels at the gauge plotted against the cross-section geometry. We note that the x axis of the plot for the AM series is arbitrary. It can be seen from the plot that the annual maximum water levels range from 24.12mOD (1990) to 25.269mOD (2000). The value for 1976 is an outlier to the dataset as the gauge was only operational for a few months in that year.

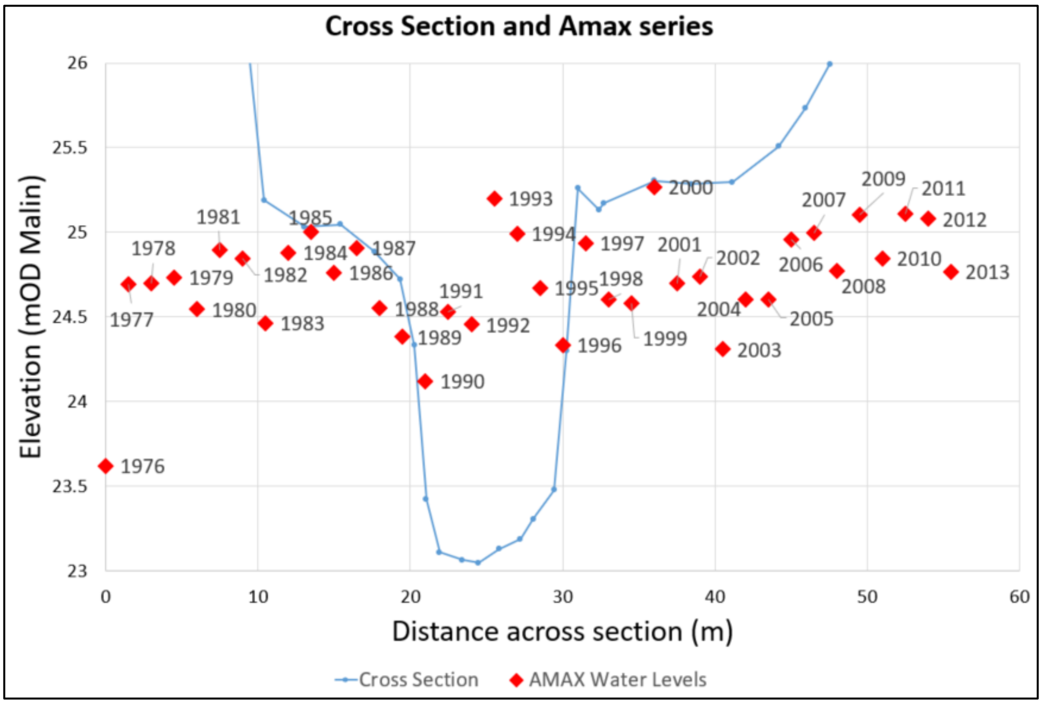

Figure 5-9: Cross Section and Amax series

5.6 Hydraulic modelling

A 1D hydraulic model of the reach was developed in Flood Modeller Pro in order to define Q-H points for flows up to the highest recorded water level at the gauge (25.269mOD – annual maximum for 2000).

The model was calibrated against spot gauged data across a range of flows and a very good match between the modelled results and the spot gauging was achieved (Table 5.2). This provides good confidence in the ability of the model to reproduce in bank flows throughout the reach.

Table 5.2: Calibration points

Spot gauging	Recorded Discharge (m^3/s)	Recorded Height (mOD)	Model WL (mOD)	Difference (m)
07/03/2014	5.09	23.854	23.95	0.096
05/02/2014	9.18	24.117	24.20	0.083
08/11/1994	15.101	24.479	24.49	0.014
08/11/1994	24.767	24.819	24.821	0.002

Once calibrated, the hydraulic model was used to derive Q-H relationships. The results of these design runs are presented in Table 5.3 and plotted in Figure 5-10 along with the gaugings and cross section geometry.

Table 5.3: Spot heights derived from the model

Discharge (m^3/s)	Modelled Water Level (mOD)	Modelled Water Stage (m)
10	24.25	1.063
15	24.488	1.301
20	24.677	1.49
25	24.827	1.64
30	24.955	1.768
35	25.071	1.884
40	25.19	2.003
45	25.27	2.083
50	25.35	2.163

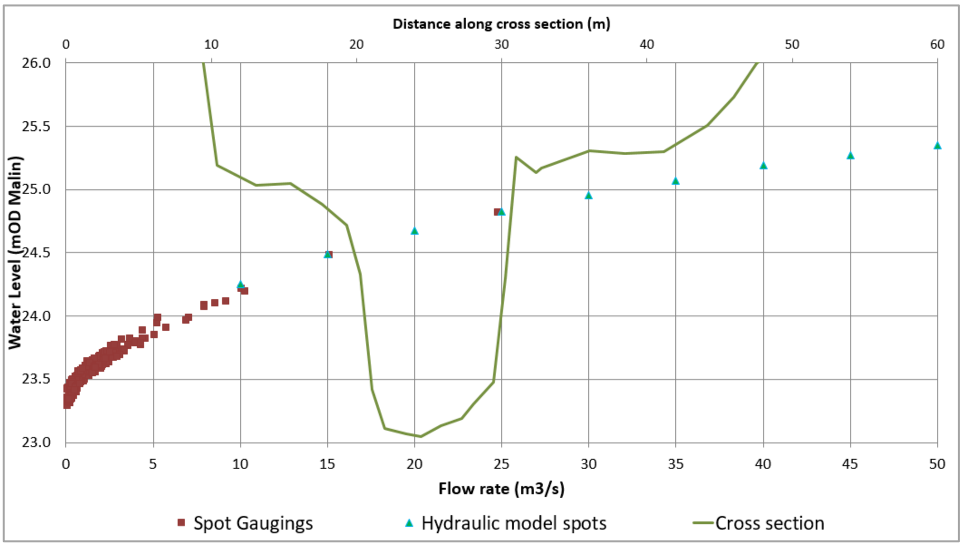

Figure 5-10: Spot gauging and hydraulic modelling points

5.7 Developing the new rating curve

Deriving a rating curve involves fitting a power-type equation to the recorded spot gauging's and the Q-H relationship as derived from the hydraulic model. Our methodology assumes that the spot gaugings are a correct representation of hydraulic conditions in the channel at the time at which the spot gaugings were recorded and that no adjustment to the points is required in order to account for the varying bed level. We have however examined this assumption as part of a sensitivity analysis in Section 5.8.

Figure 5-11 presents a log-log plot of the spot gaugings and modelled points. Power functions have been fitted to two separate groups of points that follow a consistent trend:

- Stage values up to 0.6m (labelled 'lower' in Figure 5-11);
- Stage values above 0.6m (labelled 'upper' in Figure 5-11).

The equations on the graphs present the parameters of the power functions which were used to construct the rating curves. We note that a number of different lines were fitted to the points to test the sensitivity. It was found that the derived flows were not that sensitive to minor adjustments to the fitted lines.

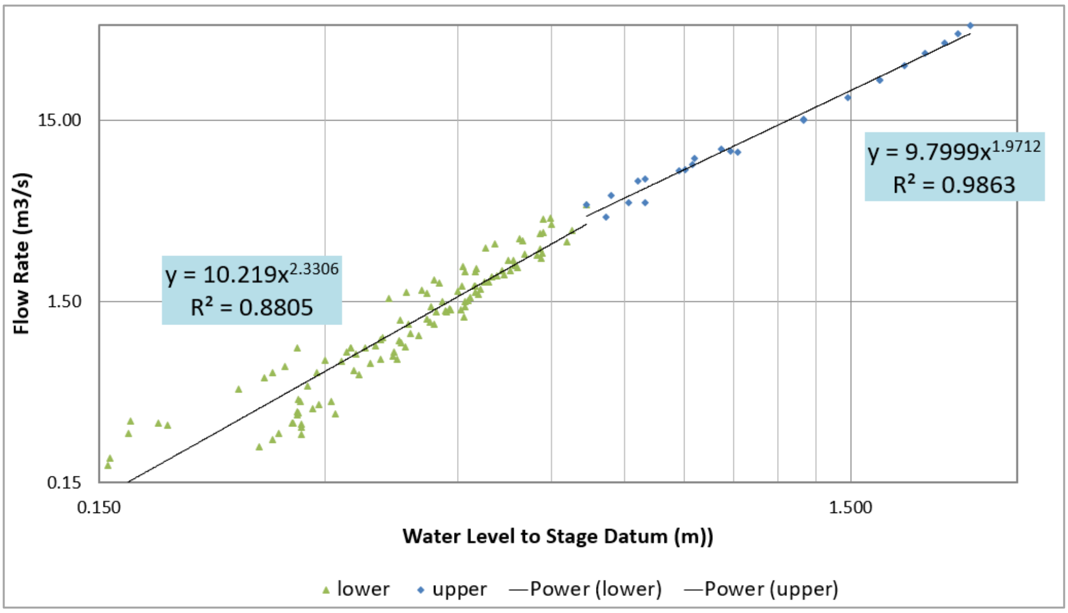

Figure 5-11: Fitting Rating Curve

The derived rating curve is presented in Figure 5-12. The most recent EPA rating curve as well the rating curve derived by the Lee CFRAM is also presented. It can be seen from the figure than the revised rating curve is slightly flatter that the curve derived as part of the Lee CFRAM: for an equivalent level, the flow rate is marginally higher by circa 1.5m^3/s.

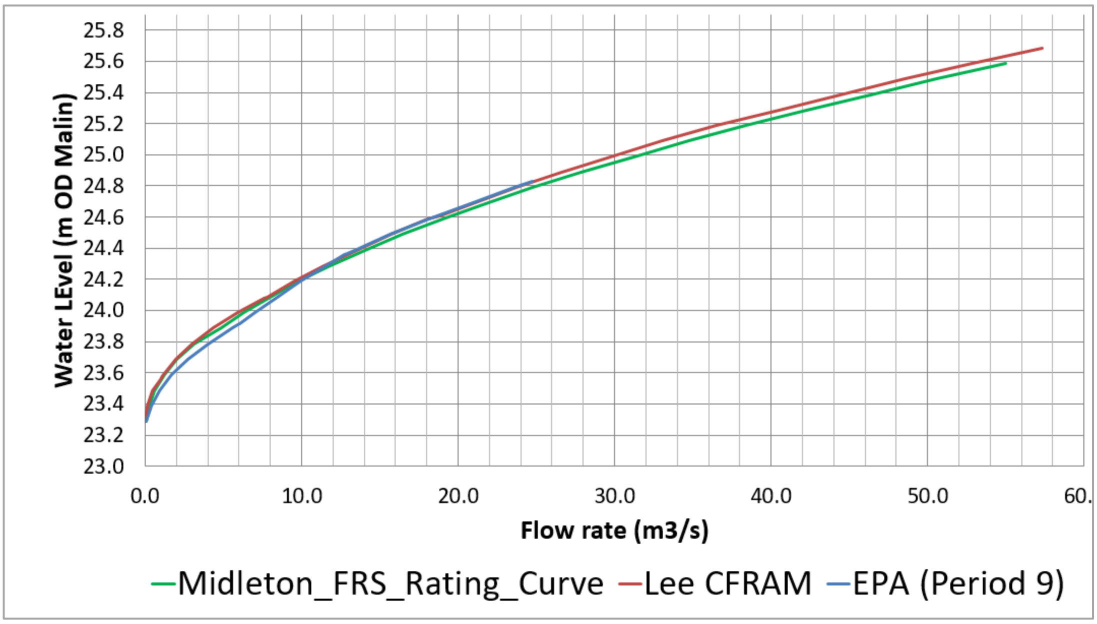

Figure 5-12: Revised rating curves

Applying the revised rating curve to the Amax time series derived a Q med value of 24.46m^3/s using all 41 years of record.

5.8 Sensitivity analysis - adjusting the DG

As presented earlier in this chapter, low flow spot gauging (Q<5m^3/s) exhibit different trends for different historic periods. A sensitivity test of the effect of artificially collapsing all the historical spot gauging to fit the most recent trend was undertaken.

While this methodology has merit in understanding the scatter and sensitivity of the flow values to the "gauge zero datum" (DG), differences between spot gauging across different periods relate to natural changes of the cross-section geometry, vegetation growth, riverbed evolution, etc. Variations of gauging records are "real" and shifting them is ignoring these changes.

As part of this sensitivity analysis requested by OPW, Arup amended the datum value of the historical gauging to shift the spot gauging in order to represent the current trend at the gauge.

The resulting data set and fitting equations are presented in Figure 5-13. We note that the Qmed derived from this revised analysis is 24.97m^3/s which is only marginally higher than the Qmed estimated in the previous section (24.46m^3/s) and also within the Standard Error of the analysis. We note that various iterations of the straight lines were fitted to the data with little difference and therefore recommend adopting the revised rating curve as presented in Section 5.7.

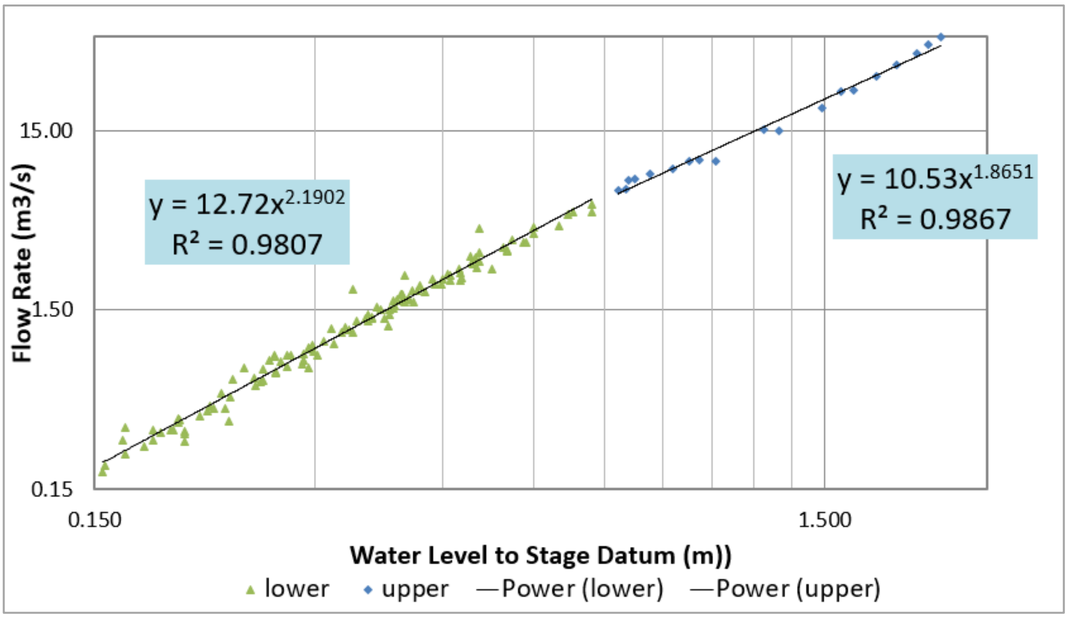

Figure 5-13: Revised Curve Fitting After Correcting the Datum Value of Spot Gauging

5.9 Spot gauges from October 2018 to August 2022

As noted earlier in the Chapter, the Ballyedmond rating review was undertaken in October/November of 2018. Since this time, the EPA have collected circa 40 additional spot gauging at the Ballyedmond gauge. It is therefore useful to consider these gauging in light of the findings of the rating review in order to establish if the new ratings may require the generated rating curve to be revised.

Figure 5-14 presents the post November 2018 spot gauging (blue markers) along with the spot gauging for the years previous to that (dark red markers) which have been used to inform the gauge review.

It can be seen from the plot that the post November 2018 spot gaugings were all taken at times of relatively low flow in the river channel - the highest flow is seen to be circa 9.8m^3/s. The spot gaugings all generally follow the same trend as indicated by the pre-November 2018 cluster of points. One spot gauging however lies outside the cluster which and can be attributed as an outlier. The flow gauging is of little consequence to the assessment of the upper rating given the relative low level of flow/height recorded.

It is therefore evident that the post November 2018 spot gaugings all follow the same trend as the spot gaugings collected up to that point in time. Consequently, the rating curve derived as part of the study is deemed to be valid and no revisions to it are required in light of the more recent ratings.

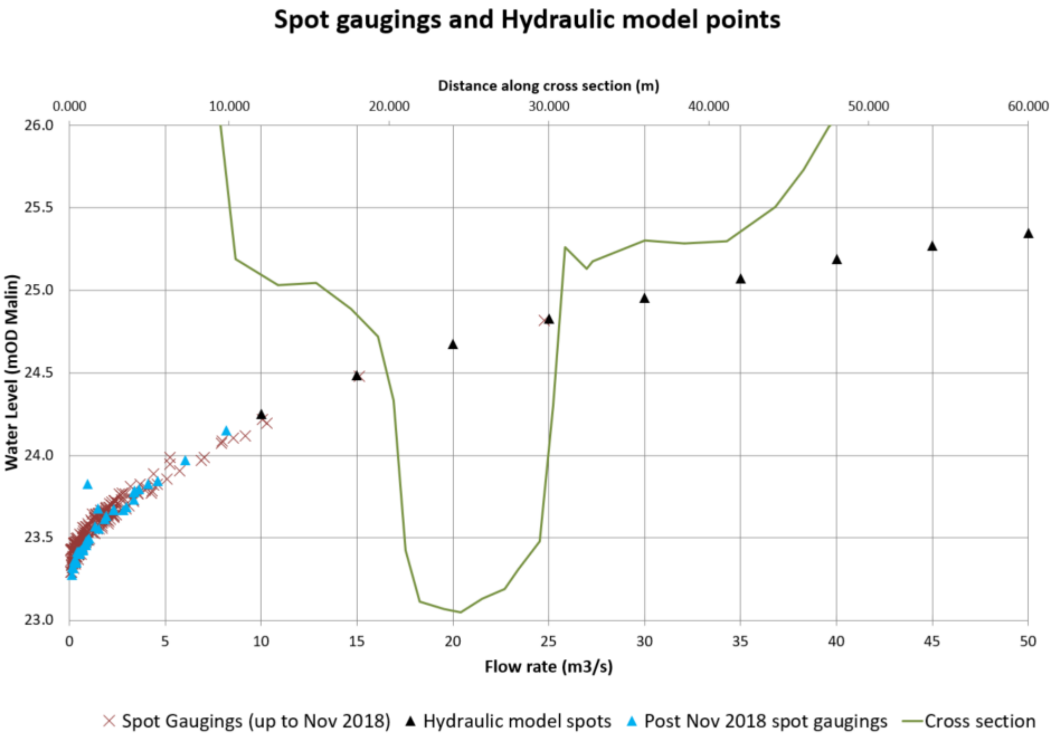

Figure 5-14: Post November 2018 Spot Gauging

6. Estimation of Index Flood

6.1 Overview

In order to establish the existing flood risk it is necessary to provide estimates of flood flows for a range of return periods, up to and including the 0.1% 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:

- Direct analysis of gauge data (refer to Section 6.3);
- Flood Studies Update methods (refer to Section 6.4);
- Flood Studies Report Statistical Method (refer to Section 6.5);
- Institute of Hydrology Report No. 124 Method (refer to Section 6.6);
- Flood Studies Report Rainfall-Runoff Method (refer to Section 6.7);

These are discussed in the following sections of this report.

Flow estimates produced by previous studies are also considered and are described in Section 6.8.

6.2 Hydrological Estimation Points

Hydrological Estimation Points (HEPs) have been developed along the modelled watercourses. This includes the Owenacurra, the Dungourney and a number of tributaries. These points are located at the upstream limits of the hydraulic model, at the junction of tributaries and at flow check points.

The location together with the watercourse name, HEP label and basic catchment descriptors is provided in Table 6.1 and illustrated in Figure 6-1. Please refer to Appendix 2 for further details on HEPs.

Table 6.1: Details of HEPs

HEP	Easting	Northing	Watercourse	Area (km^2)	SAAR (mm)	S1085 (m/km)
BAL1	188980	71743	Ballinacurra	2.55	1014	0.58
DG3	189700	74300	Dungourney	37.57	1161	11.60
DG4	189440	74020	Dungourney	49.52	1137	11.19
DG6	188387	73348	Dungourney	52.43	1132	9.94
EL1	187909	75800	Elfordstown	8.25	1103	26.22
GL1	187595	76000	Glenathonacash	12.72	1171	17.37
HAG2	189680	74300	Harrisgrove	10.33	1059	1.90
OAT1	186241	74114	Oatencake	4.21	1051	1.77
OAT3	187460	72900	Oatencake	10.33	1047	1.77
OW3	185923	76618	Owenacurra	73.95	1179	11.02
OW4	187160	75400	Owenacurra	77.09	1177	10.40
OW5	187620	75620	Owenacurra	21.34	1143	17.34
OW6	187185	74900	Owenacurra	98.98	1168	9.89

HEP	Easting	Northing	Watercourse	Area (km^2)	SAAR (mm)	S1085 (m/km)
OW7	187540	74460	Owenacurra	99.47	1168	9.68
OW8	187924	73800	Owenacurra	105.10	1163	8.88
OW9	187980	73320	Owenacurra	105.87	1162	8.90
OW10	187961	73072	Owenacurra	158.51	1147	8.90

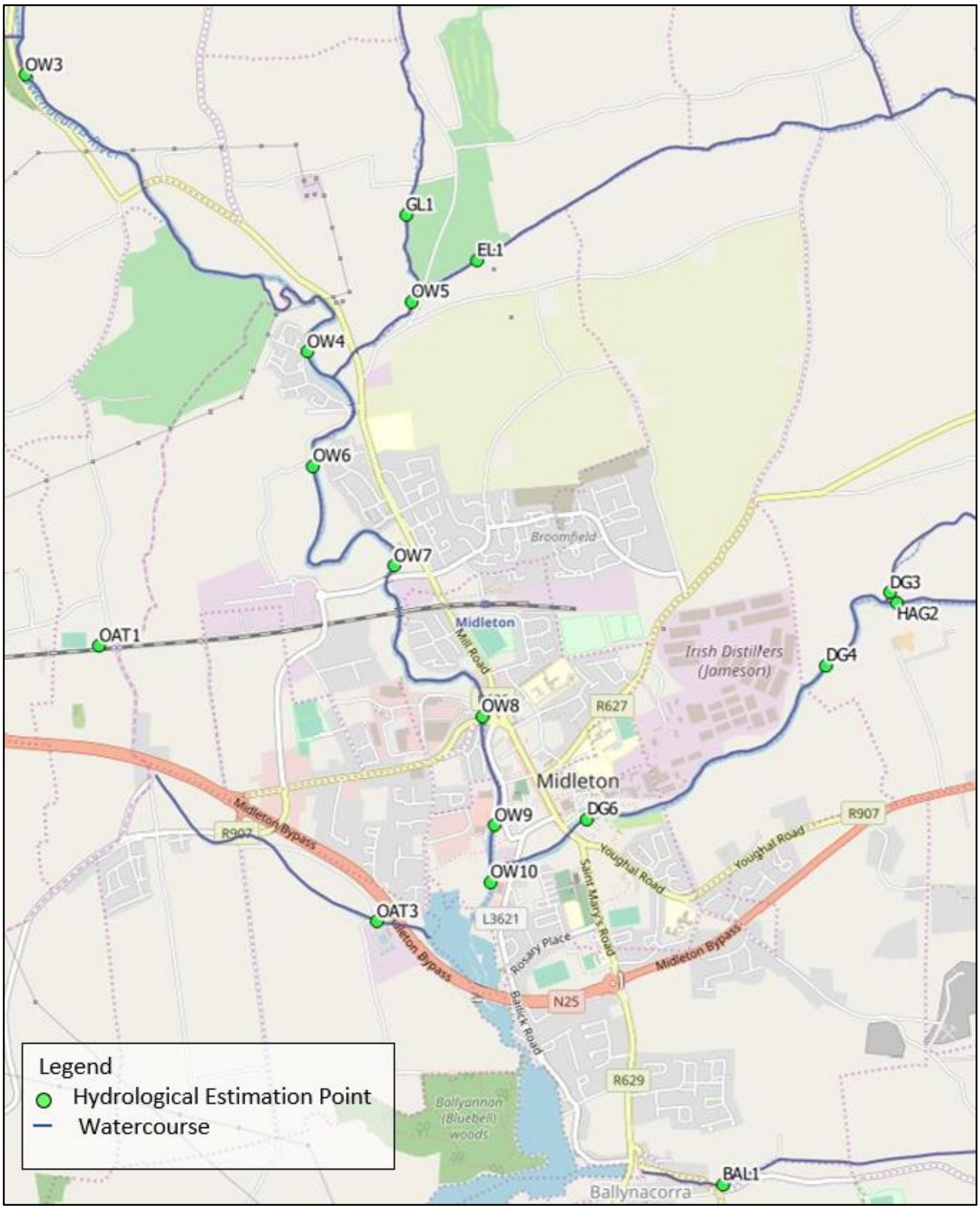

Figure 6-1: Location map of HEPs

6.3 Analysis of Gauge Data

6.3.1 Ballyedmond – Gap analysis

A gap analysis of the entire flow record at Ballyedmond was carried out. The analysis showed a data gap of 1 day was exceeded 46 times during the entire data series. A data gap longer than 30 days was exceeded four times. Figure 6-2 and Table 6.2 present the findings of the analysis.

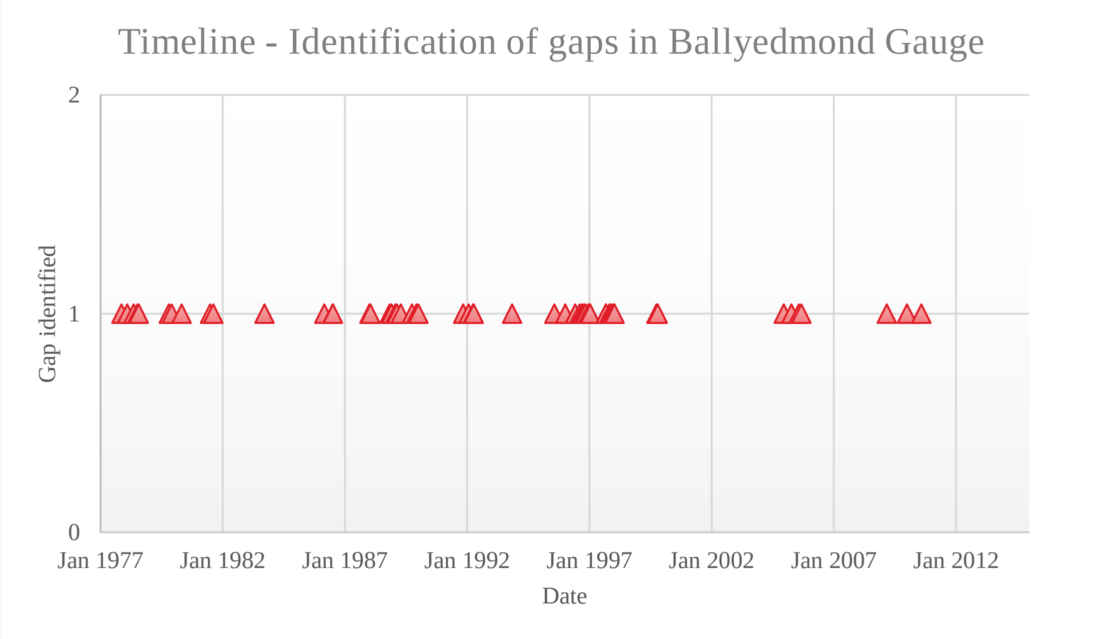

Figure 6-2: Data Gaps of Flow Record – Ballyedmond

Table 6.2: Number of occurrences with data gaps of varying duration

Duration (days)	No. of gaps in data record
1	46
5	32
10	19
20	12
30	4

Rainfall data was assessed for the data gap periods in order to assess if the gauged river flow data could be infilled using rainfall runoff methods i.e. using the rainfall data as input to a rainfall runoff model in order to generate river flow data for the catchment at the gauge.

Of particular important was the Ballyedmond gauge which ceased in 2014 before recommencing in March 2017. The very significant winter 2015/2016 flood event was therefore not recorded by the gauge. The hourly rainfall data from Cork Airport and Moore Park was therefore assessed in order to derive missing flow values for the hydrometric years (HMY) of 2014 and 2015. It was found that rainfall data from Moore Park was more representative of the weather patterns of the Owenacurra River Catchment than rainfall data from Cork Airport when the derived hydrograph shapes were considered. As a result, the FSSR16 rainfall runoff method was used to derive flows using rainfall data from Moore Park in order to infill the gaps.

Calibration of the FSSR16 model was carried out using recorded flows for the period for which rainfall data was available (2007 – 2017). The Time to Peak of the unit hydrograph was reduced to 3 hours as part of the calibration in order to better match the observed hydrograph shape. Adjustment factors were also derived for each of the events and ranged from 0.69 to 1.60 with an average of 1.08. This was subsequently applied to the simulated flows at the gauge.

Figure 6-3 presents an example of 2 calibrated events. It can be seen from the plots that a good match between the actual and simulated flows was achieved. This gives us confidence in the suitability of the FSSR16 rainfall runoff method for deriving river flows at the Ballyedmond gauge and subsequently for infilling gaps in the gauge record.

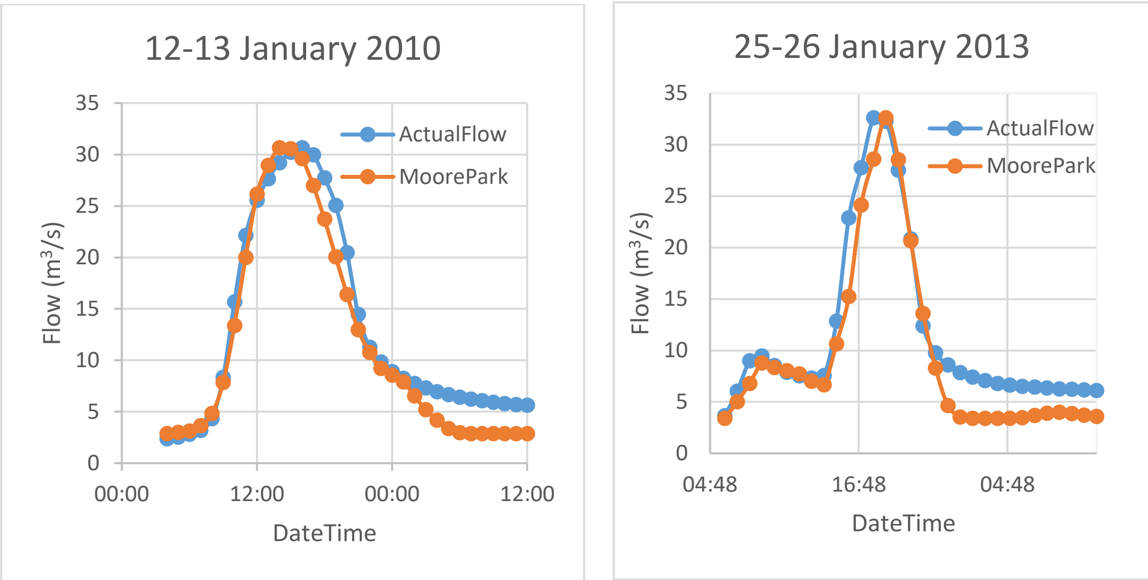

Figure 6-3: Calibrated events of actual flow and FSSR prediction method

6.3.2 Ballyedmond – Qmed Estimation

Figure 6-5 presents the complete Annual Maximum series for Ballyedmond which consists of 41 years of record. The Index Flood (Qmed) was calculated as **24.46m^3/s**. This includes the derived Amax values for HMY 2014, 2015. This value compares to an index flood of 24.40m^3/s without the derived Amax values – a difference of 0.06m^3/s which is deemed to be minor.

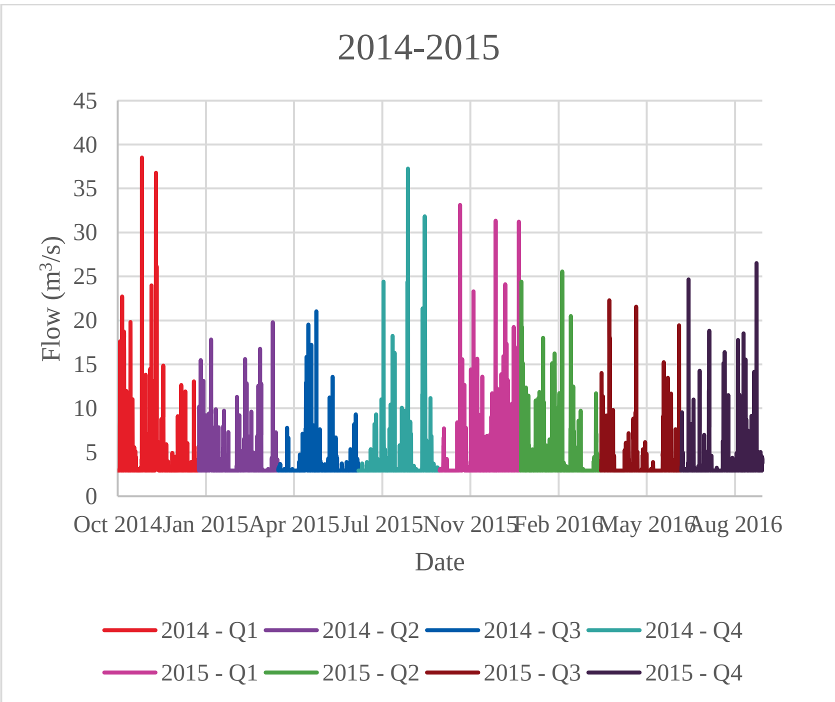

Figure 6-4: Simulated Flows for HMY 2014 and 2015

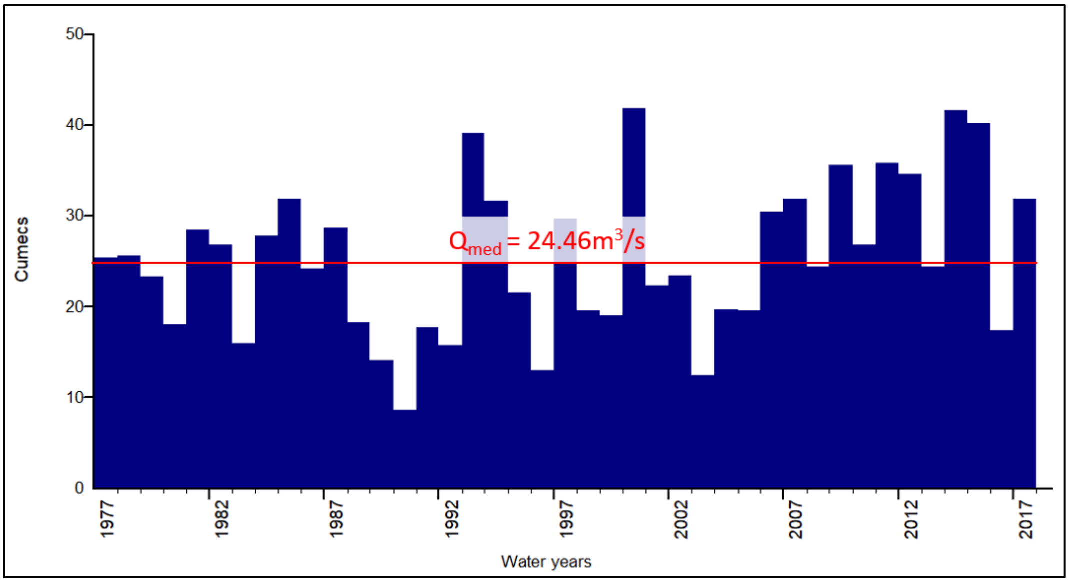

Figure 6-5: Bar chart showing complete Annual Maximum Series - Ballyedmond

6.4 Flood Studies Update

The FSU Programme was undertaken by the OPW with a view to developing new flood estimation methods for Ireland. The FSU represents a substantial update of the FSR and the IH124 methods and was developed using revised datasets specific to Ireland. It is now considered by OPW as the primary methodology for flood estimation in Ireland.

The OPW acknowledge that other methods should also be used in large hydrological estimation studies such as this one. Hence the FSR IH124 and FSR Unit Hydrograph methods were also employed as part of this study.

All hydrological estimation methods have limitations however, particularly in relation to small catchments and these should be considered when reviewing flow estimations in this report. 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 situated on much larger catchments (the median catchment area of the FSU stations is 215km^2).
- The findings of the Ballyedmond gauge rating review should be taken into account in determining the adjustment factor for Qmed estimates. For further detail, refer to Section 5.

6.4.1 FSU - 7 Variable Method

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.

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

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

The FSU 7-variable equation has a standard factorial error of approximately 1.37, 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.
- 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 physical catchment descriptors used in the FSU index flow estimation for each HEP are detailed in Appendix 2.

6.4.2 Flood Studies Update - Method 4.2a

The FSU Work Package 4.2 covers the flood estimation for small and urbanised catchments. This method was applied for all HEPs with catchment areas less than $25km^2$. The equation FSU 4.2a estimates Qmed for a rural catchment.

$$Qmed_{Rural} = 2.0951\ x\ 10^{-5} AREA^{0.9245} BFIsoils^{-0.9030} SAAR^{1.2695} FARL^{2.3163}\ \ S1085^{0.2513}$$

The FSU 4.2a-variable equation has a standard factorial error of approximately 1.686, 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.
- FARL is the flood attenuation by reservoir and lake.
- 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).

The physical catchment descriptors used in the FSU index flow estimation for each HEP are detailed in Appendix 2.

6.4.3 FSU – Summary of Index Flood

Table 6.3 below summarises the Qmed estimated at each HEP using the FSU 7- variable equation and FSU 4.2a method.

Table 6.3: FSU Qmed (rural estimates)

Location	Node Point	Index Flood (m^3/s)	
		FSU-7 var.	FSU-4.2a
Bal1	19_990_4	0.28	0.41
DG3	19_1902_4	8.42	
DG4	19_1957_2	9.35	
DG6	19_1957_5	9.52	
EL1	19_1462_5	1.79	3.45
GL1	19_965_4	3.29	5.10

Location	Node Point	Index Flood (m^3/s)	
		FSU-7 var.	FSU-4.2a
HAG2	19_1721_6	1.02	1.69
OAT1	NA	0.35	0.89
OAT3	19_1959_2	0.91	2.03
OW3	19020	16.22	
OW4	19_712_6	16.34	
OW5	19_711_1	4.87	7.92
OW6	19_1955_2	19.92	
OW7	19_1955_4	19.94	
OW8	19_1955_6	20.20	
OW9	19_1955_7	20.28	
OW10	NA	28.22	

6.4.4 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.

6.4.5 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 be located a short distance upstream or downstream from the subject site. The Qmed rural estimate at the subject site is adjusted as follows:

1. 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.
2. The FSU web portal 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 on the Owenacurra River approximately 4km north of Midleton town 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 with updated rating) of 24.46m^3/s was then adjusted for standard error in accordance with FSU WP2.2, section 13.1. For 41 years of record, this gave a final Qmed (gauged) estimate at Ballyedmond of 25.74m^3/s. Comparing this with a Qmed of 16.22m^3/s calculated using the FSU equation, implies an adjustment factor of 1.59.

6.4.6 Lower Lee FRS Adjustment

As part of the Lower Lee Flood Relief Scheme, a Qmed adjustment factor was established 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 6.4: 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

6.4.7 Standard Error Adjustment on Small Catchments

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 1.686 when applied to small catchments.

6.4.8 Selection of Design Adjustment Factor

The four possible adjustment factors identified are tabulated below:

Table 6.5: Possible FSU Qmed adjustment factors

Method	Factor
Ballyedmond pivotal site	1.59
Lower Lee FRS adjustment	1.73
FSU standard factorial error	1.37
FSU standard factorial error (small catchments)[2]	1.69

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. Therefore, the adjustment factor of 1.59 calculated using the Ballyedmond pivotal site was adopted as part of the FSU – 7 variable method. To compare Index Flows for small catchments the FSU Method - 4.2a was used using the more conservative adjustment factor of 1.69, applicable for that method, which acknowledges the higher uncertainty associated with estimating flows for these smaller catchments.

Table 6.6 below sets out the index flood flows estimated at each HEP using the selected adjustment factor for both methods.

Table 6.6: Adjusted FSU Qmed (rural) estimates

Location	Index Flow (m^3/s)	
	FSU – 7 var.	FSU–4.2a
Bal1	0.44	0.70
DG3	13.36	
DG4	14.83	

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

Location	Index Flow (m^3/s)	
	FSU – 7 var.	FSU–4.2a
DG6	15.11	
EL1	2.84	5.82
GL1	5.22	8.61
HAG2	1.62	2.84
OAT1	0.56	1.50
OAT3	1.44	3.42
OW3	25.74	
OW4	25.93	
OW5	7.73	13.36
OW6	31.62	
OW7	31.64	
OW8	32.06	
OW9	32.19	
OW10	44.78	

6.4.9 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 6.7 below.

Table 6.7: FSU Urban Adjustment Factors

Location	Adjustment Factor (UAF)
Bal1	1.0000
DG3	1.0000
DG4	1.0009
DG6	1.0243
EL1	1.0000
GL1	1.0000

Location	Adjustment Factor (UAF)
HAG2	1.0000
OAT1	1.4014*
OAT3	1.2514*
OW3	1.0000
OW4	1.0000
OW5	1.0000
OW6	1.0004
OW7	1.0030
OW8	1.0092
OW9	1.0166
OW10	1.0223

*Includes an allowance for future urbanisation, based on lands zoned for development in the Cork County Development Plan 2017-2022.

6.4.10 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 6.8: Adjusted FSU Qmed (urban) estimates

Location	Index Flow (m^3/s)	
	FSU – 7 var.	FSU – Method 4.2a
Bal1	0.44	0.70
DG3	13.36	
DG4	14.85	
DG6	15.48	
EL1	2.84	5.82
GL1	5.22	8.61
HAG2	1.62	2.84
OAT1	0.79	2.10
OAT3	1.80	4.28
OW3	25.74	
OW4	25.93	
OW5	7.73	13.36
OW6	31.63	
OW7	31.73	
OW8	32.35	
OW9	32.72	
OW10	45.78	

6.5 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 A2.

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

Table 6.9 below sets out the index flood flows estimated at each HEP using the FSR Statistical method.

Table 6.9: Qbar (urban) using FSR Statistical Method

Location	Flow	
	Qbar (m^3/s)	Qbar (68% CI) (m^3/s)
Bal1	0.32	0.48
DG3	7.45	11.18
DG4	8.74	13.11
DG6	9.32	13.98
EL1	1.37	2.06
GL1	2.97	4.46
HAG2	0.96	1.44
OAT1	0.88	1.31
OAT3	1.25	1.88
OW3	14.46	21.69
OW4	14.72	22.07
OW5	4.51	6.76
OW6	18.40	27.60
OW7	18.47	27.70
OW8	19.11	28.67
OW9	19.38	29.07
OW10	27.85	41.78

6.6 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 (QbarRural) can be extended to estimate runoff from a partially urban catchment, QbarUrban.

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

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

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 A2.

Table 6.10 below sets out the index flows using IH124 methodologies for HEPs with catchment areas below 25km^2.

Table 6.10: Qbar using IH124 Methodology

Location	Flow	
	Qbar (m^3/s)	Qbar (68% CI) (m^3/s)
Bal1	0.60	0.99
EL1	1.88	3.1
GL1	2.96	4.89
HAG2	2.19	3.61
OAT1	1.14	1.88
OAT3	2.16	3.57
OW5	4.57	7.54

6.7 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 under assumed antecedent catchment wetness conditions. The model assumes that the designed rainfall event falls uniformly across the entire catchment area for a critical duration with a specified profile.

In addition to the rainfall data there are three key parameters in the rainfall runoff model:

- Time to peak (which controls the rise of the hydrograph);
- Standard Percentage Runoff (which controls the volume of runoff);
- 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 (OAT1), 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 A2.

Table 6.11: Qbar Estimates using FSR Rainfall Runoff Method

Location	Flow (m^3/s)
Bal1	0.61
DG3	8.75
DG4	15.95
DG6	17.01
EL1	3.66
GL1	5.03
HAG2	2.84
OAT1	2.01
OAT3	4.13
OW3	24.87
OW4	25.18
OW5	8.33
OW6	31.53
OW7	31.20
OW8	32.64
OW9	32.76
OW10	48.87

6.8 Previous Studies

6.8.1 Lee CFRAMS

The hydrological schematisation of the Owenacurra catchment as utilised in the Lee CFRAMS is presented in Figure 6-6 below. The flows for each of the subcatchments are tabulated in Table 6.12.

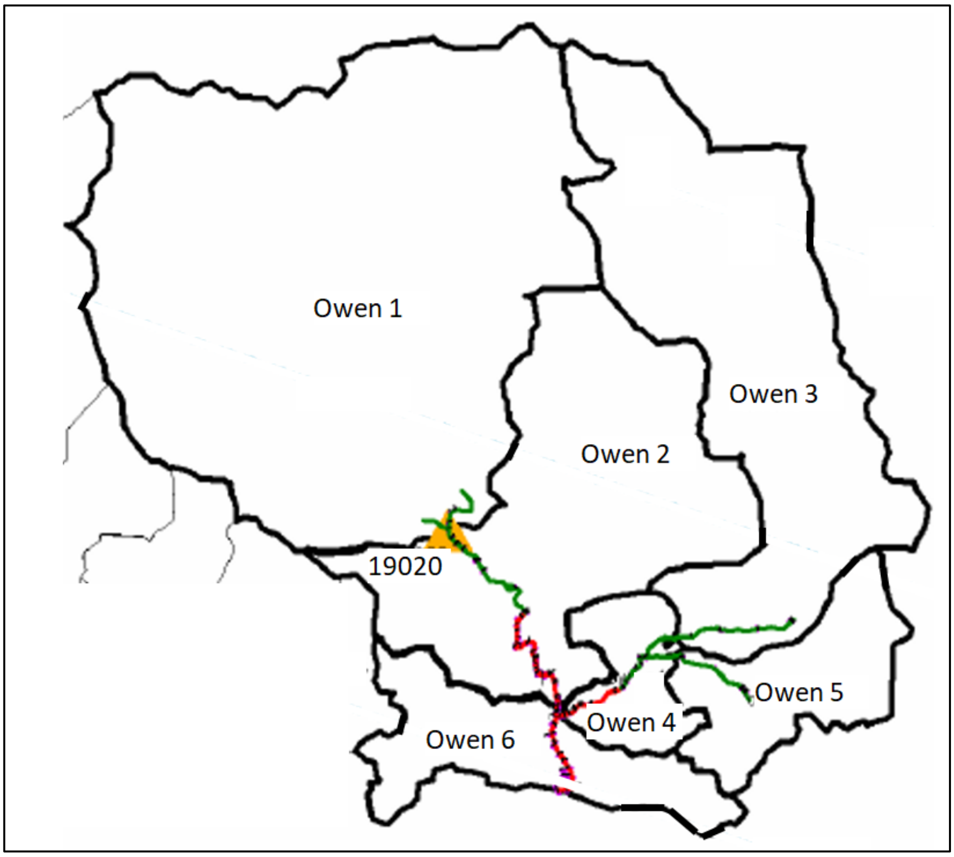

Figure 6-6: Lee CFRAM hydrological schematisation

Table 6.12: Index Flood - Lee CFRAM

Subcatchment	Index Flood (m^3/s)	HEP location
Owen 1	22.48	OW3
Owen 2	9.07	NA
Owen 3	10.40	DG3
Owen 4	1.47	NA
Owen 5	2.85	HAG2
Owen 6	2.03	NA

6.8.2 LIHAF Project

The Local Infrastructure Housing Activation Fund (LIHAF) project was carried for the Water Rock subcatchment. This consists of detailed hydrogeological survey combined with geophysical survey and tracer testing. Some connectivity between the groundwater and Water Rock Stream was found. Figure 6-7 presents the catchment area as estimated under the LIHAF project and Table 6.13 presents the index flood flows.

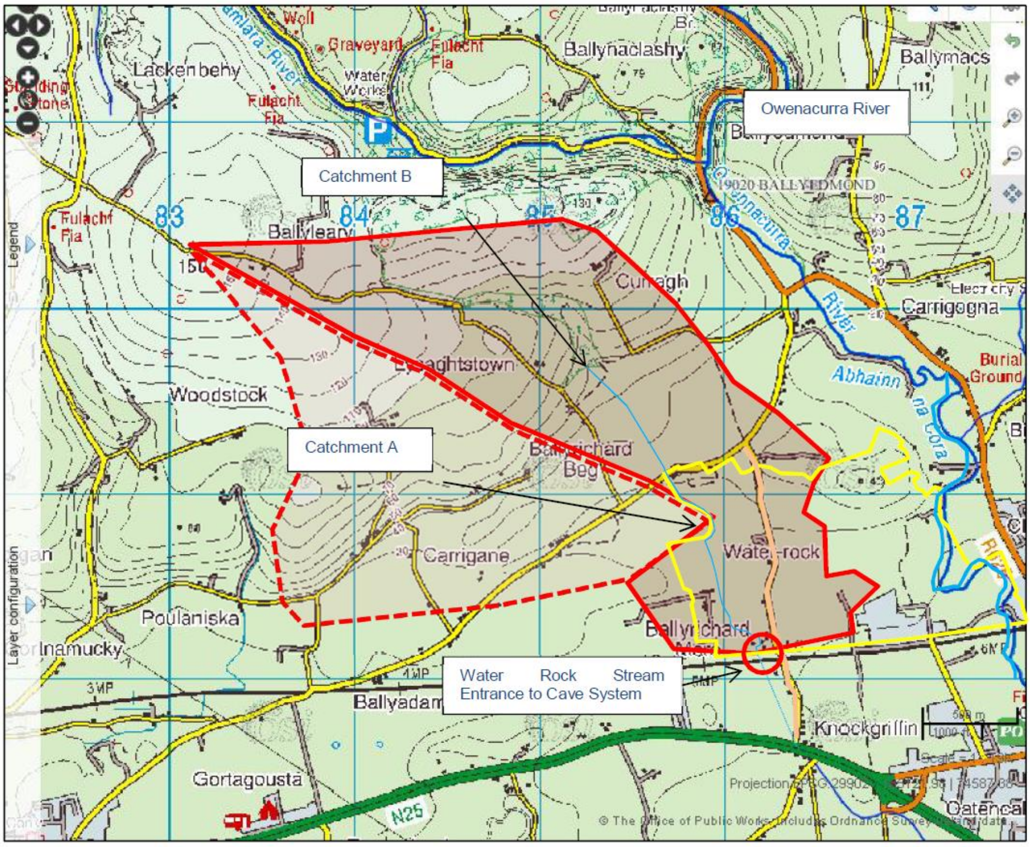

Figure 4.1 – Water Rock Stream – Catchment Area

Figure 6-7: Water Rock Catchment (extract from LIHAF FRA report, Nov 2018)

Table 6.13: LIHAF Index Fluvial Flood Flows – IH124

Location	Qbar (m^3/s) (incl. SFE of 1.65)
Catchment A (2.0km^2)	0.72
Catchment B (3.1km^2)	1.06

6.9 Selection of Design Index Flows

Given that there are a number of catchments in the study area that are small and ungauged, it was considered important to compare the index flows estimated using a range of methods. Traditionally, the index flow was expressed as Qbar, which corresponds to a statistical return period of 1 in 2.33 years. The more recent FSU method adopts Qmed as index flow, which corresponds to return period of 1 in 2 years. Table 6.14 presents a comparison of the index flood across the range of methods assessed.

Table 6.14: Comparison of Index Flood (incl. adj. factors / SFE, as applicable)

HEP Location	Qbar urban (m^3/s)				Qmed urban (m^3/s)		
	FSR	FSR-RR	IH124	LIHAF	Lee CFRAM	FSU-7var.	FSU–4.2a
Bal1	0.48	0.61	0.99		NA	0.44	0.70
DG3	11.18	8.75			10.40	13.36	
DG4	13.11	15.95			13.77	14.85	

HEP Location	Qbar urban (m^3/s)				Qmed urban (m^3/s)		
	FSR	FSR-RR	IH124	LIHAF	Lee CFRAM	FSU-7var.	FSU–4.2a
DG6	13.98	17.01			14.21	15.48	
EL1	2.06	3.66	3.10		NA	2.84	5.82
GL1	4.46	5.03	4.89		NA	5.22	8.61
HAG2	1.44	2.84	3.61		2.85	1.62	2.84
OAT1	1.32	2.01	1.88	1.78	NA	0.79	2.10
OAT3	1.88	4.13	3.57		NA	1.80	4.28
OW3	21.69	24.87			22.48	25.74	
OW4	22.07	25.18			24.12	25.93	
OW5	6.76	8.33	7.54		NA	7.73	13.36
OW6	27.60	31.53			30.19	31.63	
OW7	27.70	31.20			26.85	31.73	
OW8	28.67	32.64			31.14	32.35	
OW9	29.07	32.76			34.15	32.72	
OW10	41.78	48.87			49.01	45.78	

It is acknowledged that each of the flood estimation methods used in this study contain 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 larger catchments.

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.

For HEPs representing catchment sizes of over $25km^2$ it was felt appropriate to adopt the FSU-7 variable flows, as they appear to be reasonably conservative, while still remaining consistent with other methods.

Following a request from the OPW further analysis for the HEPs on small catchments (BAL1, EL1, GL1, HAG2, OAT1, OAT3 and OW5) was carried undertaken as part of the study and this is detailed in Section 6.10 of the report.

6.10 Design Flows for Small Catchments

Following a request from the OPW the Flood Studies Supplementary Report (FSSR) No 16 method was also used to derive design flows for the small catchments in the study area: BAL1, EL1, GL1, HAG2, OAT1, OAT3 and OW5. The findings from the analysis are to assist in the selection of the most appropriate flow estimation method for these small catchments.

Hourly rainfall data from Moore Park was applied for the Winter 2015/2016 flood using the FSSR16 module to derive flows for the event. The peak flow at each of the HEPs was then compared to the flows derived from the other methods i.e. IH124, FSU 4.2a and FSU 7-Var.

The results of the analysis indicate that the FSU-7Var method underestimates the flows of the Winter 2015/2016 event whereas the FSU 4.2a method would result in overly conservative flows.

The IH124 method was found to provide the best match to the severity of the Winter 2015 flood and was therefore adopted as the most appropriate method for small catchments. Please refer to Appendix B1.7 for further details on the work undertaken.

7. Flood Frequency Analysis

7.1 Overview

Once the index flood has been calculated, a growth curve must be established in order to allow estimation of flows at higher return period events. Flood growth curves can be derived from an analysis of annual maximum flows at the site of interest (single-site analysis) or at a group of gauging stations which are chosen from a wide area (pooled analysis). Both approaches have been adopted as part of this study and are considered in the following sections.

7.2 Single Site Analysis - Ballyedmond

The statistical analysis of the annual maximum series at the Ballyedmond gauging stations was assessed to derive a growth curve. This is done by applying a range of mathematical distributions to the gauged data.

The FSU WP 2.2 recommends considering two parameter distributions for single-site growth curves such as the Extreme Value type 1 (EV1, known as the Gumbel). For comparison, the Generalised Extreme Value (GEV), Generalised Logistic (GL) and the 3-parameter Log -Normal distributions were also applied. The software WINFAP was used to apply the statistical distribution methods and the most suitable distribution was chosen based on an assessment of the output. Figure 7-1 presents the typical distribution curve for the updated Annual Maximum data at Ballyedmond.

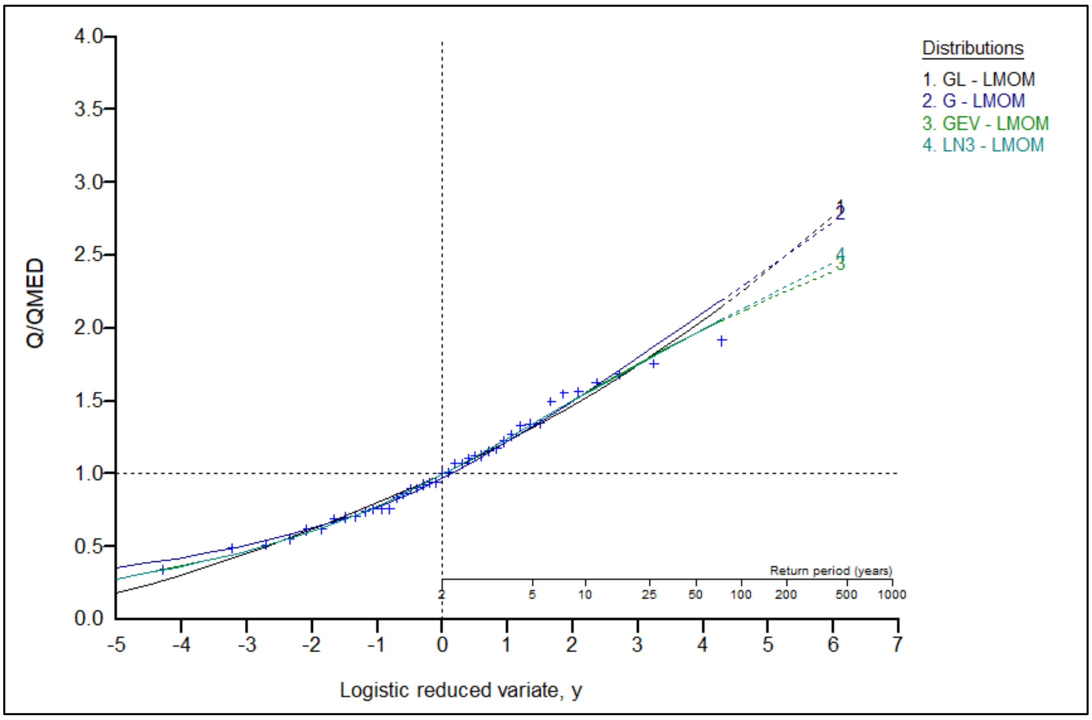

Figure 7-1: Growth Curve Fitting Single Site Analysis - Ballyedmond

The results indicate that both the GL and Gumbel distribution provide a reasonably conservative estimate of the Amax data at Ballyedmond.

The Gumbel distribution was selected as most representative distribution which is in keeping with the recommendations of the FSU. Table 7.1 presents the growth curve values for each method.

Table 7.1: Growth Curves Single Site Analysis

Return period (1 in _years)	Gumbel	Generalised Logistic	Generalised Extreme Value	3- Parameter Log Normal
2	0.97	1.02	1.02	1.02

Return period (1 in _years)	Gumbel	Generalised Logistic	Generalised Extreme Value	3- Parameter Log Normal
5	1.29	1.29	1.32	1.32
10	1.50	1.46	1.49	1.48
25	1.76	1.67	1.66	1.66
50	1.96	1.83	1.77	1.78
100	2.15	1.99	1.86	1.90
200	2.35	2.16	1.95	2.00
1000	2.80	2.56	2.09	2.22

7.3 FSU Pooling Group

The FSU growth curve is developed by using a pooling group of gauged catchments that are selected by their similarity to the subject catchment. The similarity assessment is undertaken using the tools provided on the FSU web-portal. A summary of the procedure is outlined below and more detail on the analysis can be found in Appendix B1.5.

It was deemed appropriate to carry out the pooling group analysis at HEP OW9 and HEP DG6. 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 FSU web-portal to fit distributions by the Lmedian method. Both pooling groups for HEP OW9 and HEP DG6 were found to be fairly similar and there was very little difference in the growth curves which are presented in Table 7.2.

Table 7.2: Growth Curve for HEP OW9 and DG6

Return period (1 in _years)	Growth Curve DG6	Growth Curve OW9
2	1.00	1.00
5	1.23	1.23
10	1.38	1.39
25	1.56	1.58
50	1.71	1.73
100	1.85	1.87

Return period (1 in _years)	Growth Curve DG6	Growth Curve OW9
1000	2.31	2.33

7.4 FSR 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 7.3 below.

Table 7.3: FSR Irish Growth Curve.

Return period (years	FSR Irish (1975) QT/ Qbar
2	0.95
5	1.20
10	1.37
25	1.60
50	1.77
100	1.96
1000	2.6

7.5 FSR Rainfall Runoff Growth Curve

Prior to the publication of the FSU, the FSR triangular unit hydrograph and design storm method was most widely used for ungauged catchments in Ireland. This is based on a comprehensive flood study involving many catchments throughout Britain and Ireland carried out by the UK Natural Environmental Research Council (1975).

The unit hydrograph prediction equation was derived from 1,631 events from 143 gauged catchments. The result was a triangular Unit Hydrograph described by the time to peak Tp of the catchment derived from catchment characteristics.

The instantaneous triangular unit hydrograph is defined by a time to peak Tp, a peak flow in cumecs/100km^2 Qp = 220/Tp and a base length TB = 2.52Tp. There are several Flood Study Supplementary Reports (FSSR) that slightly modified the (Tp) equation and the calculation of percentage runoff (PR).

The FSSR 16 has been applied in this study. The design rainstorm duration is obtained from the FSR formula D = (1 + 0.001SAAR) Tp. Using the prescribed FSR rules for computing the storm duration, profile and percentage runoff a 140year return period design storm is required to produce the 100year design flood.

The FSR Rainfall Runoff method was used to derive growth factors for Ballyedmond gauge location to allow comparison to the Single Site Analysis. Table 7.4 presents the growth curve. Please refer to Appendix B1.6 for a summary table of FSR RR parameters.

Table 7.4: FSR RR Growth Curve

Return period (years	FSR RR derived QT/ Qbar
2.33	1.00
5	1.41

Return period (years	FSR RR derived QT/ Qbar
10	1.66
25	2.01
50	2.30
100	2.59
1000	3.96

7.6 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 25 shows the Lee CFRAM Study Growth Curve.

Table 7.5: Lee CFRAM Study Growth Curve

Return period (years	Lee CFRAM GC
2	1.00
5	1.30
10	1.40
20	1.60
50	1.90
100	2.10
1000	2.59

7.7 Douglas FRS Growth Curve

The FSU pooling group assessment was used to derive growth curves for the Douglas FRS and this is presented in Table 7.6.

Table 7.6: Douglas FRS Growth Curve

Return period (years	Douglas GC
2	1.00
5	1.34
10	1.59
20	1.95
50	2.24
100	2.56

7.8 Blackpool FRS Growth Curve

A catchment flood frequency curve was calculated from the gauged catchments in the wider Lee catchment and this was then applied at Blackpool. The catchment frequency curve was calculated by averaging the individual curves and the resultant study growth curve is presented in Table 7.7.

Table 7.7: Blackpool FRS Growth Curve

Return period (years	Blackpool GC
2	1.00
5	1.40
10	1.68
20	2.05
50	2.31
100	2.62
1000	3.98

7.9 Selection of Growth Curve

The FSU method was used in form of a Pooling Group (PG) assessment for HEP OW9 and also for HEP DG6. The resultant growth curves were found to be very similar to each other. A single site analysis was also carried out at the Ballyedmond gauge, which provides for 41 years of annual maximum data. The resultant growth curves were compared to the Lee CFRAM study growth, the Irish National Growth Curve and also the Douglas FRS growth curve. Figure 7-2 presents a comparison of growth curves assessed.

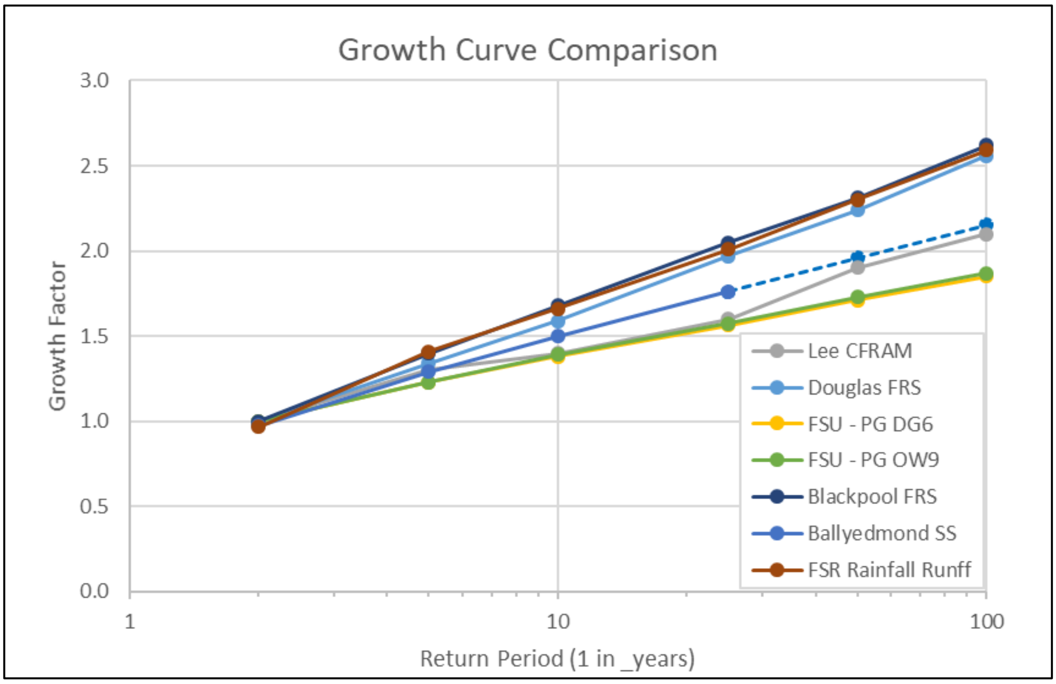

Figure 7-2: Growth Curve Comparison

This shows that the growth curves from the FSU PG assessment were found to be the flattest overall and similar to the Irish National growth curve. The growth curve from the Lee CFRAM study is also comparable up to the 25-year return period and found slightly steeper than the PG assessment for the higher return periods.

The growth curve from the Douglas FRS was found to be steeper than the growth curve from the Ballyedmond Gauge and this is expected as it represents steeper and smaller catchments. Similarly, the growth curve from the Blackpool FRS was found to be steeper and very similar to the Douglas 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. The Ballyedmond SS growth curve was selected as it provides reasonably high confidence in representing extreme events up to the 25-year return period. For more extreme events, the extrapolated growth factors from the SS analysis at Ballyedmond were found to be lower than the FSR RR method, which was adopted for the 50, 100 and 1000-year return period events.

8. Flow Hydrograph Analysis

8.1 Overview

In order to produce a design hydrograph to provide input to the hydraulic modelling, a hydrograph shape is required. Two different methods to estimate the design hydrograph shape were considered:

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 could be adopted for this study, the FSU methodology provides a number of advantages in comparison to the FSR rainfall-runoff method. These are listed as:

- The FSU method is based on river gauge recordings and utilises long term time series data from the Ballyedmond Gauge and therefore provides catchment specific hydrograph characteristics;
- The FSU method does not consider rainfall recordings and therefore bypasses any errors in rainfall data and uncertainty in its convolution to the hydrograph shape;
- Both the Owenacurra and Dungourney River catchments are reasonably large and therefore similar to most catchments available for hydrograph width analysis as part of the FSU database.

Therefore, the FSU hydrograph width analysis method was selected to derive the design hydrograph shape.

8.2 FSU Hydrograph Width Analysis

Figure 8-1 presents the design flow hydrograph shape for Midleton using the FSU hydrograph width analysis method. A number of recorded hydrographs at the Ballyedmond gauge are also included on the plot. It can be seen that the derived hydrograph width is relatively conservative in comparison to recorded events at Ballyedmond, as both the rising limb and falling limb of the hydrograph is flatter than the various recorded data.

Figure.8-2 presents a comparison of the FSU hydrograph width with the FSR RR hydrograph shape. It can be seen that there is a significant difference in the hydrographs derived from both methods given that the volume of water bounded by the FSR derived hydrograph is much less than the volume bounded by the FSU hydrograph.

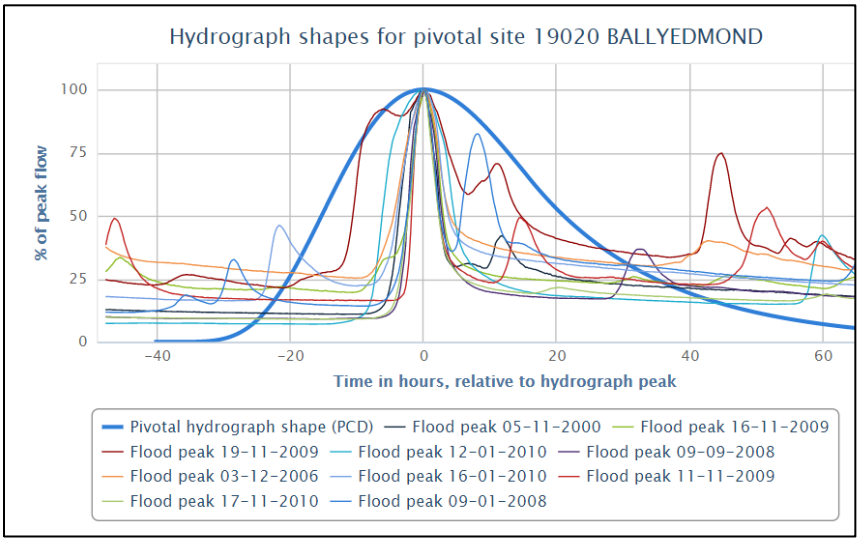

Figure 8-1: Design Flow Hydrograph Shape

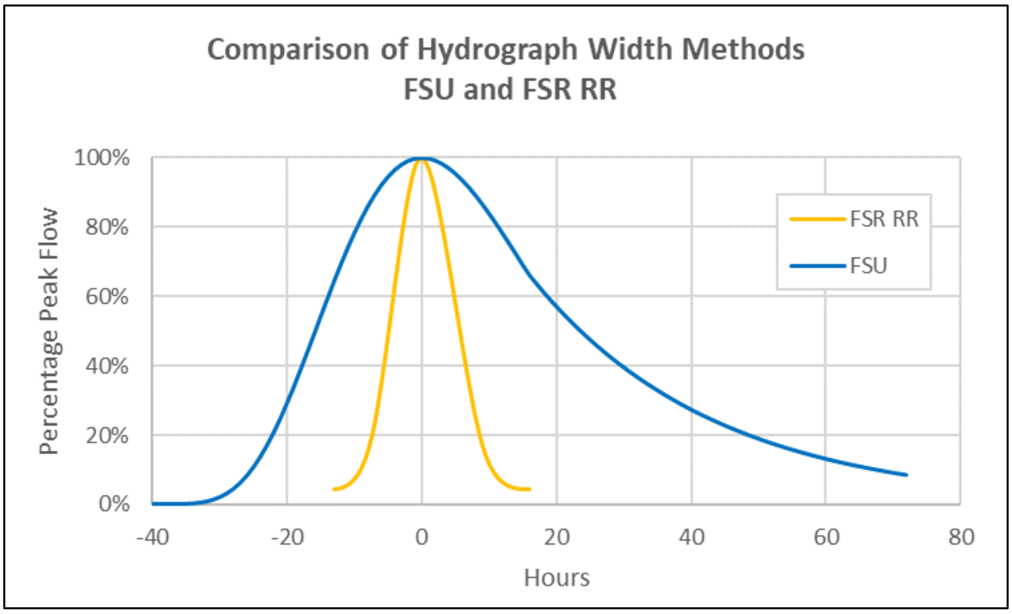

Figure.8-2: Comparison of Hydrograph Shape

9. Design tidal water levels

9.1 Overview

Downstream tidal water level boundary conditions are required for the hydraulic model for both the calibration and design runs. As the boundary of the model is located in the Owenacurra estuary circa 400m downstream of Ballinacurra, tidal water levels from this point in the estuary are used to define the boundary.

Both are now described.

9.1.1 Design model run water levels

For the design runs the tidal boundary has been firstly derived for a point in the outer harbour by combining two separate datasets:

- The extreme value tidal analysis undertaken as part of the Lee CFRAM – this has been used to set peak water level of the tidal signal;
- Recorded tidal water levels from the Cobh tidal gauge has been used to define the shape of the tidal curve;

The tidal signal in the outer harbour area however is not equivalent to the tidal signal in the Owenacurra estuary due to the hydrodynamic and metrological effects associated with the propagation of tide through the harbour. In order to account for this variation, we have used a two-dimensional MIKE 21 model of Cork Harbour to simulate the propagation of the tide through the harbour. The results of the MIKE model in the Owenacurra estuary therefore provide the design water levels for the downstream boundary condition of the model.

The MIKE 21 model is a modified version of the Cork Harbour model Arup developed as part the Lower Lee FRS. The model is calibrated against recorded water levels, current speeds and direction. The reader is referred to the ‘Supplementary Report - Option of Tidal Barrier for further details on the model development and calibration.[4] A schematic of the model is presented in Figure 9-1.

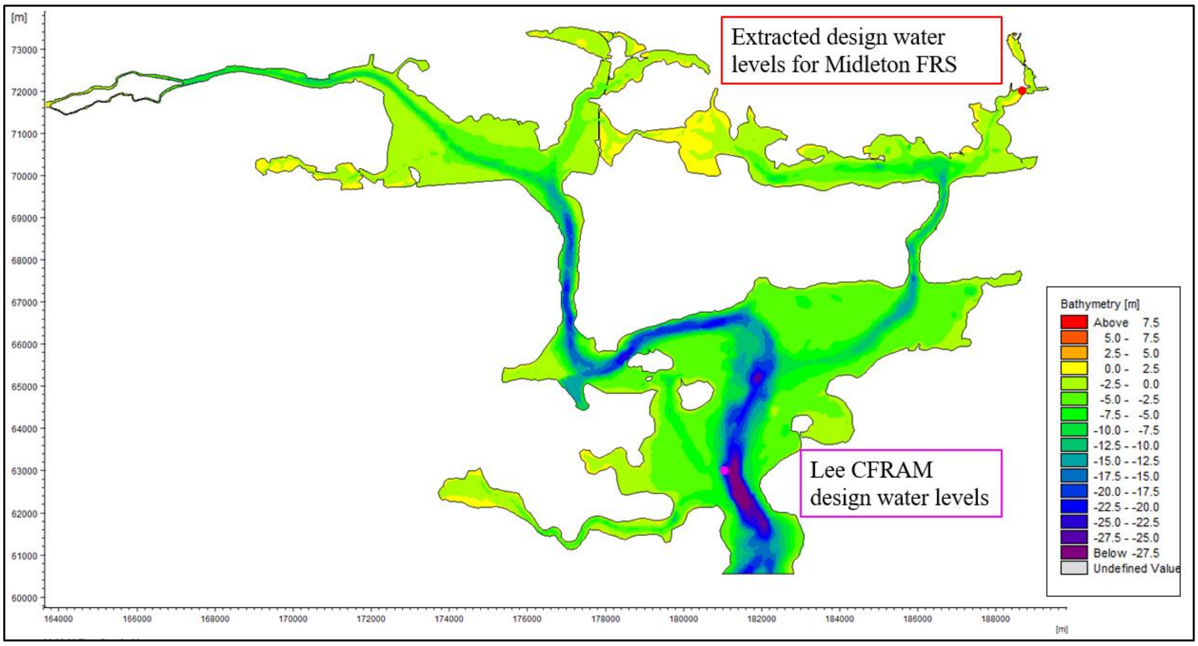

Figure 9-1: Schematic of MIKE 21 model

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[4]The report is available to download from this link: https://s3-eu-west-1.amazonaws.com/arup-s3-lower-lee-frs-ie-wp-static/wp-content/uploads/lee_valley/LLFRS_SupplementaryReportonOptionofTidalBarrier.pdf

The peak tidal water levels in the Owenacurra estuary (adjusted to mODM OSGM15[5]) are presented in Table 9.1.

Table 9.1: Peak Tidal Water Levels

Design Event (AEP)	Peak Tidal Levels in Owenacurra Estuary (mOD Malin)
50%	2.37
20%	2.48
10%	2.55
4%	2.64
2%	2.71
1%	2.78
0.5%	2.84
0.1%	3.00

9.1.2 Calibration model run water levels

For the calibration model we have used actual recorded tidal levels from the Port of Cork Gauge at Cobh as the basis for the boundary condition. The data from the gauge was adjusted to account for the difference in water level between Cobh and the Owenacurra estuary.

[5] As the model of MIKE 21 model of Cork Harbour was set-up and run to the Malin OSGM02 datum, results from the model were reduced by 57mm in order to set them to the Malin OSGM15 datum.

10. Fluvial and Tidal Joint Probability

10.1 Overview

Midleton is at risk of both tidal and fluvial flooding. Both sources will therefore contribute to the design flood event and their dependence needs to be assessed through the use of Joint Probability analysis.

Defra[6] have developed two approaches for undertaking Joint Probability analysis:

- The Analytical approach;
- Desktop study approach;

The Analytical approach is a very detailed approach and requires extensive long term records of continuous flow and tidal levels for the study area. As such records are not available for Cork Harbour and are typically not available for most sites in Ireland (or the UK), the desktop study approach is generally used in Ireland and is regarded as the industry standard method.

10.2 Desktop study approach

The desktop study approach requires an estimation of the dependence of river flows and tidal surges. The Defra research provides dependence factors based on dependence categories as outlined in Table 10.1.

Table 10.1: Dependence based on Defra research

Dependence category	Dependence factor (χ)
Independent	0.01
Modestly correlated	0.02
Well correlated	0.45
Strongly correlated	0.095
Super dependent	>/= 0.13

There will be a strong correlation between fluvial events in Midleton and surge events in Cork Harbour given that the meteorological conditions that typically result in high return period fluvial events in the Owenacurra catchment can also lead to surge conditions in the harbour.

A number of sites in the UK referred to in the Defra research have reasonably similar catchment and sea boundary orientations to the Owenacurra catchment which are stated as being either super or strongly correlated. There is therefore a very reasonable justification to assume a well or strong correlation dependence factor for Midleton.

We have adopted a conservative approach in this study and assumed a super dependent dependency between the river flows and tidal surges. A dependence factor (χ) of 0.2 has therefore been selected and has been used to derive tidal/fluvial return periods for the various design events.

The fluvial/tidal scenarios for the existing scenario in Midleton are tabulated in Table 10.2 (Fluvial dominated) and Table 10.3 (Tidal dominated) below. The scenarios highlighted in red represent the required standard of protection the scheme i.e. the preferred flood relief option for Midleton will be required to defend up to and included these fluvial/tidal events.

[6] Use of Joint Probability Methods in Flood Management, A Guide to Best Practice. &D Technical Report FD2308/TR2. Defra/Environment Agency, March 2005.

Table 10.2: Design fluvial-tidal joint probability scenarios – Fluvial Dominant

Scenario	Design Event	Fluvial contribution	Tidal contribution
Fluvial	Q2	Q2	T2
Fluvial	Q5	Q5	T2
Fluvial	Q10	Q10	T2
Fluvial	Q25	Q25	T2
Fluvial	Q50	Q50	T2
Fluvial	Q100	Q100	T5
Fluvial	Q200	Q200	T10
Fluvial	Q1000	Q1000	T50

Table 10.3: Design fluvial-tidal joint probability scenarios –Tidal Dominant

Scenario	Design Event	Fluvial contribution	Tidal contribution
Tidal	T2	Q2	T2
Tidal	T5	Q2	T5
Tidal	T10	Q2	T10
Tidal	T25	Q2	T25
Tidal	T50	Q2	T50
Tidal	T100	Q5	T100
Tidal	T200	Q10	T200
Tidal	T1000	Q50	T1000

11. Climate Change

11.1 Overview

The Climate Change Sectoral Adaptation Plan guidance document prepared by the OPW addresses potential future climate change and presents two possible future scenarios: the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS). 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.

Table 5-1 of the OPW report presents the uplifts on the current scenario for both the MRFS and HEFS. These are reproduced in the Figure 11-1 below.

Parameter	MRFS	HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Peak 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: Reduction in the time to peak (Tp) to allow 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 temporary increased runoff rates that may arise following felling of forestry.

Figure 11-1: Extract from the Climate Change Sectoral Adaptation Plan

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.

The potential impacts of climate change will be further assessed as part of the sensitivity analysis carried out using the hydraulic model. Please refer to the Midleton FRS - Hydraulics Report (Arup, October 2022).

12. Conclusion

A detailed hydrological analysis has been undertaken to determine design flows for the Midleton FRS. 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 flood flow (Qmed) estimates were produced for key points in the study area. Given that many 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, FSR RR and IH124. The analysis is presented in Section 6.

A rating review of the existing hydrometric gauge at Ballyedmond was also carried out and a revised rating curve was generated. Two missing years of annual maximum data were also generated using the FSSR 16 method.

The revised rating curve was then used to update the high flow series at the gauge. The updated flows were then analysed to provide a final Qmed, of 24.46m^3/s at the gauge site (OW3). The length of the gauge record is 41 years providing a reasonably good confidence in the estimate produced by this method.

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 IH124 index flows for HEPs on small catchments and the FSU index flows for remaining HEPs, as they appear to be conservative, while still remaining reasonably consistent with other methods. Table 12.1 presents the index flows.

Table 12.1: Index Flows

HEP Location	Index Flow (m3/s)
Bal1*	0.99
DG3	13.36
DG4	14.85
DG6	15.48
EL1*	3.10
GL1*	4.89
HAG2*	3.61
OAT1*	1.88
OAT3*	3.56
OW3	25.74
OW4	25.93
OW5*	7.54
OW6	31.63
OW7	31.73
OW8	32.35
OW9	32.72
OW10	45.78
* HEP located on small catchment	

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 Single Site Analysis at Ballyedmond up to the 25-year return period and the FSR RR method for the more extreme events. The study growth curve is presented in Table 12.2 and corresponding design flows are shown in Table 12.3.

Table 12.2: Study Growth Curve

Return period (years	Study Growth Curve
2	0.97
5	1.29
10	1.50
25	1.76
50	2.30
100	2.59
200	3.01

Return period (years	Study Growth Curve
1000	3.96

Table 12.3: Design Flows in m^3/s

HEP Location	Return Period (1in _ years)							
	2	5	10	25	50	100	200	1000
Bal1*	0.96	1.28	1.49	1.74	2.28	2.56	2.98	3.92
DG3	12.96	17.24	20.04	23.52	30.73	34.60	40.22	52.91
DG4	14.40	19.15	22.27	26.13	34.15	38.45	44.69	58.79
DG6	15.01	19.97	23.22	27.24	35.60	40.09	46.59	61.30
EL1*	3.01	4.00	4.65	5.46	7.13	8.03	9.34	12.28
GL1*	4.74	6.30	7.33	8.60	11.23	12.65	14.70	19.34
HAG2*	3.51	4.66	5.42	6.36	8.31	9.36	10.88	14.31
OAT1*	1.82	2.43	2.82	3.31	4.33	4.87	5.66	7.45
OAT3*	3.46	4.60	5.35	6.27	8.20	9.23	10.73	14.11
OW3	24.97	33.21	38.61	45.31	59.21	66.67	77.48	101.94
OW4	25.15	33.45	38.89	45.63	59.64	67.15	78.04	102.68
OW5*	7.31	9.73	11.31	13.27	17.34	19.53	22.70	29.86
OW6	30.68	40.80	47.45	55.67	72.75	81.92	95.21	125.26
OW7	30.78	40.94	47.60	55.85	72.99	82.19	95.52	125.67
OW8	31.38	41.73	48.53	56.94	74.41	83.79	97.38	128.11
OW9	31.74	42.21	49.08	57.59	75.26	84.75	98.49	129.58
OW10	44.41	59.06	68.67	80.57	105.29	118.57	137.80	181.29
* HEP located on small catchment								

For HEPs relating to small catchments (BAL1, EL1, GL1, HAG2, OAT1, OAT3 and OW5) further work is being undertaken in utilising the hydraulic model to inform the design flow method.

Design tidal water levels for the Owenacurra estuary have been derived by utilising (1) the findings of an extreme value analysis of design water levels in the outer harbour undertaken as part of the Lee CFRAM study and, (2) recorded water level data from Cobh. A 2D hydrodynamic model of the harbour was used to model the propagation of the derived design water levels in the outer harbour up into the Owenacurra estuary in order to accurately account for hydrodynamic and meteorological effects.

A joint probability assessment of fluvial/tidal events has also been undertaken as part of the study which allows for combinations of fluvial and tidal events for each joint probability event to be derived.

Appendix A

National Flood Hazard Mapping Report

A.1 National Flood Hazard Mapping Reports

Please see National Flood Hazard Mapping Reports overleaf.

OPW National Flood Hazard Mapping

Summary Local Area Report

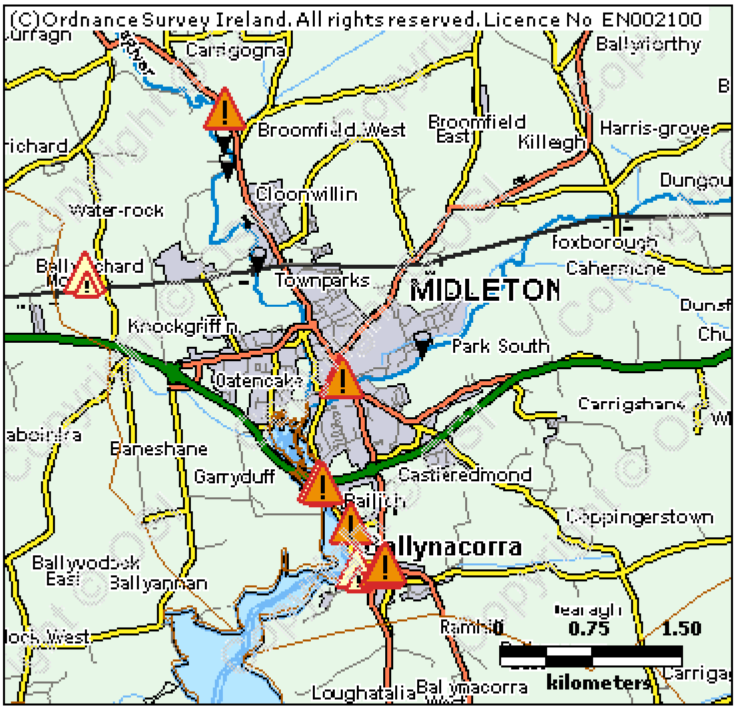
This Flood Report summarises all flood events within 2.5 kilometres of the map centre.

The map centre is in:

County: Cork

NGR: W 884 735

This Flood Report has been downloaded from the Web site www.floodmaps.ie. The users should take account of the restrictions and limitations relating to the content and use of this Web site that are explained in the Disclaimer box when entering the site. It is a condition of use of the Web site that you accept the User Declaration and the Disclaimer.



Map Scale 1:62,129

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.

13 Results

1. Midleton, Co. Cork. 5th June 2012
County: Cork
Start Date: 05/Jun/2012
Flood Quality Code:3
Additional Information: Reports (1) More Mapped Information

2. Flood Report Bailick Road Midleton 8th of October 2014
County: Cork
Start Date: 08/Oct/2014
Flood Quality Code:3
Additional Information: Reports (1) More Mapped Information

3. Main Street & Bailick Road Midleton Co.Cork on 3rd February 2014
County: Cork
Start Date: 03/Feb/2014
Flood Quality Code:3
Additional Information: Reports (1) More Mapped Information

4. Ballinacurra Village Co.Cork on 3rd.February 2014.
County:
Start Date: 03/Feb/2014
Flood Quality Code:3
Additional Information: Reports (1) More Mapped Information

5. Midleton, Co.Cork 2nd January 2014
County: Cork
Start Date: 02/Jan/2014
Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

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6. Flooding in Midleton 25th July 2013 — Start Date: 25/Jul/2013
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

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7. Flooding at Ballinacurra, Midleton, Co. Cork on 25th July 2013 — Start Date: 25/Jul/2013
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

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8. Flooding at Midleton Co.Cork 5th June 2012 — Start Date: 05/Jun/2012
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

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9. Road 96303 Ballynacorra near Midleton Oct 2004 — Start Date: 27/Oct/2004
County: — Flood Quality Code:4

Additional Information: Reports (1) More Mapped Information

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10. Midleton Broomfield West Nov 2000 — Start Date: 05/Nov/2000
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

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11. Water Rock Midleton, Cork Recurring — Start Date:
County: Cork — Flood Quality Code:3

Additional Information: Reports (1) More Mapped Information

---

12. Bailich Road Midleton recurring — Start Date:
County: Cork — Flood Quality Code:4

Additional Information: Reports (1) More Mapped Information

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13. Road 96303 Ballynacorra near Midleton recurring — Start Date:
County: — Flood Quality Code:4

Additional Information: Reports (1) More Mapped Information

Appendix B

Hydrology Calculations

B.1 Hydrology Calculations

This section presents details on the hydrological flow estimation.

B.1.1 FSU Index Flood Estimation – 7 Variable Equation

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_990_4

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	2.55	km^2	Catchment Area
BFIsoils	=	0.66		Base flow index derived from soils data
SAAR	=	1014	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.61		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	0.58	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) = **0.28** m³/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name Ballyedmond
Pivotal Site Station Number 19020

Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*(1+URBEXT)1.4*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**0.44**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**0.44**	m³/s	

ARUP

HEP DG3

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0	**Subcatchment:**	19_1902_4

2.0 Flood Studies Update Physical Catchment Descripto

AREA	=	37.57	km^2	Catchment Area
BFIsoils	=	0.66		Base flow index derived from soils data
SAAR	=	1161	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.95		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	11.60	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) = **8.42** m³/s

4.0 Qmed Adjustment Factor (Pivotal S

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**13.35**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	**0.00**		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	**1.00**		
Qmed (urban, adjusted)	=	**13.35**	m³/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_1957_2

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	49.52	km^2	Catchment Area
BFIsoils	=	0.69		Base flow index derived from soils data
SAAR	=	1137	mm	Standard annual average rainfall (1961-1990)
FARL	=	0.98		Flood attenuation by reservoirs and lakes
DRAIND	=	0.83		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	11.19	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) = **9.35** m³/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name Ballyedmond
Pivotal Site Station Number 19020

Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**14.83**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.001		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.0009		
Qmed (urban, adjusted)	=	**14.85**	m³/s	

ARUP

HEP DG6

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0	**Subcatchment:**	19_1957_5

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	52.43	km^2	Catchment Area
BFIsoils	=	0.69		Base flow index derived from soils data
SAAR	=	1132	mm	Standard annual average rainfall (1961-1990)
FARL	=	0.98		Flood attenuation by reservoirs and lakes
DRAIND	=	0.81		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	9.94	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) = **9.52** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Sit

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*(1+URBEXT)1.48*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**15.11**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	**0.02**		
UAF	=	*$(1+URBEXT)^{1.482}$*		*Urban adjustment factor*
UAF	=	**1.02**		
Qmed (urban, adjusted)	=	**15.48**	m^3/s	

ARUP

HEP EL1

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_1462_5

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	8.25	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1103	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.55		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	26.22	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) = **1.79** m³/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name Ballyedmond

Pivotal Site Station Number 19020

Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*(1+URBEXT)1.4*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**2.84**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**2.84**	m³/s	

ARUP

HEP GL1

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0	**Subcatchment:**	19_965_4

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	12.72	km^2	Catchment Area
BFIsoils	=	0.67		Base flow index derived from soils data
SAAR	=	1171	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.94		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	17.37	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) = **3.29** m³/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**5.22**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**5.22**	m³/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_1721_7

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	10.33	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1059	mm	Standard annual average rainfall (1961-1990)
FARL	=	0.92		Flood attenuation by reservoirs and lakes
DRAIND	=	0.49		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	1.67	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) = **1.02** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal siteestimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**1.62**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**1.62**	m^3/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: Sink - Not indicated on FSU Web Portal (Manual)

2.0 Flood Studies Update Physical Catchment Descriptors

AREA	=	4.21	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1051	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.15		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	1.77	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) = **0.35** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Sit

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**0.56**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.26		HEP OAT1
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	**1.40**		
Qmed (urban, adjusted)	=	**0.79**	m^3/s	

ARUP

HEP OAT3

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0	**Subcatchment:**	19_1959_2 - PCDs (incl. catchment area) corrected from FSU node

2.0 Flood Studies Update Physical Catchment Descripto

AREA	=	10.33	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1047	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.21		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	1.77	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)	=	**0.908**	m^3/s

4.0 Qmed Adjustment Factor (Pivotal S

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**1.44**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	**0.16**		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	**1.25**		
Qmed (urban, adjusted)	=	**1.80**	m^3/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0	**Subcatchment:**	19020 - at Ballyedmont

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	73.9548	km^2	Catchment Area
BFIsoils	=	0.664		Base flow index derived from soils data
SAAR	=	1179.07	mm	Standard annual average rainfall (1961-1990)
FARL	=	1		Flood attenuation by reservoirs and lakes
DRAIND	=	0.989		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	11.0166	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) = **16.22** m³/s

4.0 Qmed Adjustment Factor (Pivotal Site

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**25.74**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	**0.00**		
UAF	=	$(1+URBEXT)^{1.482}$		*Urban adjustment factor*
UAF	=	**1.00**		
Qmed (urban, adjusted)	=	**25.74**	m³/s	

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_712_6

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	77.09	km^2	Catchment Area
BFIsoils	=	0.67		Base flow index derived from soils data
SAAR	=	1177	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.95		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	10.40	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) = **16.34** m³/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name Ballyedmond

Pivotal Site Station Number 19020

Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**25.93**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**25.93**	m³/s	

HEP OW5

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_711_1

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	21.34	km^2	Catchment Area
BFIsoils	=	0.67		Base flow index derived from soils data
SAAR	=	1143	mm	Standard annual average rainfall (1961 - 1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.81		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	17.34	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) = **4.87** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name Ballyedmond

Pivotal Site Station Number 19020

Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**7.73**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	**0.00**		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	**1.00**		
Qmed (urban, adjusted)	=	**7.73**	m^3/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0	**Subcatchment:**	19_1955_2

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	98.98	km^2	Catchment Area
BFIsoils	=	0.67		Base flow index derived from soils data
SAAR	=	1168	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.92		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	9.89	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) = **19.92** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name Ballyedmond
Pivotal Site Station Number 19020

Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**31.61**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.0003		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.0004		
Qmed (urban, adjusted)	=	**31.63**	m^3/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_1955_4

2.0 Flood Studies Update Physical Catchment Descriptors

AREA	=	99.47	km^2	Catchment Area
BFIsoils	=	0.67		Base flow index derived from soils data
SAAR	=	1168	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.93		Drainage density, relates to the length stream network and catchment area NETLEN/AREA)
S1085	=	9.68	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) = **19.94** m³/s

4.0 Qmed Adjustment Factor (Pivotal Sit

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**31.64**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.002		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.003		
Qmed (urban, adjusted)	=	**31.74**	m³/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Updat

1.0 Subcatchment: 19_1955_6

2.0 Flood Studies Update Physical Catchment Descripto

AREA	=	105.10	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1163	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.89		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	8.88	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) = **20.20** m^3/s

4.0 Qmed Adjustment Factor (Pivotal

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**32.05**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.006		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.009		
Qmed (urban, adjusted)	=	**32.35**	m^3/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_1955_7

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	105.87	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1162	mm	Standard annual average rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.89		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	8.90	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) = **20.28** m^3/s

4.0 Qmed Adjustment Factor (Pivotal Site

Pivotal Site Name		Ballyedmond		
Pivotal Site Station Number		19020		
Qmed piv (gauged)	=	24.46	m^3/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m^3/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**32.19**	m^3/s	

5.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	**0.01**		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	**1.02**		
Qmed (urban, adjusted)	=	**32.72**	m^3/s	

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update

1.0 Subcatchment: 19_1955_7 + 19_1957_6

2.0 Flood Studies Update Physical Catchment Descriptors:

Descriptor		Value	Unit	Description
AREA	=	158.51	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1147	mm	Standard annual average rainfall (1961-1990)
FARL	=	0.99		Flood attenuation by reservoirs and lakes
DRAIND	=	0.85		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	9.39	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) = **28.22** m³/s

4.0 Qmed Adjustment Factor (Pivotal Site)

Pivotal Site Name Ballyedmond
Pivotal Site Station Number 19020

Qmed piv (gauged)	=	24.46	m³/s	Qmed at the pivotal site from gauge records
Qmed piv (rural, PCD)	=	16.22	m³/s	Qmed at the pivotal site estimated from PCD equation
URBEXT	=	0.00		From FSU Webportal
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.00		
Qmed piv (Urban, PCD)	=	16.22		
AdjFac	=	*Qmed piv (gauged)/Qmed piv (rural, PCD)*		
AdjFac	=	1.51		
Error of estimate for pivot st		1.28		*SE(Qmed gauge) = (st.dev)/(Sqrt(N))*
Total adjustment factor		**1.59**		*(Qmed piv (gauged) + SE) / Qmed piv (PCD)*
Qmed (rural, adjusted)	=	*AdjFac x Qmed (rural, PCD) for subject site*		
Qmed (rural, adjusted)	=	**44.78**	m³/s	

5.0 Adjustment for Urbanisation

Urban area	=		km²	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.02		
UAF	=	*$(1+URBEXT)^{1.48}$*		*Urban adjustment factor*
UAF	=	1.022		
Qmed (urban, adjusted)	=	**45.78**	m³/s	

B.1.2 FSU Index Flood Estimation – Method 4.2a

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update **Method 4.2a**

1.0	**Subcatchment:**	19_990_4

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	2.55	km^2	Catchment Area
BFIsoils	=	0.66		Base flow index derived from soils data
SAAR	=	1014	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.61		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	0.58	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) $2.0951 \times 10^{-5}\ AREA^{0.9245}\ BFIsoils^{-0.9030}\ SAAR^{1.2695}\ FARL^{2.3163}\ S1085^{0.2513}$

Qmed (rural, PCD) = **0.41** m^3/s

4.0 Adjustment for Urbanisation

Urban area	=	0.00	km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**0.41**	m^3/s	

5.0 Standard Factorial Error

Standard Factorial Error	=	1.686	
Qbar (68% Confidence)	=	**0.70**	m^3/s

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update **Method 4.2a**

1.0 Subcatchment: 19_1462_5

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	8.25	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1103	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.55		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	26.22	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) $2.0951 \times 10^{-5}\ AREA^{0.9245}\ BFIsoils^{-0.9030}\ SAAR^{1.2695}\ FARL^{2.3163}\ S1085^{0.2513}$

Qmed (rural, PCD) = **3.45** m^3/s

4.0 Adjustment for Urbanisation

Urban area	=	0.00	km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**3.45**	m^3/s	

5.0 Standard Factorial Error

Standard Factorial Error	=	1.686	
Qbar (68% Confidence)	=	**5.82**	m^3/s

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update **Method 4.2a**

1.0 Subcatchment: 19_965_4

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	12.72	km^2	Catchment Area
BFIsoils	=	0.67		Base flow index derived from soils data
SAAR	=	1171	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.94		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	17.37	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) $2.0951 \times 10^{-5}\ AREA^{0.9245}\ BFIsoils^{-0.9030}\ SAAR^{1.2695}\ FARL^{2.3163}\ S1085^{0.2513}$

Qmed (rural, PCD) = **5.10** m^3/s

4.0 Adjustment for Urbanisation

Urban area	=	0.00	km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**5.10**	m^3/s	

5.0 Standard Factorial Error

Standard Factorial Error	=	1.686	
Qbar (68% Confidence)	=	**8.61**	m^3/s

ARUP

HEP HAG2

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update **Method 4.2a**

1.0 Subcatchment: 19_1721_7

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	10.33	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1059	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	0.92		Flood attenuation by reservoirs and lakes
DRAIND	=	0.49		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	1.67	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) $2.0951 \times 10^{-5}\ AREA^{0.9245}\ BFIsoils^{-0.9030}\ SAAR^{1.2695}\ FARL^{2.3163}\ S1085^{0.2513}$

Qmed (rural, PCD) = **1.69** m^3/s

4.0 Adjustment for Urbanisation

Urban area	=	0.00	km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**1.69**	m^3/s	

5.0 Standard Factorial Error

Standard Factorial Error	=	1.686	
Qbar (68% Confidence)	=	**2.84**	m^3/s

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update **Method 4.2a**

1.0 Subcatchment: Sink - Not indicated on FSU Web Portal (Manual)

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	4.21	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1051	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.15		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	1.77	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) $2.0951 \times 10^{-5}\ AREA^{0.9245}\ BFIsoils^{-0.9030}\ SAAR^{1.2695}\ FARL^{2.3163}\ S1085^{0.2513}$

Qmed (rural, PCD) = **0.89** m^3/s

4.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.40		
Qmed (urban, adjusted)	=	**1.25**	m^3/s	

5.0 Standard Factorial Error

Standard Factorial Error	=	1.686	
Qbar (68% Confidence)	=	**2.10**	m^3/s

ARUP

HEP OAT3

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update **Method 4.2a**

1.0 Subcatchment: 19_1959_2 - PCDs (incl. catchment area) corrected from FSU node

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	10.33	km^2	Catchment Area
BFIsoils	=	0.68		Base flow index derived from soils data
SAAR	=	1047	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.21		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	1.77	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) $2.0951 \times 10^{-5}\ AREA^{0.9245}\ BFIsoils^{-0.9030}\ SAAR^{1.2695}\ FARL^{2.3163}\ S1085^{0.2513}$

Qmed (rural, PCD) = **2.03** m^3/s

4.0 Adjustment for Urbanisation

Urban area	=		km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.25		
Qmed (urban, adjusted)	=	**2.54**	m^3/s	

5.0 Standard Factorial Error

Standard Factorial Error	=	1.686	
Qbar (68% Confidence)	=	**4.28**	m^3/s

ARUP

HEP OW5

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Update **Method 4.2a**

1.0 Subcatchment: 19_711_1

2.0 Flood Studies Update Physical Catchment Descriptors:

AREA	=	21.34	km^2	Catchment Area
BFIsoils	=	0.67		Base flow index derived from soils data
SAAR	=	1143	mm	Standard annual averagen rainfall (1961-1990)
FARL	=	1.00		Flood attenuation by reservoirs and lakes
DRAIND	=	0.81		Drainage density, relates to the length stream network and catchment area (NETLEN/AREA)
S1085	=	17.34	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) $2.0951 \times 10^{-5}\ AREA^{0.9245}\ BFIsoils^{-0.9030}\ SAAR^{1.2695}\ FARL^{2.3163}\ S1085^{0.2513}$

Qmed (rural, PCD) = **7.92** m^3/s

4.0 Adjustment for Urbanisation

Urban area	=	0.00	km^2	Urbanised area as per Corine landcover 2000 (optional)
URBEXT	=	0.00		
UAF	=	$(1+URBEXT)^{1.48}$		*Urban adjustment factor*
UAF	=	1.00		
Qmed (urban, adjusted)	=	**7.92**	m^3/s	

5.0 Standard Factorial Error

Standard Factorial Error	=	1.686	
Qbar (68% Confidence)	=	**13.36**	m^3/s

B.1.3 FSR Index Flood Estimate

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0	**Subcatchment:**	19_990_4

2.0 Physical Catchment Descriptors:

AREA	=	2.55
MSL	=	1.55
J50K	=	1.00
J1inch	=	1.05
Fs	=	0.99
H10	=	
H85	=	
S1085	=	0.58
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1014
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **0.32** m^3/s

4.0 Adjustment for Urbanisation

CWI	=	125.00	Catchment Wetness Index
PR	=	*(102.4 x SOIL) + 0.28 x (CWI-125)*	
PR	=	**30.72**	

Qu bar/Qr bar = $(1 + URBAN)^{1.5}\ (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar	=	**1.00**	
Qbar_urban	=	**0.32**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.5	
Qbar (68% Confidence)	=	**0.48**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1902_4

2.0 Physical Catchment Descriptors:

AREA	=	37.57
MSL	=	16.64
J50K	=	13.00
J1inch	=	13.34
Fs	=	0.82
H10	=	
H85	=	
S1085	=	11.60
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1161
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **7.45** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

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

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.00**

Qbar_urban = **7.45** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **11.18** m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1957_2

2.0 Physical Catchment Descriptors:

AREA	=	49.52
MSL	=	17.14
J50K	=	13.00
J1inch	=	13.34
Fs	=	0.58
H10	=	
H85	=	
S1085	=	11.19
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1137
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **8.73** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

PR = $(102.4 \times SOIL) + 0.28 \times (CWI-125)$

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.00**

Qbar_urban = **8.74** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **13.11** m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1957_5

2.0 Physical Catchment Descriptors:

AREA	=	52.43
MSL	=	18.64
J50K	=	14.00
J1inch	=	14.36
Fs	=	0.59
H10	=	
H85	=	
S1085	=	9.94
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.02
SAAR	=	1132
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **9.04** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

PR = $(102.4 \times SOIL) + 0.28 \times (CWI-125)$

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.03**

Qbar_urban = **9.32** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **13.98** m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1462_5

2.0 Physical Catchment Descriptors:

AREA	=	8.25
MSL	=	3.29
J50K	=	1.00
J1inch	=	1.05
Fs	=	0.19
H10	=	
H85	=	
S1085	=	26.22
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1103
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **1.37** m^3/s

4.0 Adjustment for Urbanisation

CWI	=	125.00	Catchment Wetness Index
PR	=	*(102.4 x SOIL) + 0.28 x (CWI-125)*	
PR	=	**30.72**	

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar	=	**1.00**	
Qbar_urban	=	**1.37**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.5	
Qbar (68% Confidence)	=	**2.06**	m^3/s

ARUP

HEP GL1

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_965_4

2.0 Physical Catchment Descriptors:

AREA	=	12.72
MSL	=	6.29
J50K	=	5.00
J1inch	=	5.18
Fs	=	0.97
H10	=	
H85	=	
S1085	=	17.37
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1171
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **2.97** m^3/s

4.0 Adjustment for Urbanisation

CWI	=	125.00	Catchment Wetness Index
PR	=	*(102.4 x SOIL) + 0.28 x (CWI-125)*	
PR	=	**30.72**	

Qu bar/Qr bar = $(1 + URBAN)^{1.5}\ (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar	=	**1.00**	
Qbar_urban	=	**2.97**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.5	
Qbar (68% Confidence)	=	**4.46**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1721_7

2.0 Physical Catchment Descriptors:

AREA	=	10.33
MSL	=	4.56
J50K	=	1.00
J1inch	=	1.05
Fs	=	0.11
H10	=	
H85	=	
S1085	=	1.90
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1059
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **0.96** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

PR = $(102.4 \times SOIL) + 0.28 \times (CWI-125)$

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.00**

Qbar_urban = **0.96** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **1.44** m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: Sink - Manual catchment deriviation

2.0 Physical Catchment Descriptors:

AREA	=	4.21	
MSL	=	0.73	
J50K	=	1.00	
J1inch	=	1.05	
Fs	=	0.53	
H10	=		
H85	=		
S1085 (m/km)	=	1.77	
LAKE	=	0.00	
Urban Area	=		
URBAN	=	0.26	(includes future development)
SAAR	=	1051	
SOIL	=	0.30	

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **0.56** m³/s

4.0 Adjustment for Urbanisation

CWI	=	125.00	Catchment Wetness Index
PR	=	*(102.4 x SOIL) + 0.28 x (CWI-125)*	
PR	=	**30.72**	

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar	=	**1.56**	
Qbar_urban	=	**0.88**	m³/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.5	
Qbar (68% Confidence)	=	**1.31**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1959_2 - PCDs (incl. catchment area) corrected from FSU node

2.0 Physical Catchment Descriptors:

AREA	=	10.33	
MSL	=	1.23	
J50K	=	1.00	
J1inch	=	1.05	
Fs	=	0.11	
H10	=		
H85	=		
S1085	=	1.77	
LAKE	=	0.00	
Urban Area	=		
URBAN	=	0.16	(includes future development)
SAAR	=	1047	
SOIL	=	0.30	

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **0.94** m³/s

4.0 Adjustment for Urbanisation

CWI	=	125.00	Catchment Wetness Index
PR	=	*(102.4 x SOIL) + 0.28 x (CWI-125)*	
PR	=	**30.72**	

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar	=	**1.33**	
Qbar_urban	=	**1.25**	m³/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.5	
Qbar (68% Confidence)	=	**1.88**	m^3/s

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19020 - at Ballyedmond

2.0 Physical Catchment Descriptors:

AREA	=	73.95
MSL	=	13.99
J50K	=	27
J1inch	=	27.51
Fs	=	0.87
H10	=	
H85	=	
S1085	=	11.02
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1179
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **14.46** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

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

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.00**

Qbar_urban = **14.46** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **21.69** m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_712_6

2.0 Physical Catchment Descriptors:

AREA	=	77.09
MSL	=	15.99
J50K	=	27
J1inch	=	27.51
Fs	=	0.83
H10	=	
H85	=	
S1085	=	10.40
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1177
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **14.72** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

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

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5}\,(1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.00**

Qbar_urban = **14.72** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **22.07** m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0	**Subcatchment:**	19_711_1

2.0 Physical Catchment Descriptors:

AREA	=	21.34
MSL	=	6.70
J50K	=	7.00
J1inch	=	7.23
Fs	=	0.78
H10	=	
H85	=	
S1085	=	17.34
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1143
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **4.51** m^3/s

4.0 Adjustment for Urbanisation

CWI	=	125.00	Catchment Wetness Index
PR	=	*(102.4 x SOIL) + 0.28 x (CWI-125)*	
PR	=	**30.72**	

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar	=	**1.00**	
Qbar_urban	=	**4.51**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.5	
Qbar (68% Confidence)	=	**6.76**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1955_2

2.0 Physical Catchment Descriptors:

AREA	=	98.98
MSL	=	16.67
J50K	=	35.00
J1inch	=	35.57
Fs	=	0.83
H10	=	
H85	=	
S1085	=	9.89
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1168
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **18.39** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

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

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.00**

Qbar_urban = **18.40** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **27.60** m^3/s

ARUP

HEP OW7

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1955_4

2.0 Physical Catchment Descriptors:

AREA	=	99.47
MSL	=	17.67
J50K	=	35.00
J1inch	=	35.57
Fs	=	0.83
H10	=	
H85	=	
S1085	=	9.68
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.00
SAAR	=	1168.00
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **18.40** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

PR = $(102.4 \times SOIL) + 0.28 \times (CWI-125)$

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.00**

Qbar_urban = **18.47** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **27.70** m^3/s

HEP OW8

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0	**Subcatchment:**	19_1955_6

2.0 Physical Catchment Descriptors:

AREA	=	105.10
MSL	=	18.67
J50K	=	36.00
J1inch	=	36.57
Fs	=	0.80
H10	=	
H85	=	
S1085	=	8.88
LAKE	=	0.00
Urban Area	=	
URBAN	=	**0.01**
SAAR	=	1163
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **18.89** m^3/s

4.0 Adjustment for Urbanisation

CWI	=	125.00	Catchment Wetness Index
PR	=	*(102.4 x SOIL) + 0.28 x (CWI-125)*	
PR	=	**30.72**	

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar	=	**1.01**	
Qbar_urban	=	**19.11**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.5	
Qbar (68% Confidence)	=	**28.67**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1955_7

2.0 Physical Catchment Descriptors:

AREA	=	105.87
MSL	=	19.17
J50K	=	36.00
J1inch	=	36.57
Fs	=	0.80
H10	=	
H85	=	
S1085	=	8.90
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.01
SAAR	=	1162
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **18.98** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

PR = $(102.4 \times SOIL) + 0.28 \times (CWI-125)$

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.02**

Qbar_urban = **19.38** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **29.07** m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Flood Studies Report

1.0 Subcatchment: 19_1955_7 + 19_1957_6

2.0 Physical Catchment Descriptors:

AREA	=	158.51
MSL	=	19.17
J50K	=	51.00
J1inch	=	51.63
Fs	=	0.74
H10	=	
H85	=	
S1085	=	9.39
LAKE	=	0.00
Urban Area	=	
URBAN	=	0.01
SAAR	=	1147
SOIL	=	0.30

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **27.27** m^3/s

4.0 Adjustment for Urbanisation

CWI = 125.00 Catchment Wetness Index

PR = $(102.4 \times SOIL) + 0.28 \times (CWI-125)$

PR = **30.72**

Qu bar/Qr bar = $(1 + URBAN)^{1.5} (1 + 0.3 \times URBAN \times (70/PR-1))$

Qu bar/Qr bar = **1.02**

Qbar_urban = **27.85** m^3/s

5.0 Standard Factorial Error

Standard Factorial Error = 1.5

Qbar (68% Confidence) = **41.78** m^3/s

B.1.4 IH 124 – Index Flood Estimation

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Institute of Hydrology Report No.124

1.0	**Subcatchment:**	19_990_4

2.0 Physical Catchment Descriptors:

AREA	=	2.55	km^2	Catchment Area
SAAR	=	1014	mm	Standard annual average rainfall (1961-1990)
SOIL	=	0.30		Base flow index derived from soils data

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD)	=	**0.60**	m^3/s

4.0 Adjustment for Urbanisation

CWI		125.00	Catchment Wetness Index
CIND	=	*102.4SOIL + 0.28(CWI - 125)*	
CIND	=	**30.72**	
URBAN	=	**0.00**	Fraction of urbanised area in the catchment

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

Nc = *0.92-0.00024.S.* *or* *for 500 ≤ SAAR ≤ 1100mm*
0.74-0.000082.SAAR *for 1100 ≤ SAAR ≤ 3000mm*

Nc	=	**0.68**	
Qu bar/Qr bar	=	**0.68**	
Qbar_urban	=	**0.60**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.65	
Qbar (68% Confidence)	=	**0.99**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Institute of Hydrology Report No.124

1.0 Subcatchment: 19_1462_5

2.0 Physical Catchment Descriptors:

AREA	=	8.25	km^2	Catchment Area
SAAR	=	1103	mm	Standard annual average rainfall (1961-1990)
SOIL	=	0.30		Base flow index derived from soils data

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD)	=	**1.88**	m^3/s

4.0 Adjustment for Urbanisation

CWI		125.00		Catchment Wetness Index
CIND	=	*102.4SOIL + 0.28(CWI - 125)*		
CIND	=	**30.72**		
URBAN	=	**0.00**		Fraction of urbanised area in the catchment

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

Nc = *0.92-0.00024.SAAR* or *for 500 ≤ SAAR ≤ 1100mm*
0.74-0.000082.SAAR *for 1100 ≤ SAAR ≤ 3000mm*

Nc	=	**0.65**	
Qu bar/Qr bar	=	**0.65**	
Qbar_urban	=	**1.88**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.65	
Qbar (68% Confidence)	=	**3.10**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Institute of Hydrology Report No.124

1.0	**Subcatchment:**	19_1462_5

2.0 Physical Catchment Descriptors:

AREA	=	12.72	km^2	Catchment Area
SAAR	=	1171	mm	Standard annual average rainfall (1961-1990)
SOIL	=	0.30		Base flow index derived from soils data

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD)	=	**2.96**	m^3/s

4.0 Adjustment for Urbanisation

CWI		125.00		Catchment Wetness Index
CIND	=	*102.4SOIL + 0.28(CWI - 125)*		
CIND	=	**30.72**		
URBAN	=	**0.00**		Fraction of urbanised area in the catchment

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

Nc = *0.92-0.00024.S.* or *for 500 ≤ SAAR ≤ 1100mm*
0.74-0.000082.SAAR *for 1100 ≤ SAAR ≤ 3000mm*

Nc	=	**0.64**	
Qu bar/Qr bar	=	**0.64**	
Qbar_urban	=	**2.96**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.65	
Qbar (68% Confidence)	=	**4.89**	m^3/s

Job Title	Midleton FRS
Job Number	252803
Calculation	Institute of Hydrology Report No.124

1.0 Subcatchment: 19_1721_7

2.0 Physical Catchment Descriptors:

AREA	=	10.33	km^2	Catchment Area
SAAR	=	1059	mm	Standard annual average rainfall (1961-1990)
SOIL	=	0.30		Base flow index derived from soils data

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **2.19** m^3/s

4.0 Adjustment for Urbanisation

CWI 125.00 Catchment Wetness Index

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND = **30.72**

URBAN = **0.00** Fraction of urbanised area in the catchment

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

Nc = 0.92-0.00024.S*i* or for 500 ≤ SAAR ≤ 1100mm
0.74-0.000082.SAAR for 1100 ≤ SAAR ≤ 3000mm

Nc	=	**0.67**	
Qu bar/Qr bar	=	**0.67**	
Qbar_urban	=	**2.19**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.65	
Qbar (68% Confidence)	=	**3.61**	m^3/s

ARUP

HEP OAT1

Job Title	Midleton FRS
Job Number	252803
Calculation	Institute of Hydrology Report No.124

1.0	**Subcatchment:**	Sink - Not indicated on FSU Web Portal (Manual)

2.0 Physical Catchment Descriptors:

AREA	=	4.21	km^2	Catchment Area
SAAR	=	1051	mm	Standard annual average rainfall (1961-1990)
SOIL	=	0.30		Base flow index derived from soils data

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD)	=	**0.98**	m^3/s

4.0 Adjustment for Urbanisation

CWI		125.00	Catchment Wetness Index
CIND	=	*102.4SOIL + 0.28(CWI - 125)*	
CIND	=	**30.72**	
URBAN	=	**0.26**	Fraction of urbanised area in the catchment

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

Nc = *0.92-0.00024.S.* *or* *for 500 ≤ SAAR ≤ 1100mm*
0.74-0.000082.SAAR *for 1100 ≤ SAAR ≤ 3000mm*

Nc	=	**0.67**	
Qu bar/Qr bar	=	**1.17**	
Qbar_urban	=	**1.14**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.65	
Qbar (68% Confidence)	=	**1.88**	m^3/s

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Institute of Hydrology Report No.124

1.0 Subcatchment: 19_1959_2 - PCDs (incl. catchment area) corrected from FSU node

2.0 Physical Catchment Descriptors:

AREA	=	10.33	km^2	Catchment Area
SAAR	=	1047	mm	Standard annual average rainfall (1961-1990)
SOIL	=	0.30		Base flow index derived from soils data

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD) = **2.16** m^3/s

4.0 Adjustment for Urbanisation

CWI 125.00 Catchment Wetness Index

CIND = 102.4SOIL + 0.28(CWI - 125)

CIND	=	**30.72**		
URBAN	=	**0.16**		Fraction of urbanised area in the catchment

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

Nc = *0.92-0.00024.S.* or *for 500 ≤ SAAR ≤ 1100mm*
0.74-0.000082.SAAR *for 1100 ≤ SAAR ≤ 3000mm*

Nc	=	**0.67**	
Qu bar/Qr bar	=	**0.96**	
Qbar_urban	=	**2.16**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.65	
Qbar (68% Confidence)	=	**3.57**	m^3/s

ARUP

Job Title	Midleton FRS
Job Number	252803
Calculation	Institute of Hydrology Report No.124

1.0 Subcatchment: 19_711_1

2.0 Physical Catchment Descriptors:

AREA	=	21.34	km^2	Catchment Area
SAAR	=	1143	mm	Standard annual average rainfall (1961-1990)
SOIL	=	0.30		Base flow index derived from soils data

3.0 Mean Annual Flood (Rural)

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

Qbar (rural, PCD)	=	**4.57**	m^3/s

4.0 Adjustment for Urbanisation

CWI 125.00 Catchment Wetness Index

CIND = *102.4SOIL + 0.28(CWI - 125)*

CIND	=	**30.72**	
URBAN	=	**0.00**	Fraction of urbanised area in the catchment

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

Nc = *0.92-0.00024.S.* *or* *for 500 ≤ SAAR ≤ 1100mm*
0.74-0.000082.SAAR *for 1100 ≤ SAAR ≤ 3000mm*

Nc	=	**0.65**	
Qu bar/Qr bar	=	**0.65**	
Qbar_urban	=	**4.57**	m^3/s

5.0 Standard Factorial Error

Standard Factorial Error	=	1.65	
Qbar (68% Confidence)	=	**7.54**	m^3/s

B.1.5 Pooling Group Assessment FSU

B.1.5.1

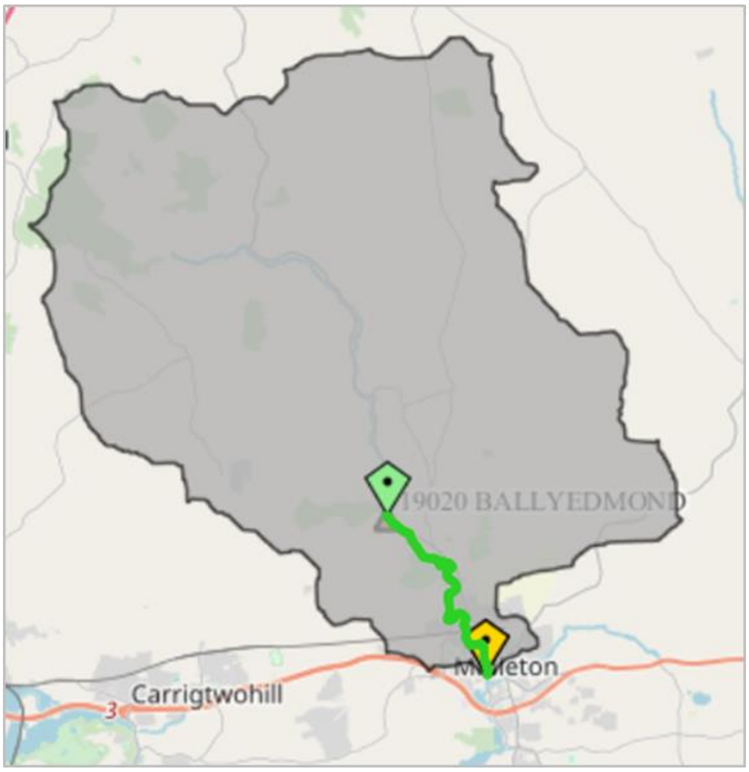

Figure B.12-1: HEP OW9

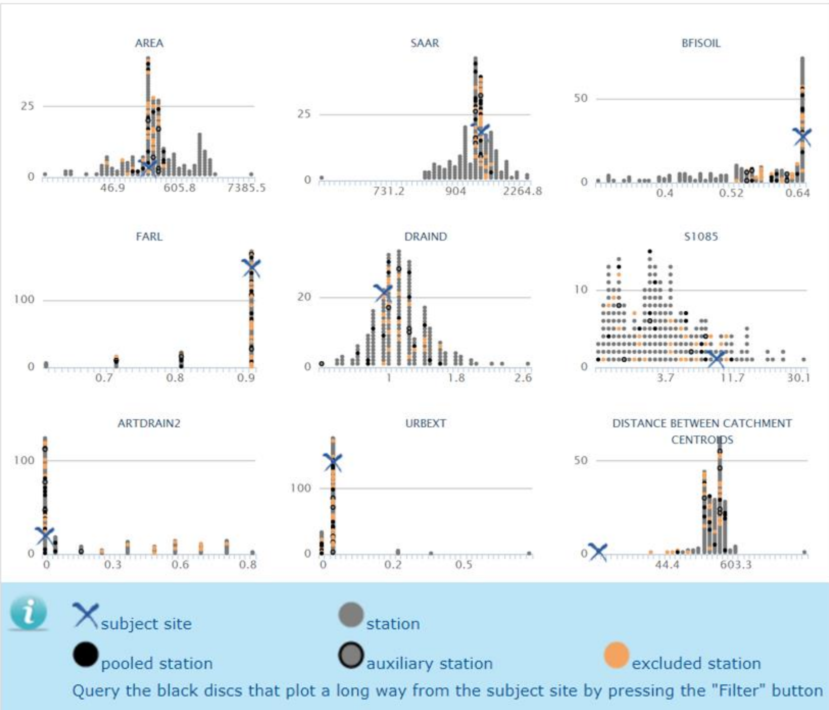

Figure B.12-2: CATs

Table B.1: Pooling Group Members

Station	Euclidean DIST(ij)	# years in FSU database	Cumulative # station-years
19020	0.309	28	28
26018	0.691	48	76
06012	0.696	47	123
25044	0.699	40	163
06070	0.784	27	190
29001	0.791	40	230
16005	0.884	30	260
06011	0.953	48	308
29071	0.977	26	334
35001	0.997	29	363
18005	1.036	50	413
25158	1.076	18	431
29011	1.088	22	453
15007	1.114	25	478
26008	1.119	49	527
07004	1.134	48	575
26006	1.136	52	627
16003	1.165	27	654
26020	1.216	33	687

Legend: Pooled Auxiliary Selected

Table B.2: Members excluded from Pooling Group

Excluded Station	Euclidean DIST(ij)	# years in FSU
19046	0.464	9
19016	0.512	11
19015	0.571	28
25038	0.695	17
16006	0.74	33
25027	0.773	42
13002	0.829	19
26010	0.885	35
25014	0.895	54
34011	0.902	30
26014	0.922	16
25020	0.926	35
18001	0.945	48
30021	0.947	26
16012	1.02	28
22009	1.023	24
30005	1.052	49
30037	1.075	21

Table B.3: Pooled Group Summary

Number of station-years pooled	479
Number of stations	14
Mean length of A-max records pooled	35
Pooled L-CV	0.136
Pooled L-skewness	0.129
Pooled L-kurtosis	0.145
Return period (y):	100
Distribution:	GEV
Heterogeinity statistics based upon weighted S.D. of the L-CVs	
H	54.545
H*	59.177
Heterogeinity statistics based upon average distance from site to the regional average on a graph L-CV VS. L-Skewness	
H	2.373
H*	7.202
Heterogeinity statistics based upon average distance from site to the regional average on a graph L-Skewness VS. L-Kurtosis	
H	0.541
H*	6.671

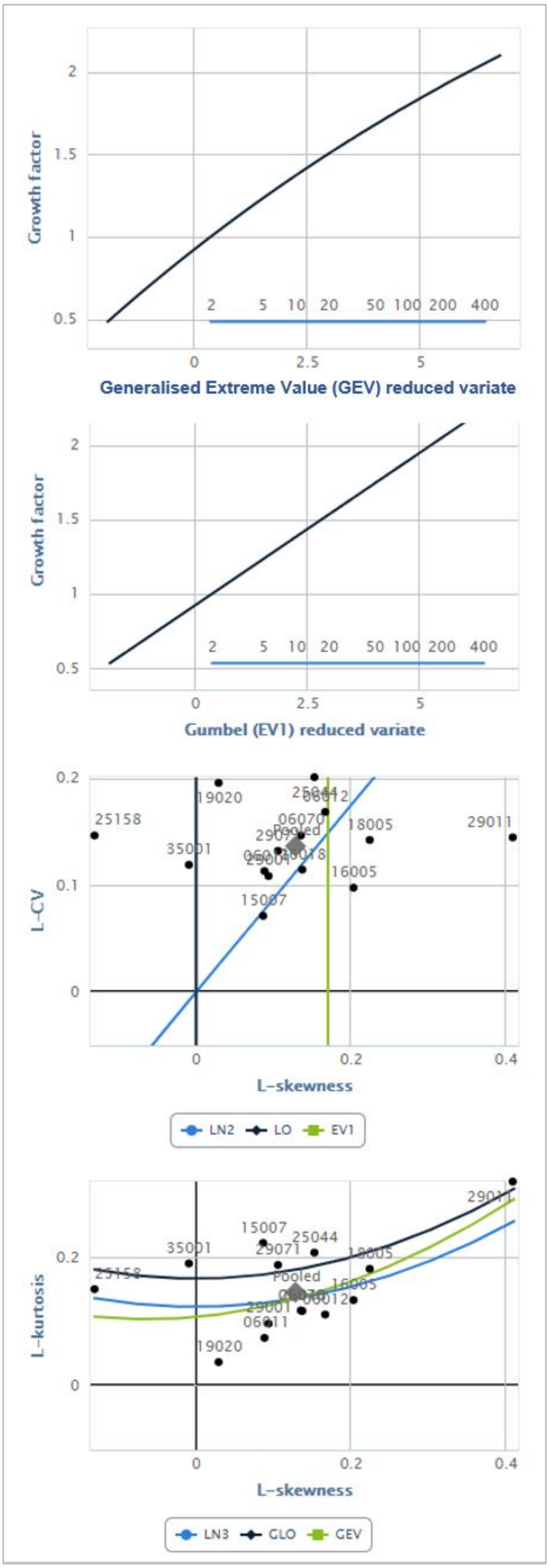

Figure B.12-3: Goodness of Fit

B.1.5.2 HEP DG6

Figure B.12-4: HEP DG6

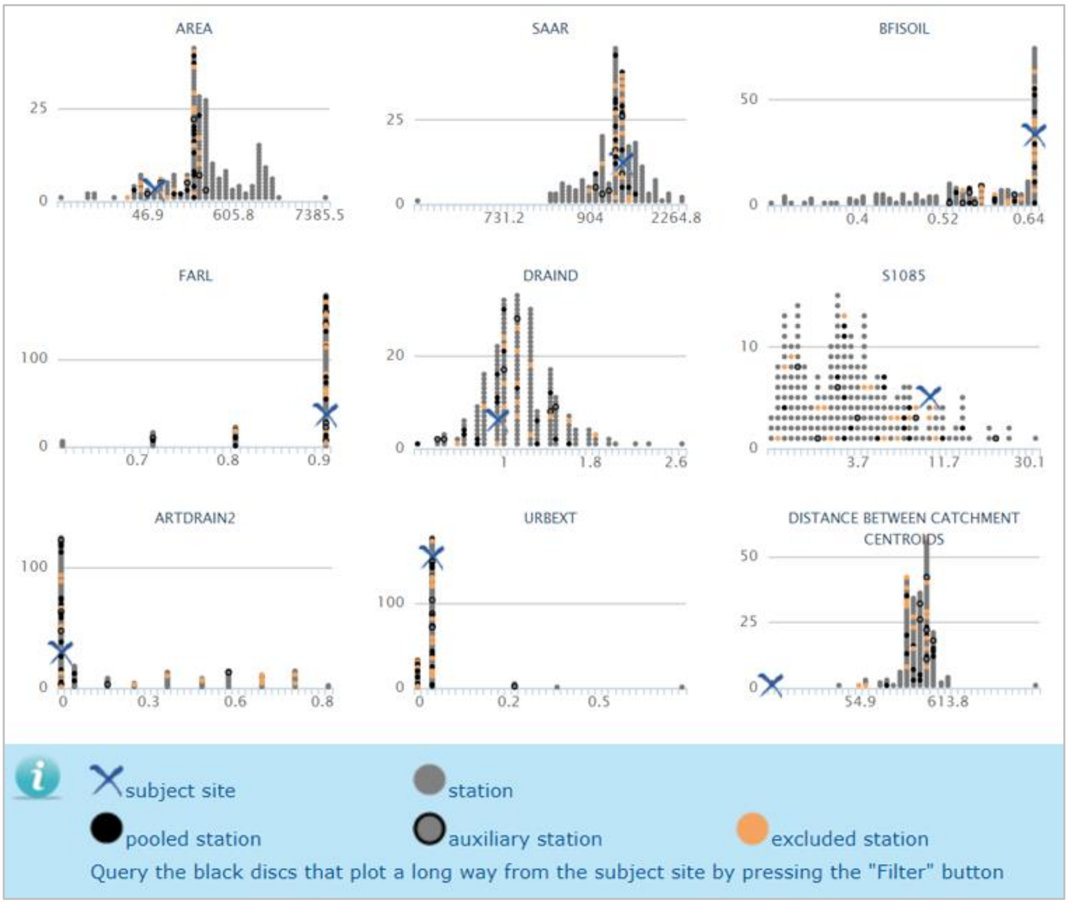

Figure B.12-5: CATs

Table B.4: Pooling Group Members

Station	Euclidean DIST(ij)	# years in FSU database	Cumulative # station-years
19020	0.39	28	28
26018	0.833	48	76
25044	0.911	40	116
19016	0.915	11	127
25040	0.971	19	146
16005	1.005	30	176
06012	1.005	47	223
29001	1.006	40	263
06070	1.046	27	290
29071	1.274	26	316
06011	1.297	48	364
26020	1.339	33	397
25023	1.349	33	430
26009	1.359	35	465
25158	1.371	18	483
29004	1.42	32	515
09010	1.422	19	534
26022	1.453	33	567
34024	1.457	28	595
06031	1.468	18	613
07004	1.471	48	661
26006	1.477	52	713

Legend: Pooled Auxiliary Selected

Table B.5: Members excluded from Pooling Group

Excluded Station	Euclidean DIST(ij)	# years in FSU
19046	0.363	9
13002	0.575	19
22009	0.709	24
30020	0.767	16
16006	0.775	33
25027	0.91	42
26010	0.977	35
26058	1.033	24
25038	1.111	17
25014	1.13	54
19015	1.135	28
25020	1.227	35
30021	1.158	26
25022	1.274	22
34011	1.279	30
06026	1.362	46
16051	1.398	13
26014	1.398	16

Table B.6: Pooled Group Summary

Number of station-years pooled	521
Number of stations	16
Mean length of A-max records pooled	33
Pooled L-CV	0.133
Pooled L-skewness	0.107
Pooled L-kurtosis	0.112
Return period (y):	100
Distribution:	EV1
Heterogeinity statistics based upon weighted S.D. of the L-CVs	
H	57.037
H*	62.186
Heterogeinity statistics based upon average distance from site to the regional average on a graph L-CV VS. L-Skewness	
H	2.017
H*	7.221
Heterogeinity statistics based upon average distance from site to the regional average on a graph L-Skewness VS. L-Kurtosis	
H	-0.321
H*	6.467

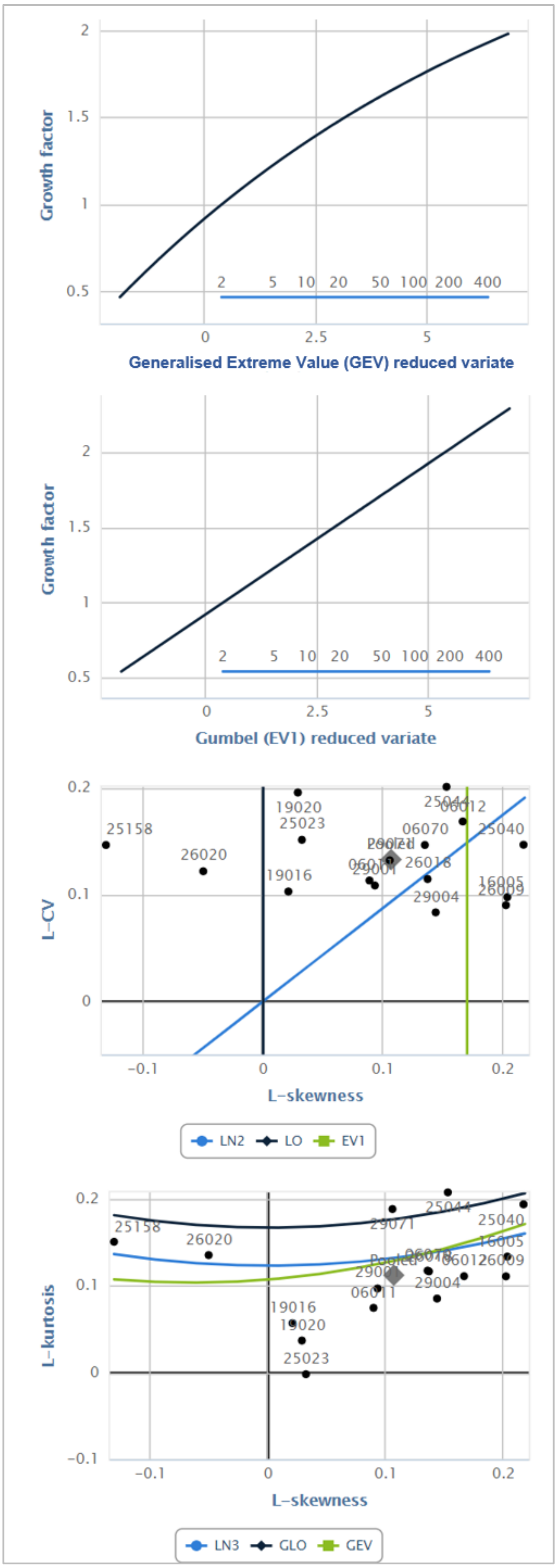

Figure B.12-6: Goodness of Fit

B.1.6 FSR Rainfall Runoff Method – Summary Table

FSR Rainfall Runoff Method - Summary Table

Location	Area	Length	Slope	SAAR	M5-2D	M5-25D	Jenkinson r	Urban Fraction	SPR	Critical Storm Duration
Bal1	2.55	1.55	0.58	1014	66	198	0.27	0.00	30.00	17.97
DG3	37.57	16.64	11.60	1161	71	213	0.27	0.00	30.00	11.51
DG4	49.52	17.14	11.19	1137	71	213	0.27	0.00	30.00	11.73
DG6	52.43	18.64	9.94	1132	71	213	0.27	0.02	30.00	12.43
EL1	8.25	3.29	26.22	1103	70	210	0.27	0.00	30.00	6.06
GL1	12.72	6.29	17.37	1171	70	210	0.27	0.00	30.00	8.05
HAG2	10.33	4.56	1.90	1059	70	210	0.27	0.00	30.00	15.54
OAT1	4.21	0.73	1.77	1051	71	212	0.27	0.26	30.00	10.38
OAT3	10.33	1.23	1.77	1047	71	212	0.27	0.16	30.00	11.73
OW3	73.95	13.99	11.02	1179	72	216	0.27	0.00	30.00	11.25
OW4	77.09	15.99	10.40	1177	72	216	0.27	0.00	30.00	11.82
OW5	21.34	6.70	17.34	1143	71	212	0.27	0.00	30.00	8.18
OW6	98.98	16.67	9.89	1168	71	213	0.27	0.00	30.00	12.14
OW7	99.47	17.67	9.68	1168	71	212	0.27	0.00	30.00	12.39
OW8	105.10	18.67	8.88	1163	71	212	0.27	0.01	30.00	12.90
OW9	105.87	19.17	8.90	1162	71	212	0.27	0.01	30.00	12.97
OW10	158.51	19.42	8.90	1147	71	212	0.27	0.01	30.00	12.75

B.1.7 Dungourney EPA Gauge Data

B.1.8 Design Flows for Small Catchments

The Flood Studies Supplementary Report (FSSR) No 16 method was used to assist in the selection of the most appropriate flow estimation method for small catchments.

Hourly rainfall data from 1st November 2015 until 30 December 2015 recorded at Moore Park was applied using the FSSR16 module of Flood Modeller Pro to simulated flows at each HEP. Figure B.12-7 presents the recorded rainfall data and simulated flows at OW3, as example and
Table B.7 presents peak flows at each HEP.

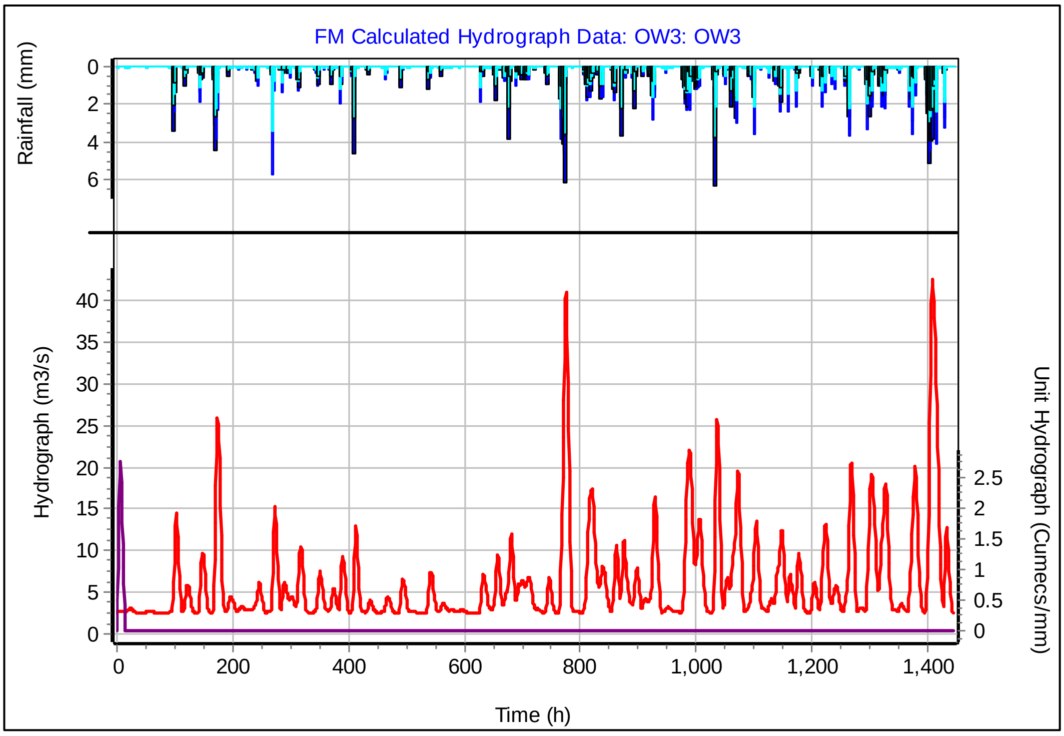

Figure B.12-7: FSSR16 module output for the December 2015 event

Table B.7: Peak flows derived from FSSR16 method for Winter 2015 event

HEP Location	**Peak Flow Winter 2015 Flood** (m³/s)
Bal1	1.17
DG3	17.22
DG4	27.90
DG6	29.28
EL1	5.84
GL1	8.00
HAG2	4.85
OAT1	2.81
OAT3	6.30
OW3	42.52

HEP Location	Peak Flow Winter 2015 Flood
	(m^3/s)
OW4	43.68
OW5	13.28
OW6	55.27
OW7	55.16
OW8	55.74
OW9	58.16
OW10	87.32

Flows derived using the FSSR16 method for the Winter 2015 event (as presented in Table B.7) were then compared to the range of potential design flows based on the FSU Method. The corresponding return period, was then estimated at each HEP and findings are presented in Table B.8.

Table B.8: Severity estimation for event-based flows for each HEP based on the FSU derived design flows

HEP	FSSR 16 Peak Flow Winter 2015 flood	Severity when compared to FSU flows	FSU derived flows (m^3/s) Return Period (1i n _ years)							
Location	(m3/s)	(1 in _ years)	2	5	10	25	50	100	200	1000
Bal1	1.17	97	0.4	0.6	0.7	0.8	1.0	1.2	1.3	1.8
DG3	17.22	5	13.0	17.2	20.0	23.5	30.7	34.6	40.2	52.9
DG4	27.90	31	14.4	199.2	22.3	26.1	34.2	38.5	44.7	58.8
DG6	29.28	31	15.0	20.0	23.2	27.2	35.6	40.1	46.6	61.3
EL1	5.84	39	2.8	3.7	4.3	5.0	6.5	7.4	8.5	11.2
GL1	8.00	12	5.1	6.7	7.8	9.2	12.0	13.5	15.7	20.7
HAG2	4.85	197	1.6	2.1	2.4	2.9	3.7	4.2	4.9	6.4
OAT1	2.81	675	0.8	1.0	1.2	1.4	1.8	2.0	2.4	3.1
OAT3	6.30	606	1.8	2.3	2.7	3.2	4.2	4.7	5.4	7.1
OW3	42.52	20	25.0	33.2	38.6	45.3	59.2	66.7	77.5	101.9
OW4	43.68	22	25.2	33.5	38.9	45.6	59.6	67.2	78.0	102.7
OW5	13.28	23	7.5	10.0	11.6	13.6	17.8	20.0	23.3	30.6
OW6	55.27	24	30.7	40.8	47.5	55.7	72.8	81.9	95.2	125.3

HEP	FSSR 16 Peak Flow Winter 2015 flood	Severity when compared to FSU flows	FSU derived flows (m^3/s) Return Period (1i n _ years)							
Location	(m3/s)	(1 in _ years)	2	5	10	25	50	100	200	1000
OW7	55.16	24	30.8	40.9	47.6	55.9	73.0	82.2	95.5	125.7
OW8	55.74	23	31.4	41.7	48.5	56.9	74.4	83.8	97.4	128.1
OW9	58.16	26	31.7	42.2	49.1	57.6	75.3	84.8	98.5	129.6
OW10	87.32	32	44.4	59.1	68.7	80.6	105.3	118.6	137.8	181.3

The severity of flows ranges from 1 in 3-year return period to 1 in 675-year return when compared to flows derived using the FSU method.

The flood review report (Arup, June 2016) estimated the Winter 2015 flood to be of an approximate severity of circa 1 in 10 to 1 in 20 years and flows estimated for the majority of HEPs correspond to a comparable return period. Return periods for HEPs Bal1, HAG2, OAT1 and OAT3 were found to be significantly higher when based on the FSU derived flows. All of these HEPs are located on small catchments and it is suggested that FSU flows underestimate the severity and therefore result in such high return periods when compared to the FSSR16 derived flows.

Both the IH124 and FSU4.2a method were then applied for HEPs on small catchments to re-evaluate the severity of the Winter 2015. Table B.9 presents findings for the IH124 derived flows.

Table B.9: Severity estimation for event-based flows for each HEP based on the IH124 derived design flows for small Catchments

HEP	FSSR 16 derived Peak Flow for Winter 2015 flood	Severity when compared to IH124 flows	IH 124 derived Flows (m^3/s) Return Period (1in _ years)						
Location	(m3/s)	(1 in XX years)	2	5	10	25	50	100	200
Bal1	1.17	4	1.0	1.3	1.5	1.7	2.3	2.6	3.0
DG3	17.22								
DG4	27.90								
DG6	29.28								
EL1	5.84	31	3.0	4.0	4.7	5.5	7.1	8.0	9.3
GL1	8.00	18	4.7	6.3	7.3	8.6	11.2	12.7	14.7
HAG2	4.85	6	3.5	4.7	5.4	6.4	8.3	9.3	10.9
OAT1	2.81	10	1.8	2.4	2.8	3.3	4.3	4.9	5.7
OAT3	6.30	25	3.5	4.6	5.4	6.3	8.2	9.2	10.7

HEP	FSSR 16 derived Peak Flow for Winter 2015 flood	Severity when compared to IH124 flows	IH 124 derived Flows (m^3/s) Return Period (1in _ years)						
Location	(m3/s)	(1 in XX years)	2	5	10	25	50	100	200
OW3	42.52								
OW4	43.68								
OW5	13.28	25	7.3	9.7	11.3	13.3	17.3	19.5	22.7
OW6	55.27								
OW7	55.16								
OW8	55.74								
OW9	58.16								
OW10	87.32								

Results show that the severity of HEPs on small catchments is between a 1 in 4 to 31-year return period, which is consistent with the estimated severity for other HEPs.

The same exercise was carried out using the more recent method for estimating flows on small catchments FSU 4.2a and Table B.10 presents findings.

Table B.10: Severity estimation for event-based flows for each HEP based on the FSU 4.2a derived design flows for small Catchments

HEP	FSSR 16 derived Peak Flow for Winter 2015 flood	Severity when compared to IH124 flows	FSU 4.2a derived Flows (m^3/s) Return Period (1in _ years)						
Location	(m3/s)	(1 in XX years)	2	5	10	25	50	100	200
Bal1	1.17	20	0.7	0.9	1.1	1.2	1.6	1.8	2.11
DG3	17.22								
DG4	27.90								
DG6	29.28								
EL1	5.84	2	5.65	7.51	8.73	10.2 4	13.3 9	15.0 7	17.52
GL1	8.00	<2	8.3	11.1	12.9	15.1	19.8	22.3	25.89
HAG2	4.85	22	2.8	3.7	4.3	5.0	6.5	7.4	8.55
OAT1	2.81	6	2.0	2.7	3.2	3.7	4.8	5.4	6.32
OAT3	6.30	9	4.2	5.5	6.4	7.5	9.8	11.1	12.88

HEP	FSSR 16 derived Peak Flow for Winter 2015 flood	Severity when compared to IH124 flows	FSU 4.2a derived Flows (m^3/s) Return Period (1in _ years)						
Location	(m3/s)	(1 in XX years)	2	5	10	25	50	100	200
OW3	42.52								
OW4	43.68								
OW5	13.28	2	13.0	17.2	20.0	23.5	30.7	34.6	40.21
OW6	55.27								
OW7	55.16								
OW8	55.74								
OW9	58.16								
OW10	87.32								

Results show a severity of less than a 1 in 10-year return period for 5 of the 7 HEPs with 3 HEPs corresponding to a 1 in 2-year return period or less.

It is therefore suggested that the FSU 4.2a method provides an overly conservative design flow estimation, which in turn results in the relatively low return period of the Winter 2015 flood.

This analysis provides confidence in selecting the IH124 method for flow estimation for HEPs located on small catchments.