FINAL

DUNDALK AND ARDEE FLOOD RELIEF SCHEMES

Hydrology Report – Dundalk

Project no. 123160

Prepared for:

Louth County Council

June 2022

Table of contents

List of Figures

List of Tables

Details of document preparation and issue:

Version no.	Prepared	Checked	Reviewed	Approved	Issue date	Issue status
P01	Emay Toha/ Ioanna Pappa/ Maike Lindeke-Rexhausen/ Alex Lee/ Naomi Betts/ Alice Johnson	Emay Toha/ Alice Johnson	Rob Fraser	Jack Mason	22.4.2021	Draft
P02	Emay Toha/ Maike Lindeke-Rexhausen/ Alice Johnson	Rob Fraser	Rob Fraser	Jack Mason	30.7.2021	Draft Final
P03.01	Emay Toha/ Alice Johnson	Emay Toha/ Alice Johnson	Fabio Spaliviero	Jack Mason	08.12.2021	Draft Final 2
P03.02	Alice Johnson	Jamie Reynolds	Fabio Spaliviero	Pinelopi Tsira	31.03.2022	Draft Final 3
P03	Jamie Reynolds/ Pinelopi Tsira	Richard Hein	Rob Fraser	Jack Mason	20.06.2022	Final

Project no. 123160 Client's reference no.

File name: 123160-BUK-ZZ-00-RP-HY-00004

Notice:

This report was prepared by Binnies UK Limited (BUKL) solely for use by Louth County Council. This report is not addressed to and may not be relied upon by any person or entity other than Louth County Council for any purpose without the prior written permission of BUKL. BUKL, its directors, employees and affiliated companies accept no responsibility or liability for reliance upon or use of this report (whether or not permitted) other than by Louth County Council for the purposes for which it was originally commissioned and prepared.

In producing this report, BUKL has relied upon information provided by others. The completeness or accuracy of this information is not guaranteed by BUKL.

1. Introduction

1.1 Overview and Purpose of Study

Binnies UK Limited (BUKL) and Nicholas O'Dwyer Limited (NOD) joint venture have been commissioned to carry out the Dundalk and Ardee Flood Relief Scheme (FRS) by Louth County Council (LCC), working in partnership with the Office Public Works (OPW).

The overall objective of this project is the identification, design and submission (for planning consent) of an FRS to alleviate the risk of flooding to the communities of Dundalk and Ardee. This Hydrology Report focusses on Dundalk, with Ardee covered by a separate report.

1.2 Hydrology Report Aims and Outline

The aim of the Hydrology Report is to record the hydrological analysis work described below. The numbers in brackets within the headings below are the associated sections in the Project Brief.

- Level of Detail (3.3.1): flood flow estimation for the relevant modelled and additional modelled river reaches and the calibration of hydrological models.
- Review of Available Data (3.3.2):
    - CFRAM hydrology data (3.3.2.1): including data recorded since the CFRAM study.
    - Historic flood data analysis (3.3.2.2): two recent floods are listed in the brief.
    - Hydrometric data analysis (3.3.2.3): at two gauges.
    - Rating curve (stage-discharge relationship) reviews (3.3.2.4): at two gauges.
    - Meteorological data analysis (3.3.2.5): rainfall depths and volumes.
    - Flood Studies Update (FSU) physical catchment descriptors (3.3.2.6).
    - Catchment boundaries (3.3.2.7).
    - River network (3.3.2.8).
    - Hydrological Estimation Points (3.3.2.9).
    - Hydrological Method Statement (HMS) Report (3.3.2.10): recorded the review work.
    - Hydrological Assessment Technical Workshop (3.3.2.11): has been carried out on 9th March 2021.
- Design flood parameters (3.3.3):
    - Design Event Probabilities (3.3.3.1): with an Annual Exceedance Probability (AEP) of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1%.
    - Estimation of design flood parameters (3.3.3.2).
    - Design event flow estimation methods (3.3.3.3).
- Joint probability analysis (3.3.4).
- Climate and catchment changes (3.3.5).

1.3 Previous Studies

The North Western – Neagh Bann Catchment Flood Risk Assessment and Management (CFRAM) Study is the most recent and detailed flood risk assessment and mapping study carried out in the area (published in 2016). Dundalk is located within the Neagh Bann International River Basin District (IRBD), which represents one single Unit of Management, UoM 06. The

Dundalk hydrology calculations within CFRAM are recorded in the UoM 06 Hydrology Report[1]. Dundalk was identified as an Area for Further Assessment (AFA) in the CFRAM study. And it is within the CFRAM UoM 06 Model 4.

[1] North Western – Neagh Bann CFRAM Study UoM 06 Hydrology Report (https://www.floodinfo.ie/publications/?a=643)

2. Catchment Overview

2.1 Study Area

Dundalk is located in County Louth. The study area extends southwards along the coast of Dundalk Bay to cover the coastal village of Blackrock. The Castletown River is the largest river within the study area which originates as the White Water and Tullyvallen Rivers approximately 5km north of Newtownhamilton in County Armagh (in Northern Ireland). The Castletown River flows in a south-westerly direction before entering Castletown Estuary in Dundalk north. It is tidally influenced as far as 2km upstream of Castletown Estuary. The total area of the overall study area is 287km^2.

Figure 2-1 shows the study and scheme areas including the OSi Geometric River Network.

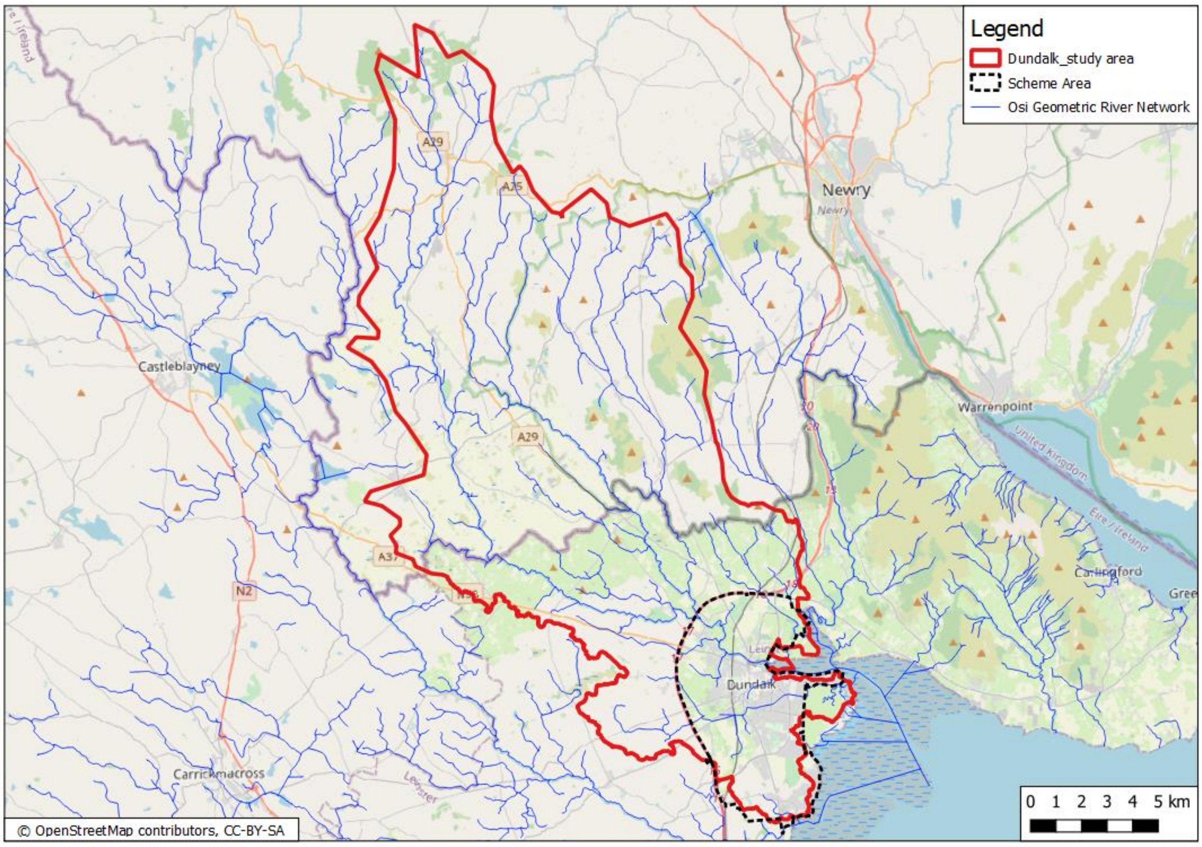


Figure 2-1 –Dundalk study area

2.2 Watercourses

Figure 2-2 shows the watercourses included in the scheme area. A reach of Castletown River is the largest watercourse considered. Castletown River is joined by Kilcurry River at the eastern side of the study area. Other minor watercourses include Blackrock Watercourse, Green Gates Watercourse and Aghaboys Watercourse.

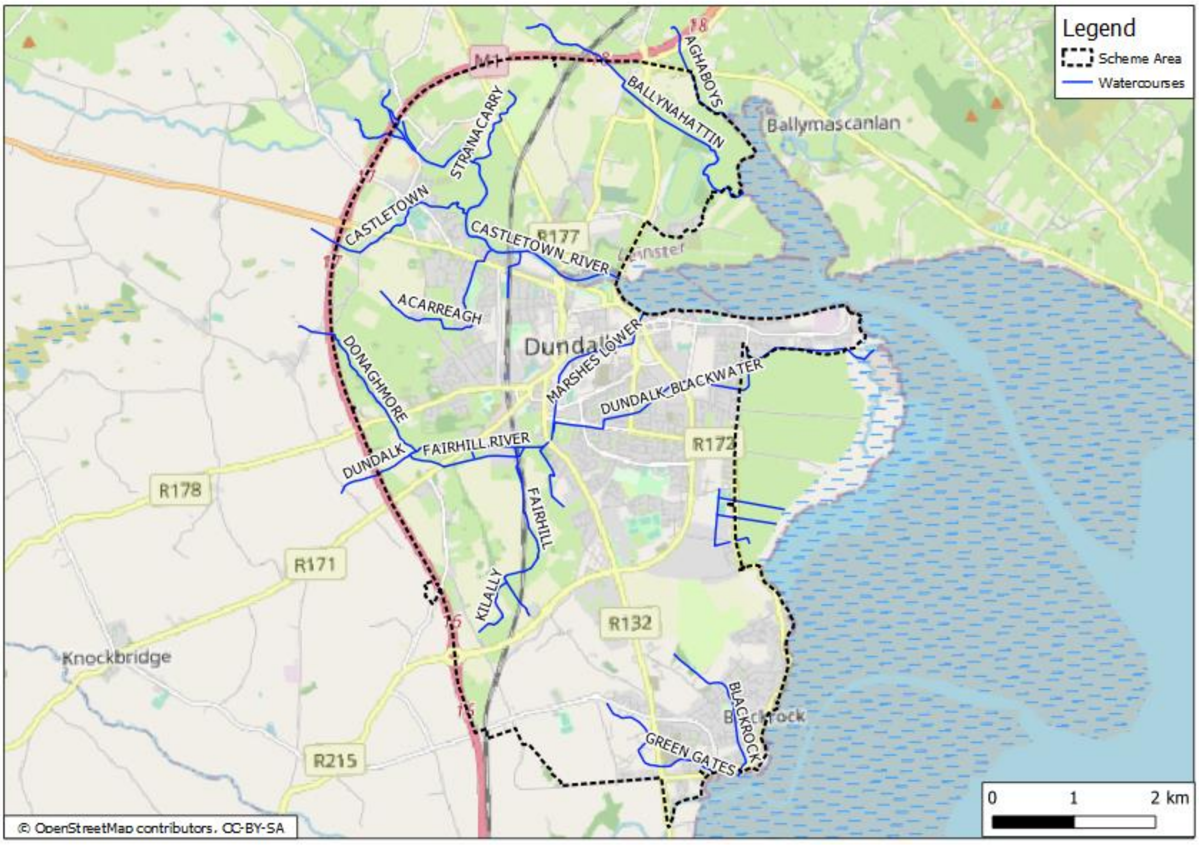


Figure 2-2 – Watercourses in Dundalk study area

2.3 Topography

Figure 2-3 illustrates the overall study area topography and Figure 2-4 illustrates the local scheme area topography. The highest elevation is about 300mOD in the north-west corner near Newtownhamilton in County Armagh and much of the upstream catchment is quite steep. The scheme area is low and flat with elevations ranging from 0 to 40mOD.

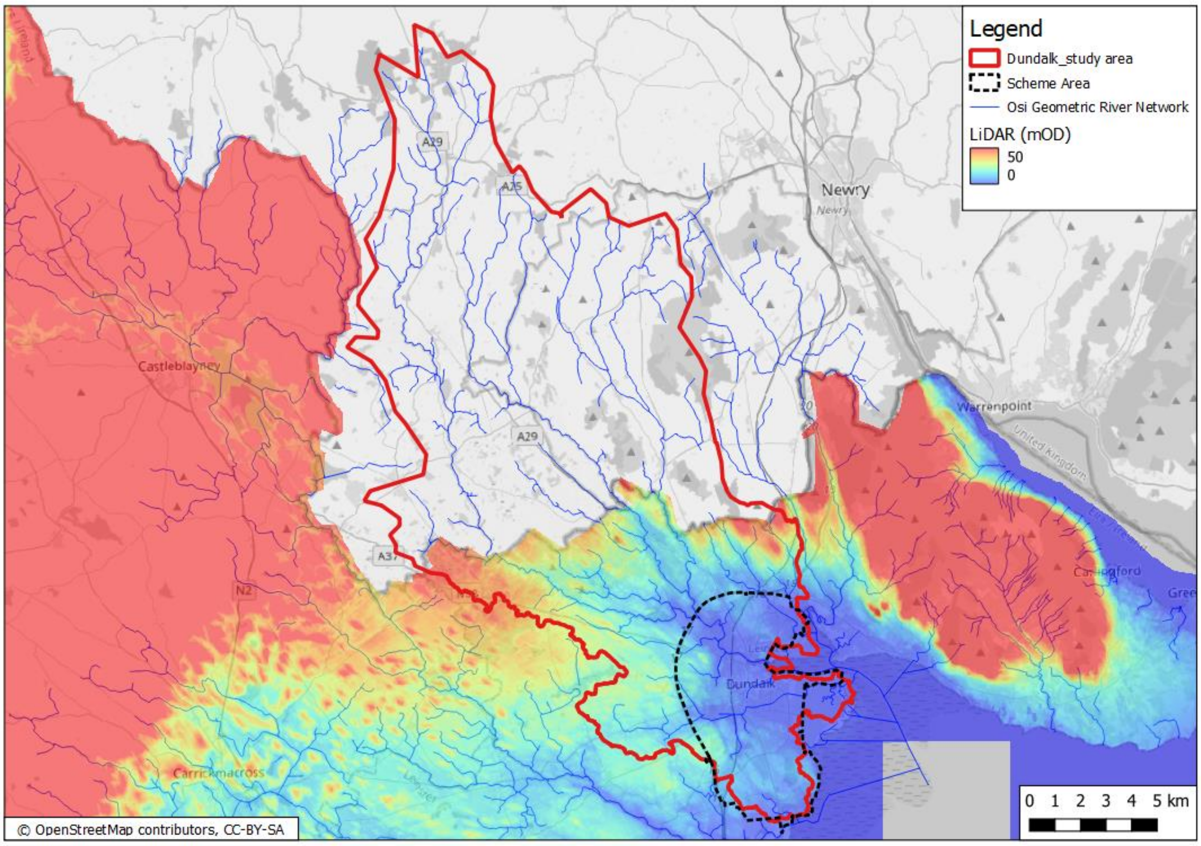


Figure 2-3 – Topography in Dundalk study area

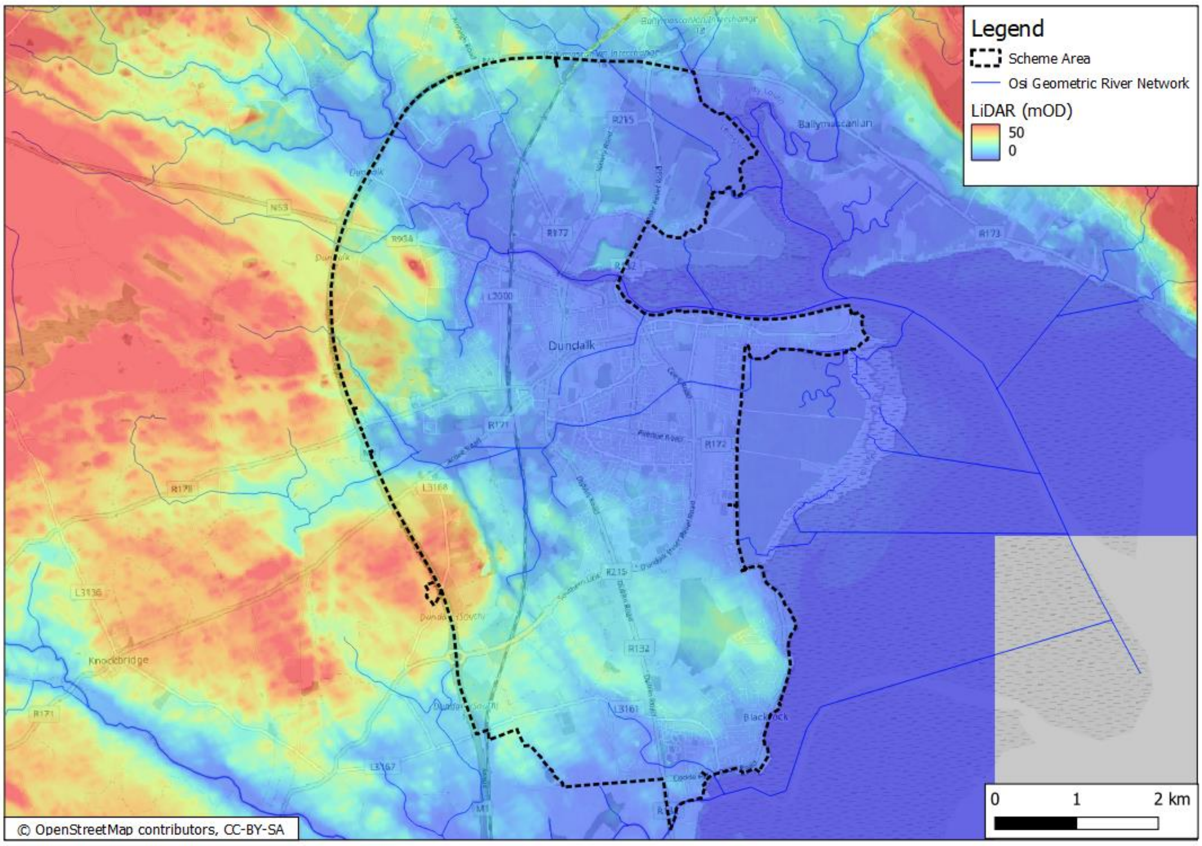


Figure 2-4 – Topography in Dundalk scheme area

2.4 Land Use

The majority of the scheme area is covered by the urban area of Dundalk town and Blackrock, as shown in Figure 2-5. There are also large expanses of wetlands along the coast. Other land uses include agricultural areas, pastures and arable land.

In the mountains, to the north east, there are areas of woodland, moors and heathland and bogs.

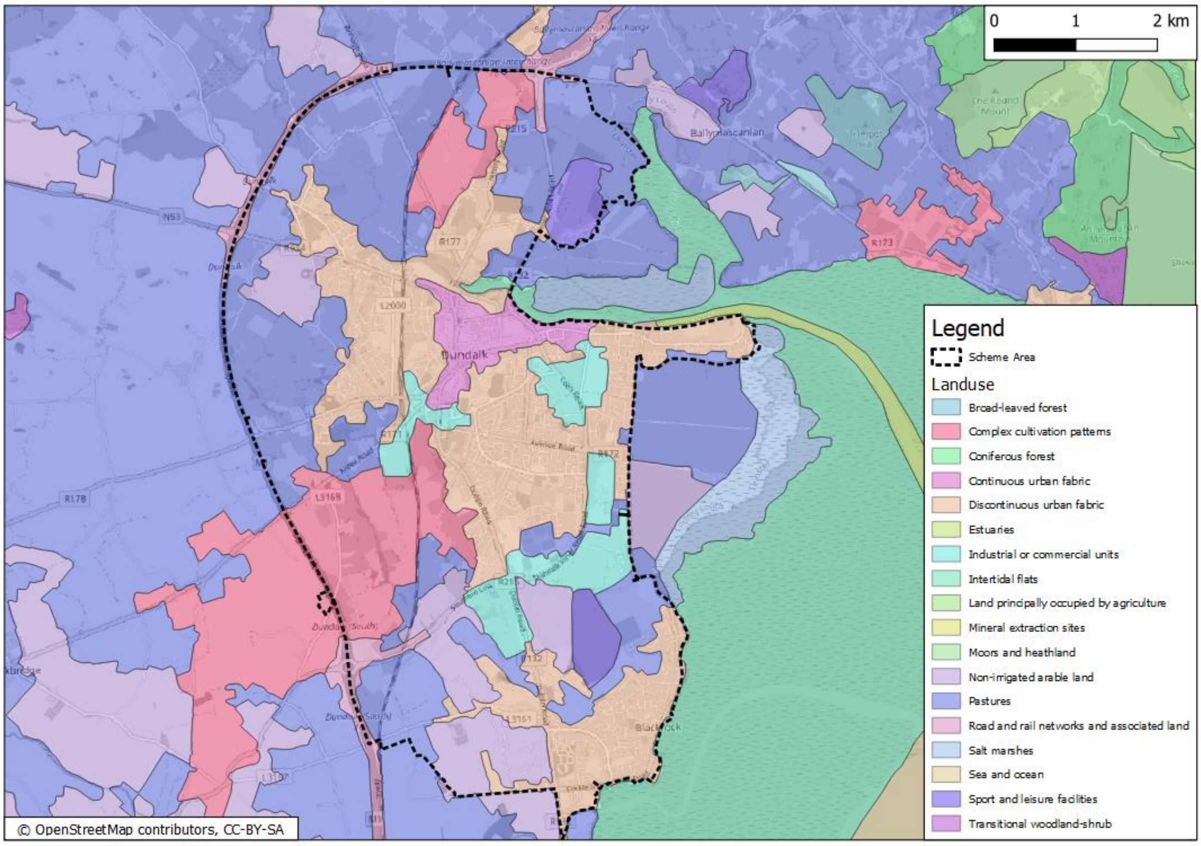


Figure 2-5 – Landuse map

2.5 Groundwater

Figure 2-6 illustrates the aquifer bodies within the study area. Dundalk is underlain by greywacke with some areas of limestone bedrock to the north. There is an area of locally important gravel aquifer to the east of the town, underlaying the marshes. The limestone bedrock is also classified as locally important.

Within the study are there is a range of national groundwater vulnerability classifications from ‘Low’ to ‘Extreme’. Permeability of the subsoil is recorded as ‘moderate’ in most of the inland area and ‘low’ along the coast. Estimated groundwater recharge values range from 100mm/yr to 400mm/yr to the east.

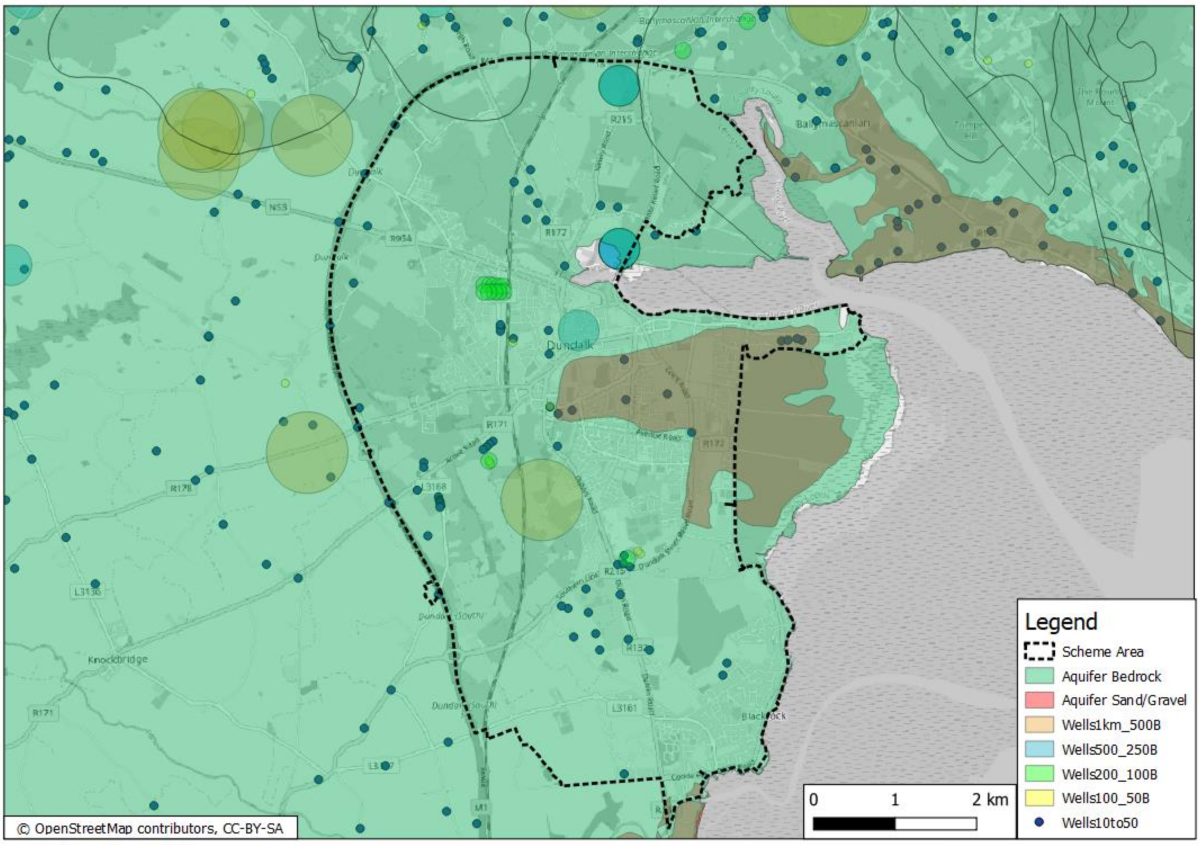


Figure 2-6 – Groundwater map

3. Data Review and Analysis

3.1 Overview

A data review was carried out and presented in the Hydrological Method Statement Report[2]. This review is reproduced in the following sections.

3.2 CFRAM Hydrology

We have reviewed the CFRAM hydrology data and found that, in general, the approach remains valid.

The CFRAM approach was:

- Index flood estimated from Physical Catchment Descriptors as all catchment is effectively ungauged. Adjustment factor applied based on nearby gauges in adjacent catchments.
- Growth factors calculated from a pooling region assessment of 104 gauging stations within catchments in the eastern side of Ireland and Northern Ireland. Generalised growth curves were developed based on catchment area.
- Design flow hydrographs assessed using the FSU Hydrograph Shape generation tool.

The CFRAM method and flood estimates provide a useful basis for comparison. However, new flood estimates will need to be derived to include the additional sub-catchment inflow points.

3.3 Catchment Characteristic Data

(a) River network

OSi Geometric River Network (River Network) data has been downloaded from the EPA website. Figure 3-1 shows the River Network (blue line) and CFRAM model watercourses (light-green thick line) and additional reaches identified in the Brief (yellow thick line).

We have reviewed the River Network against the CFRAM river network and using available LIDAR/topographical data, current and historical OSi mapping in GeoHive and field inspections. In general, no discrepancies have been found. A number of watercourses that have been added in the CFRAM study and additional reaches identified in the Brief are given below:

- CFRAM study: Blackrock River, Kilally Stream and connection between Marshes Lower and Dundalk/Blackrock Streams; and
- Additional reaches: Open channel/culvert between the railway track and the 'Clan Na Gael' football field (Reach No.1), a short open channel of Dundalk/Blackrock Stream in the area around Hardy's Lane and its junction with the Blackrock Road (Reach No.2) and watercourse at the junction of Red Barns Road and Riverside drive (Reach No.3).
- The connection between Dundalk, Dundalk Blackwater and Marshes Lower Rivers is currently unclear and will be checked once we receive the new CCTV and topographic survey data. This has no effect on the hydrology analysis and will be reported in the Hydraulic Modelling report as described in Section 4.2.

---

[2] Binnies UK Limited, December 2020, Dundalk and Ardee Flood Relief Scheme – Hydrological Method Statement – Dundalk, Draft Report.

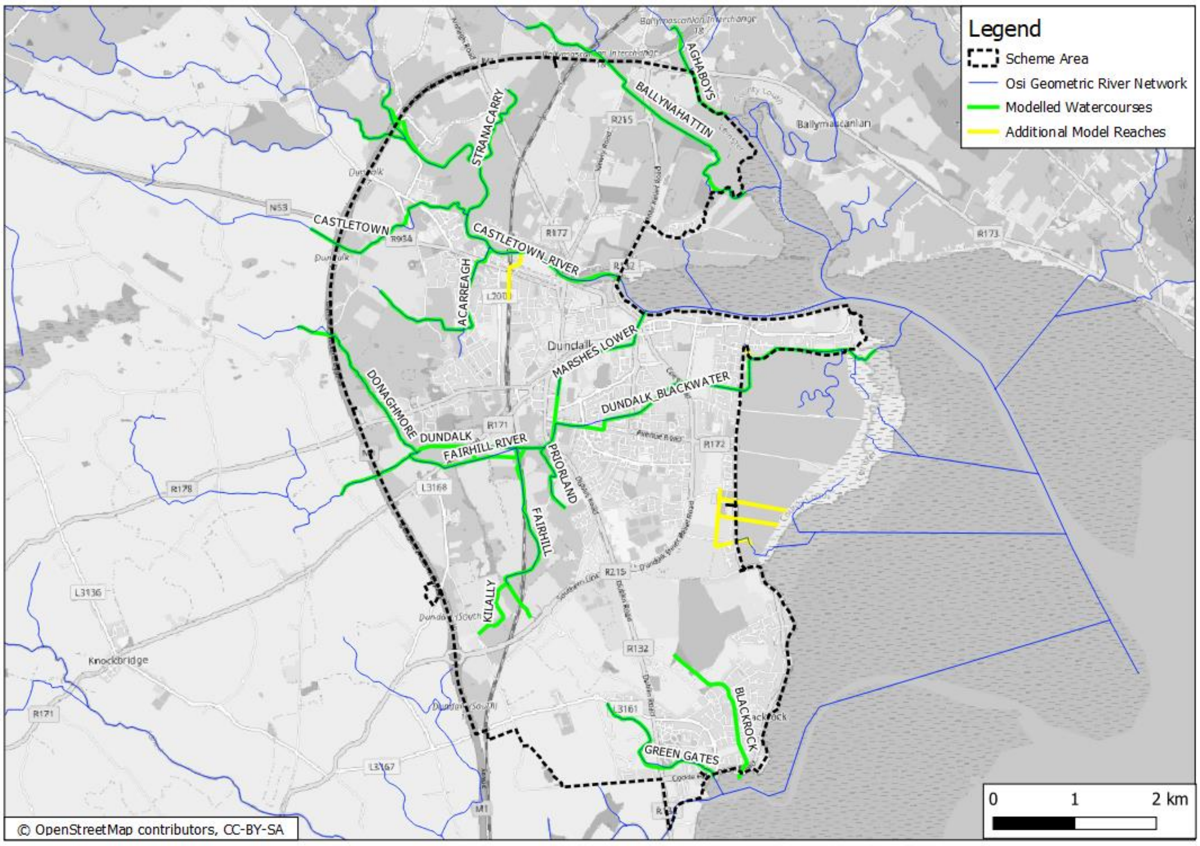


Figure 3-1 – River network

(b) Physical Catchment Descriptors

The FSU Physical Catchment Descriptors (PCDs) for both gauged and ungauged locations for the study area in GIS format have been provided by OPW.

Figure 3-2 shows the PCDs locations, OSi Geometric River Network and catchment areas.

Table 3-1 outlines the PCD checks that have been carried out. The comparisons for each Hydrological Estimation Point (HEP) are tabulated in Appendix A, with the adopted values listed in Appendix B.

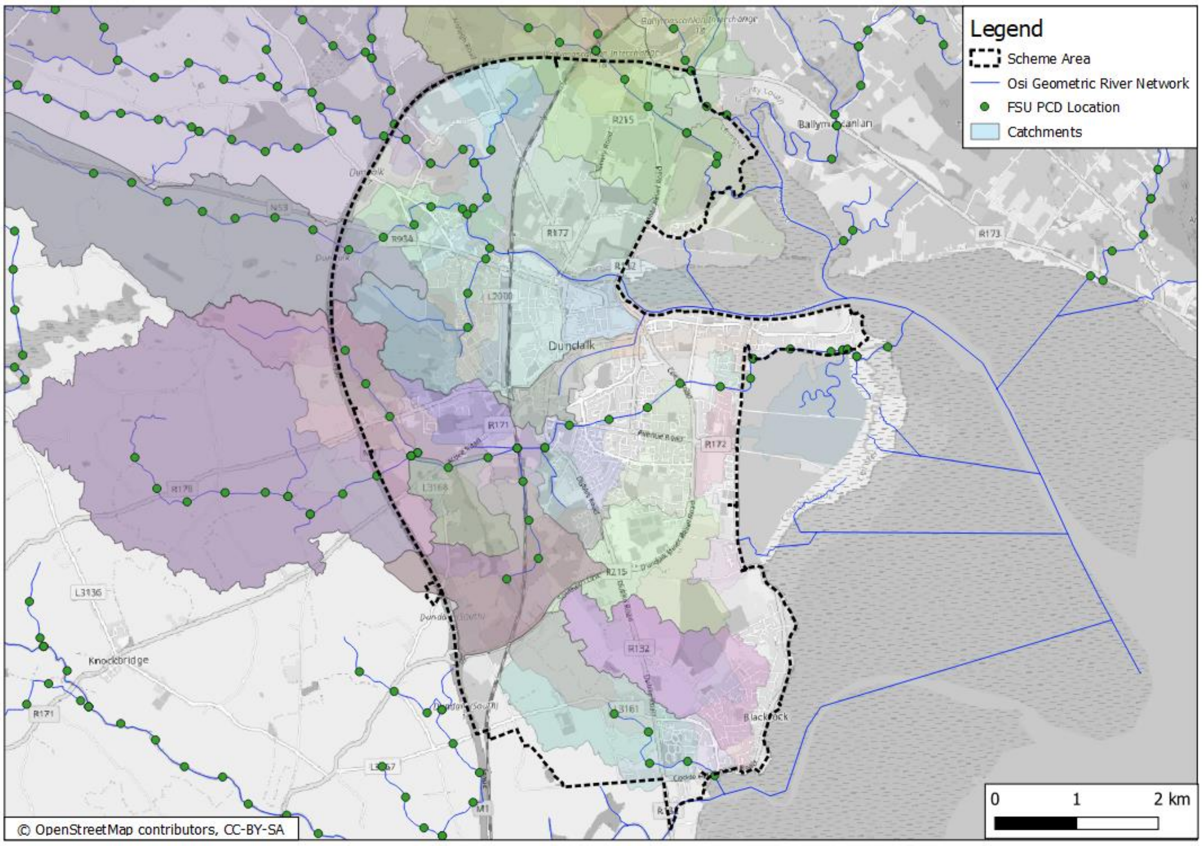


Figure 3-2 – FSU PCDs location

Table 3-1 –PCD checks

Descriptor name	Code	Datasets used	Notes
Catchment area	AREA	Lidar DTM (2m and 5m)	Generally the catchment areas match reasonably closely. The exceptions are the cross-border catchments with their headwaters in Northern Ireland (Kilcurry River, Cull Water, Castletown/ Creggan River). The FSU PCDs do not include the Northern Ireland part of the catchments. The Lidar derived catchments have been supplemented with the catchment boundaries in Northern Ireland from the FEH Web Service. Adopted catchment areas are based on the Lidar DTM for consistency at points without FSU PCDs.
Standard Period Average Annual Rainfall	SAAR	Met Eireann 1981-2010 SAAR point data	SAAR values from Met Eireann 1981-2010 SAAR point data are adopted (this dataset includes Northern Ireland so covers the whole catchment).
Drainage density	DRAIND	NETLEN (network length), AREA	Generally the values match well with FSU PCDs. The newly derived values (from Lidar and the OSi Geometric Network) have been adopted.
Mainstream slope	S1085	MSL (main stream length) route polyline, Lidar DTM	Generally the values match well with FSU PCDs. The S1085 values derived from the Lidar DTM have been adopted.
Index of urban extent	URBEXT	Corine 2018 landcover dataset	URBEXT values from Corine 2018 land cover data set are adopted. For the Northern Irish parts of the catchment, URBEXT2000 values from the FEH Web Service were used give a whole catchment URBEXT value.

(c) Hydrological Estimation Points (HEP)

CFRAM HEP spatial data has been provided by OPW. We have added HEPs data in accordance to Section 3.3.2.9 of the Brief. The HEPs data is shown on Figure 3-3 to Figure 3-6. Appendix A lists the HEPs data for Dundalk.

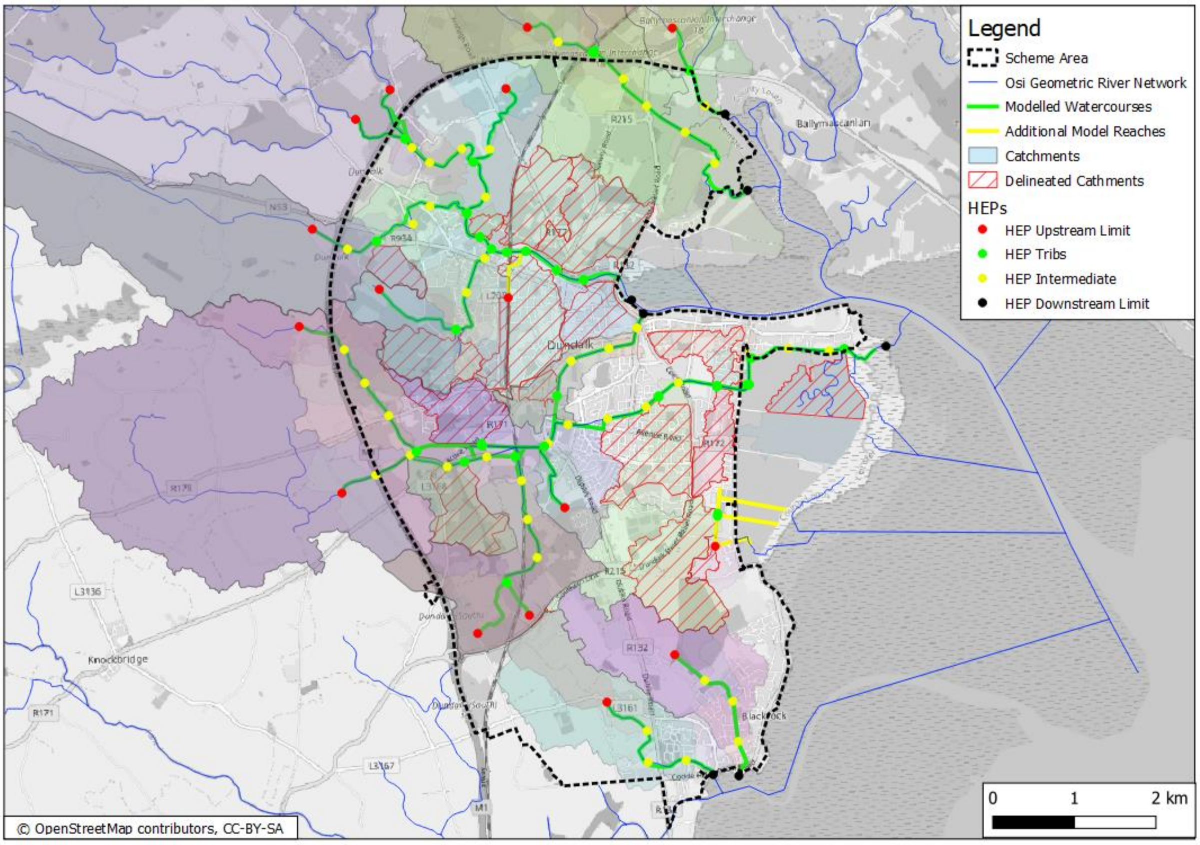


Figure 3-3 – Hydrological Estimation Points (Overview)

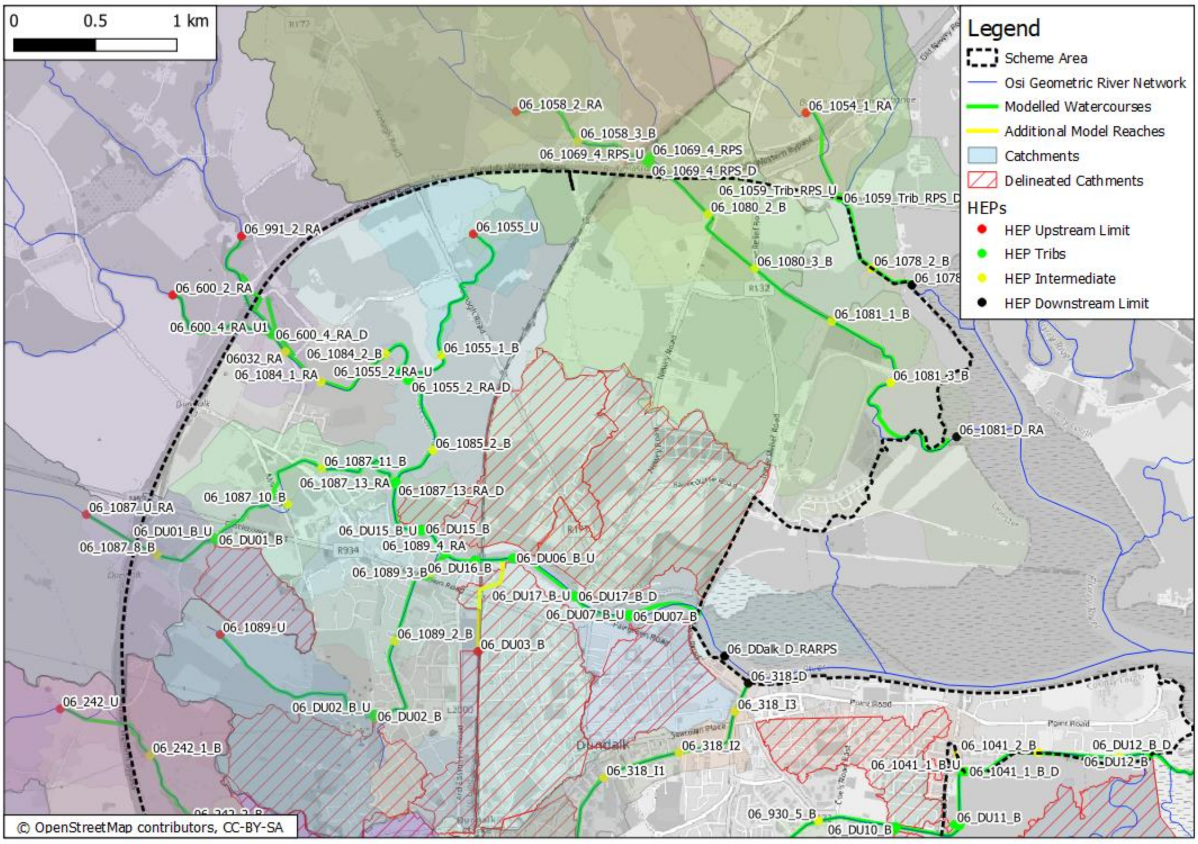


Figure 3-4 – Hydrological Estimation Points (Dundalk north)

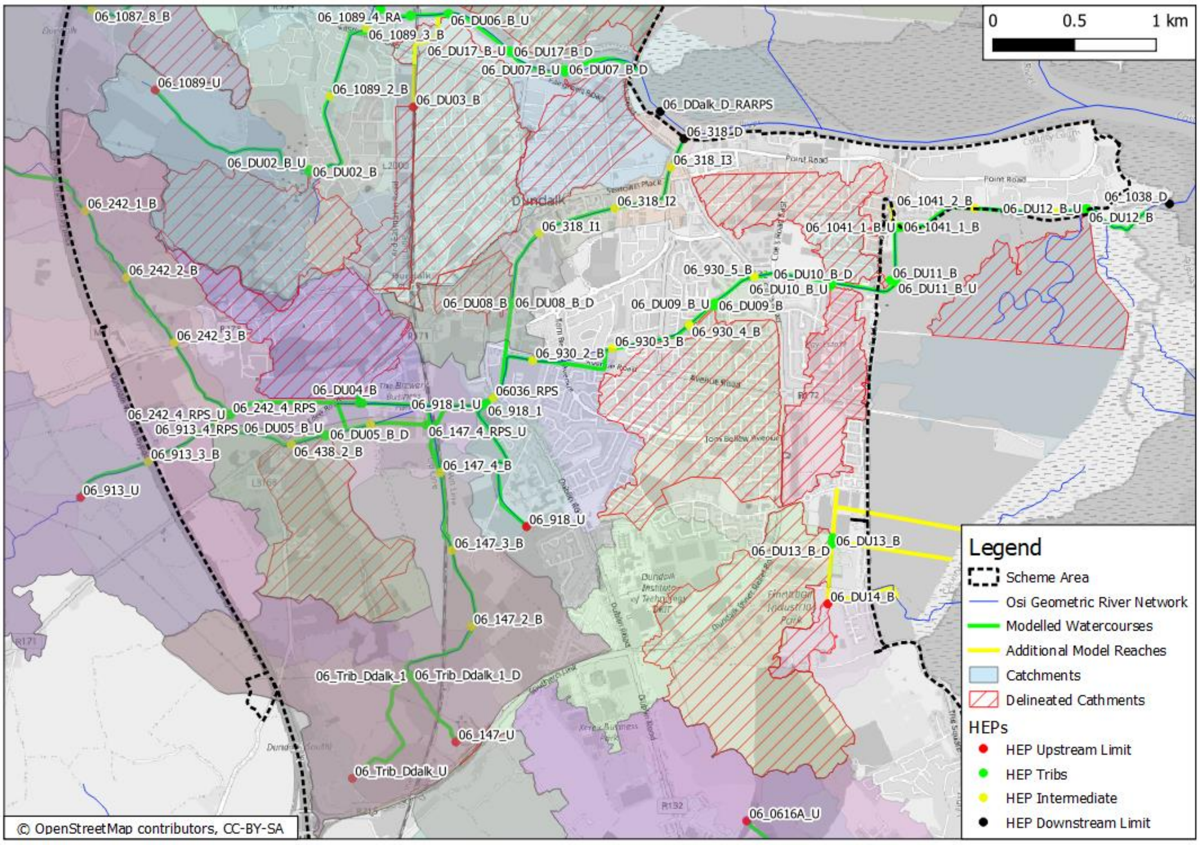


Figure 3-5 – Hydrological Estimation Points (Dundalk south)

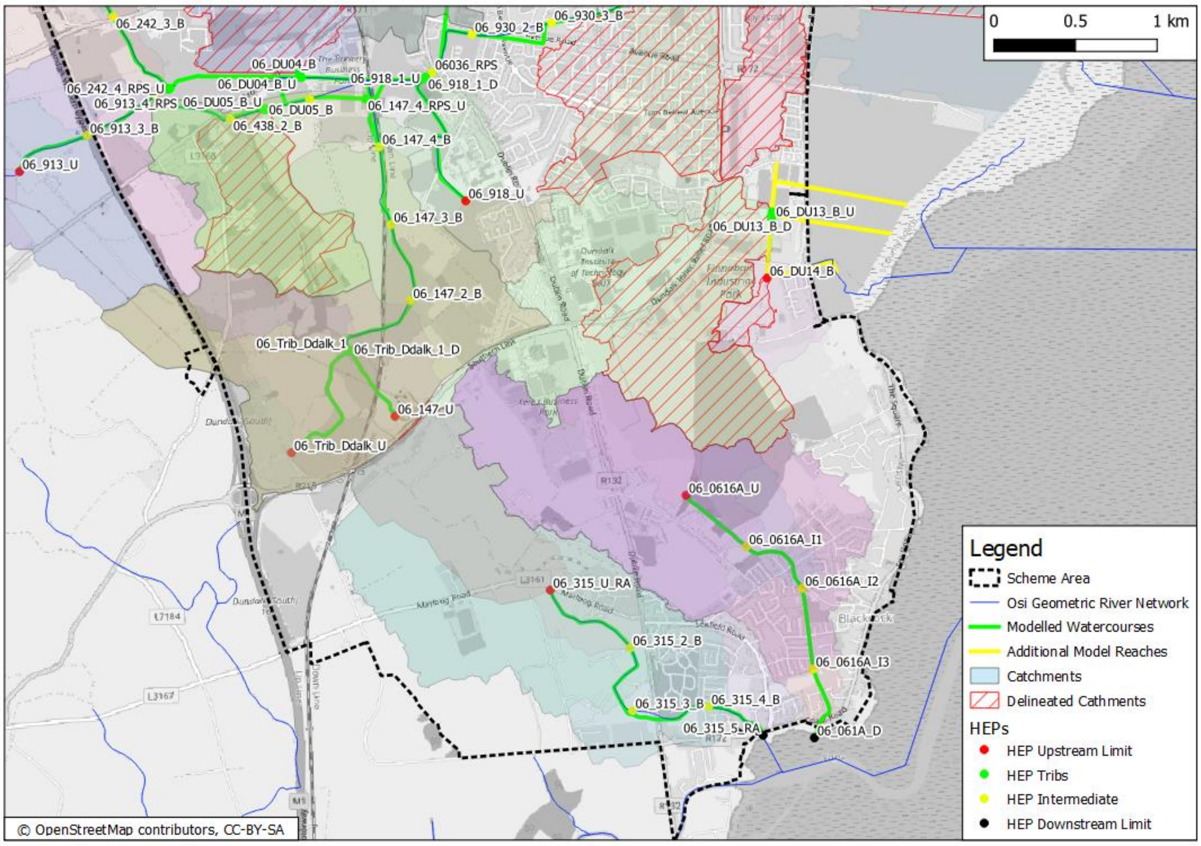


Figure 3-6 – Hydrological Estimation Points (Blackrock)

3.4 Meteorological Data

Observed rainfall data from Met Éireann rainfall gauges within the study area have been collected. Figure 3-7 shows the location of these gauges. There are three daily gauges in Dundalk at Omeath, Riverstown and LH Dundalk (data for this gauge is not available). The hourly stations Ballyhaise, Dunsany and Dublin Airport are located to the west and south of the study area in Counties Cavan, Meath and Dublin, respectively (about 57 to 65km from Dundalk).

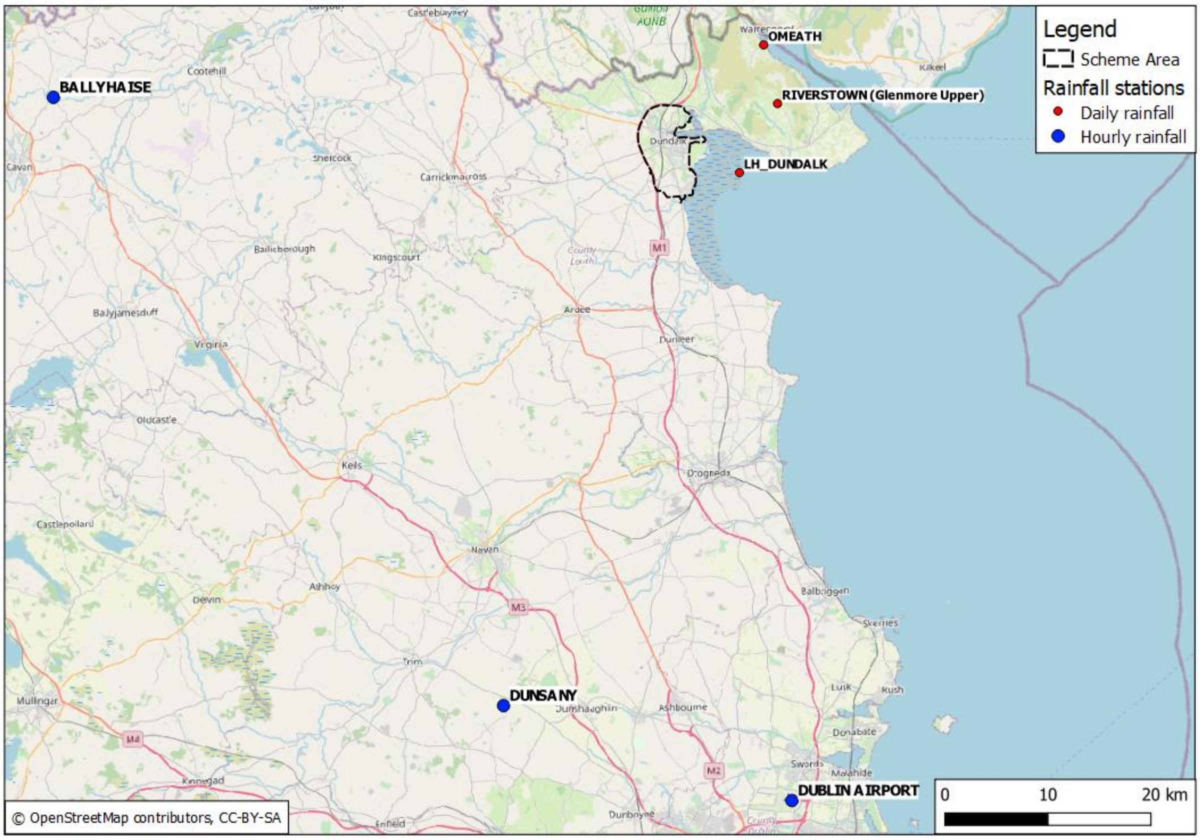


Figure 3-7 – Met Éireann rainfall stations

The assessment of recent daily rainfall data (01/01/2014- 31/01/2021) collected at the two gauging stations in the vicinity of the study area suggests that data are relatively well correlated with a correlation coefficient of $\rho = 0.88$. The average rainfall recorded at these stations appears to be similar; in the order of 3.2mm in Omeath and 3.4mm in Riverstown. The record at Omeath indicates that the station has been slightly dryer for the above period (28.7% and 26.2% at Riverstown); however, with the maximum recorded cumulative daily rainfall being significantly higher compared to the one recorded at Riverstown (80.6mm and 68.6mm, respectively).

Table 3-2 lists the highest daily rainfall to have occurred since the CFRAM study and their estimated probabilities. The probabilities for these events have been carried out by reference to the FSU Depth-Duration-Frequency model.

Table 3-2 shows that:

- Rainfalls at Riverstown and Omeath gauging stations differ in magnitude, resulting at significant events being recorded at only one of the two while the other showing unexceptional rainfall data.
- The most significant rainfalls have occurred on 2nd May 2015 at both locations; with estimated frequencies of around 1 in 32 and 87 at Riverstown and Omeath, respectively.
- Significant rainfalls at Omeath have also occurred in July 2018 with an estimated frequency of around 1 in 40; and also in September and December 2015, and in July 2019, with estimated frequencies of around 1 in 3.
- Significant rainfalls at Riverstown have also occurred in June 2019 with an estimated frequency of around 1 in 6; in December 2015 with an estimated frequency of around 1 in 5; and also in March 2017, with an estimated frequency of around 1 in 3.
- The observed rainfalls on the dates identified in the Brief and subsequent comments on the Hydrological Method Statement (HMS) were unexceptional.

Table 3-2 Rainfalls depths and rainfall frequency in Dundalk.

Date	Omeath gauge			Riverstown gauge		
	Depth [mm]	AEP [%]	Rainfall frequency [1 in X years]	Depth [mm]	AEP [%]	Rainfall frequency [1 in X years]
03/01/2014 *(Brief)*	0	-	-	1.3	-	-
13/11/2014	48.1	24.4	4	45.1	28.6	4
14/11/2014 *(Brief)*	18.5	-	-	19.6	-	-
21/11/2014	35.8	66.7	2	34.3	66.7	2
02/05/2015	**80.6**	**1.2**	**87**	**68.6**	**3.1**	**32**
22/08/2015	36.3	66.7	2	30.9	76.9	-
11/09/2015	43.1	40	3	31.4	76.9	-
03/12/2015	15.0	-	-	48.2	21.3	5
29/12/2015	43.9	37	3	34.5	66.7	2
04/01/2016	21.3	-	-	39.7	45.5	2
27/01/2016 *(Brief)*	1.0	-	-	1.4	-	-
09/07/2016 *(Brief)*	30.3	83.3	-	24.7	-	-
15/10/2016	39.5	52.6	2	33.2	71.4	-
03/03/2017	23.8	-	-	41.7	38.5	3
19/10/2017	31.4	83.3	-	37.4	55.6	2
14/03/2018	36.5	66.7	2	26.2	-	-
28/07/2018	71.3	2.5	40	37.3	55.6	2
04/06/2019	32.3	83.3	-	50.1	17.5	6
19/07/2019	43.0	40	3	40.1	45.5	2
10/08/2019	33.0	90.9	-	36.4	58.8	2
06/11/2019	10.2	-	-	35.3	62.5	2
26/07/2020	23.4	-	-	35.8	62.5	2
24/08/2020	33.6	76.9	-	40.4	43.5	2
01/09/2020 *(HMS)*	12	-	-	21.7	-	-

3.5 Hydrometric Data

(a) Available hydrometric data sources

Hydrometric data have been collated from OPW's Hydrometric office, waterlevel.ie, Environmental Protection Agency's (EPA) website (epa.ie) and FSU websites for the following gauging stations:

- 06036 Ladyswell; and

- 06015 Brewery Park.

Sources and details of hydrometric data considered in the assessment are outlined on Table 3-3 below. As the table indicates, there is very limited information available for the two stations.

Station 06036 - Ladyswell, was originally operated by EPA, with 15-min flow data and spot gaugings records being available for the period September 1979 – July 1993. The station was taken over by OPW in May 2019. The OPW record includes continuous 15-min water level data since October 2018, AMAX water level series for 2018 and 2019 and one spot gauging measurement taken in 2019.

Station 06015 - Brewery Park is an OPW operated station and was installed in July 2019. The data record available for this station includes 15-min continuous water level data since July 2019 and the AMAX water level figure for 2019.

It should be noted that rating reviews have not been undertaken previously for either of the two stations. According to OPW's Hydrometric Office, there are plans to gauge and rate these stations in 2021.

Table 3-3 Available hydrometric data

No	Station/Data	CFRAM Report	Waterlevel.ie	EPA	OPW
1	**06036 Ladyswell**				
	• AMAX series				2018 to 2019
	• Continuous flow			1979 to 1993	-
	• Continuous water level	Not available	2018 to 2020		2018 to 2019
	• Spot gauging water level			-	2019
	• Spot gauging flow			1978 to 1993	2019
	• Rating equation(s)			-	Not available
2	**06015 Brewery Park**				
	• AMAX series				2019
	• Continuous flow		-		Not available
	• Continuous water level	Not available	2019 to 2020	Not available	-
	• Spot gauging water level		-		Not available
	• Spot gauging flow		-		Not available
	• Rating equation(s)		-		Not available

(b) Data analysis

The hydrological analysis undertaken as part of this study is based on the guidance presented within the Flood Studies Update (FSU) Packages 2.1 and 2.2. The hydrometric data record will be used to estimate the annual maxima (AMAX) and median annual flood flows (QMED) at the two gauging stations. This record comprises 15-minute continuous water level and flow data spanning across the periods indicated on Table 3-3, above.

(c) Ladyswell Gauging Station

Table 3-4 below outlines the AMAX flows and water levels calculated based on evidence collected from 06036- Ladyswell gauging station. Figures for hydrological years in the period 1979 – 1992 were calculated from the EPA 15-min continuous flow record. The OPW record was used to calculate the AMAX water level series for the period 2018-2019. The data suggests that the median AMAX flow in the period 1979-1992 was 0.90m^3/s and that the median AMAX water level in the period 2018-2019 was 4.36m AOD.

It is noted that a rating equation is not available for this station, hence it is not possible to estimate the median flow QMED value for the recent data with information currently available. A re-evaluation of the above will be attempted again at the next stage, when survey data at the gauge will be completed. The initial rating review assessment (see section 4.2, below) indicates the water level – flow relationship is not consistent between different modelled floods. If that is confirmed by the full rating review, it will not be possible to generate flow estimates from the recorded water levels.

Table 3-4 AMAX water levels – Ladyswell (06036)

Hydrological Year[1]	AMAX [m^3/s]	AMAX [mAOD]	Date
1979	1.05	-	22/01/1980
1980	0.80	-	12/06/1981
1981	1.35	-	05/01/1982
1982	0.86	-	09/11/1982
1983	-	-	-
1984	-	-	-
1985	-	-	-
1986	-	-	-
1987	0.38	-	07/06/1988
1988	0.61	-	03/04/1989
1989	0.93	-	01/03/1990
1990	1.08	-	21/03/1991
1991	0.82	-	23/12/1991
1992	0.99	-	25/11/1992
2018	-	4.27	17/03/2019
2019	-	4.44	25/02/2020
MEDIAN (1979-1992)	**0.90**	**-**	
MEDIAN (2018-2019)	**-**	**4.36**	

[1]The hydrological year corresponds to the period 1st October to 30th September.

(d) Brewery Park Gauging Station

Table 3-5 below outlines the 10 highest water level figures recorded at 06015- Brewery Park gauging station for the period July 2019 – November 2020. The data suggests that 8 of the 10 highest water levels occurred during November 2019, with the maximum stage being 4.637m on 11th November 2019. A similar stage figure (4.636m) was recorded on 25th February 2020.

With such a short period of record, this information is of limited value in the hydrological assessment, except for validation of the hydraulic model water level predictions. The initial rating review assessment (see section 5, below) indicates a reasonably consistent water level – flow relationship. This will allow flows to be estimated from the water level records. It should be however noted that the rating review for this station will be re-evaluated at the next stage with up-to-date survey data.

Table 3-5 Max Water Levels recorded at Brewery Park (06015) in 2019[1]

Date[2]	Max Water Level [m] (waterlevel.ie)
11/11/2019 21:00	4.637
25/02/2020 02:00	4.636
08/11/2019 15:00	4.623
23/11/2019 17:00	4.518
27/11/2019 13:00	4.502
26/11/2019 11:00	4.495
03/11/2019 01:00	4.435
03/11/2019 21:00	4.412
20/11/2019 10:00	4.410
20/12/2019 04:00	4.407

[1]The hydrological year corresponds to the period 1st October to 30th September.
[2]Time rounded to the nearest hour.

(e) Summary

Currently there is not sufficient hydrometric flow data available from both Ladyswell and Brewery Park gauging stations to use for the design flood estimation assessment, except for validation of the hydraulic model water level predictions. Therefore, the entire study area is considered as ungauged for this hydrological assessment.

3.6 Flood History

(a) Overview

The following section records flooding that has occurred in Dundalk: looking first at historical floods, as covered in the CFRAM study; and then at floods that have occurred since the CFRAM study was completed.

(b) Historical floods

The following historical floods for the Dundalk and Blackrock AFA were identified in the CFRAM UoM06 Inception Report and CFRAM UoM06 Flood Risk Management Plan Report:

- Jan-2016
- Nov-2014

- Jan-2014
- Oct-2011
- Sep-2010
- Oct-2004
- Feb-2002
- Nov-2000
- Dec-1981
- Feb-1977
- Dec-1954
- Nov-1954

January 2016 – Flooding occurred in Dundalk in January 2016. As reported by the Irish Independent, a number of homes were affected by flooding caused by high water levels in the River Blackwater. Local and major roads including the M1 motorway were affected causing significant disruption to travel. Subsidence near the railway line also caused the track between Newry and Dundalk to close.

November 2014 - Flood event response reports describe flooding which occurred in Dundalk on the 14th and 15th November. A watercourse exceeded its banks at Regan's Terrace in Dundalk resulting in flooding of two residential properties. Within the same catchment three residential properties at Mounthamilton were affected when a watercourse exceeded its banks on Ardee Road. Four large industrial properties were also flooded internally at the nearby Mounthamilton Industrial Estate.

January 2014 - Flood event response reports describe flooding which occurred in Dundalk, Blackrock and Carlingford. On Main Street in Blackrock three properties were affected by flooding caused by a combination of high tide, surge and wave overtopping. Flood depths of approximately 300mm were measured on Main Street (R172). At George's Quay in Dundalk a flood level of 3.45m (OD Malin OSGM02) was recorded and the Dundalk Port Inner Relief Road (N52) was flooded to a typical depth of around 250mm. Three commercial properties were reported to have been affected.

October 2011 – From the CFRAM reports, www.argus.ie reported that Dundalk suffered some flooding although it escaped severe flooding. The heavy rain led to flooding at the Castletown Road and also flooding on the Ardee Road. As the heavy rains coincided with high tides, the council also had 500 sandbags on standby for distribution if necessary.

September 2010 - On 6th September 2010, flooding occurred due to heavy rainfall, high tides and strong easterly winds. Anecdotal information reported in the Dundalk Democrat estimated this event to have an Annual Exceedance Probability (AEP) of 2%. St Alphonsus Road was reported to be one of the areas worst affected.

October 2004 - Details were found on www.floodinfo.ie which indicated that flooding occurred in Dundalk in October 2004. In Dundalk, flooding was caused by heavy rainfall (20.5mm on October 27th and 16.5mm on October 28th). High tides impeded drainage although gullies had been cleaned prior to this event. However, no details of flood extents or damage caused are available.

February 2002 - Information was found on www.floodinfo.ie indicating that flooding occurred on 2nd February 2002 in Dundalk & Blackrock South due to heavy rain, high tides and strong easterly winds.

Correspondence from the Dundalk Area Senior Executive Engineer described a flooding event in Blackrock, caused by a high tide and easterly gales. The sea wall was undermined, an old lifeboat house was flooded and houses along Main Street were damaged. Also, Village Green/new Golf Links Road and Wallis Road/Rock Road junction were badly affected. The Lismore area was affected by flooding due to the downstream culvert capacity not being sufficient. Gardens were flooded and roads impassable – remedial work has since been carried out.

In Dundalk, an unprecedented high tide was recorded (3.65mOD Malin OSGM02) along with gale force easterly winds. Fairgreen was flooded. The Dundalk to Blackrock Road, Racecourse Road and Moorland Road were flooded. An old sand embankment on Marsh Road was breached in four locations resulting in up to half a meter of water in gardens and the flooding of one house and a construction site on the R172.

The high tide also came over the quay wall and onto the public road at Quay Street.

November 2000 - The review indicated that a flood event occurred Dundalk in November 2000.

Correspondence from the Louth County Secretary to the Department of Environment and Local Government, dated 10th November 2000, indicated that on 2nd November that flooding occurred in Dundalk from blocked or overwhelmed culverts and from the Ramparts River. Flooded areas included Fatima (North West Dundalk) and Dundalk brewery was also flooded.

The letter estimated that, in the Dundalk/Carlingford engineering area, approximately IR£100,000 worth of damage was done when the edge of c. 20 miles of road was washed away. In addition, a further IR£100,000 would be required to repair culverts. Within the Dundalk UDC area, repairs to damaged roads, upgrading of culverts and drains was estimated to cost an additional IR£100,000.

December 1981 - Flooding occurred in Dundalk & Blackrock South on 3rd December 1981 due to heavy rainfall, high tides and strong winds.

The Dundalk Democrat indicated that in Blackrock flood water entered most houses and business premises along the exposed length of village for several hundred yards. Damage was caused to the sea wall fronting the village. Walls to the swimming pool were also damaged.

Articles in the Dundalk Democrat were downloaded from www.floodinfo.ie, which indicated a flooding event in Dundalk on the same date when the tide rose above the quay wall. The Town Engineer reported that the tide was 450mm higher than any previously recorded tide.

The worst affected areas were at Seatown and Quay Street, where basements of houses were "flooded to depths of several feet and in some cases, almost to their ceilings". Flooding also occurred at Fair Green, St. Marys Road, Broughton Street, Castle Road, St. Patrick's Terrace and St. Brigid's Terrace. Offices of C.C.O. coal firm, a local shop, PMPA offices, the Harbour Offices and a number of houses were flooded. The Newry Road, from Lisdoo corner to the Racecourse Road, was also flooded when floodwater entered over the sloblands. Some houses at Lisdoo corner flooded.

The Dundalk Democrat reported one fatality from the floods when a man drowned at Race Course Road. Gardaí suspect he was caught unexpectedly by a tidal surge, which is reported "to have reached a height of several feet after it crossed the sea banks along the estuary of the Ballymascanlon River". Other people had to be evacuated from their homes in this area also and sheep, pigs and domestic animals were drowned.

February 1977 - Information contained in a Consultant's report[3] indicates that in early February 1977, prolonged rainfall caused the Rampart River to burst its banks inundating considerable areas of land in the Dundalk urban district. The flooding caused extensive disruption to traffic flow and to business in the low-lying areas adjacent to the Ardee Road, as well as causing damage to stocks and domestic dwellings in the area. This report also notes that flood relief works were carried out within two years of this event.

December 1954 - Archive articles from the Dundalk Democrat indicate that flooding occurred on 8th December 1954 in Dundalk. Flooding was caused by prolonged rainfall, high tides and strong easterly winds. This was exacerbated when stream flow was impeded by debris in a culvert near the Fatima housing estate. Some speculated that an open sluice valve was to blame for some of the flooding. Houses were flooded to a depth of over 200mm on Quay Street with houses also flooded in Ladywell Terrace. Gardens were flooded at Thomastown while "there was up to three feet of water at the Castletown Bridge". There was also flooding at O'Hanlon Park, Castleblaney Road, Ardee Road, Fatima Park and Mill Road.

November 1954 - The historical data from www.floodinfo.ie indicated that flooding occurred in Dundalk on 8th November 1954 due to high tides, strong winds and heavy rainfall. It was reported that the worst flood spot around the town was at Castletown, under the railway bridge, where there was "over 5 feet of water lying under the bridge". In addition, flooding occurred at Long Avenue up to the doorsteps of houses at the pork factory, at Fair Green and the basement and playground of the Convent New Schools. It was also reported that three warehouses on Quay Street were flooded with water "at least 12 inches high".

Other events / areas mentioned –

Extracts from Louth Meeting Minutes No.5 – Dundalk Town highlight areas subject to flooding:

- Fairgreen Rd, Dundalk - Heavy rain in conjunction with high tides floods low lying land at Fairgreen Road/R177 junction. Runoff unable to discharge via tidal sluice valves. Floods every 3 or 4 years.
- St. Nicholas Avenue, Dundalk – open area North of this flooded historically due to embankment failure.
- Balmer's Bog, Dundalk – Outlet culverted under N11 acts as a constriction with land upstream regularly flooded, sometimes backing up to R171 (Armagh Road).

[3] Patrick J. Tobin & Co. Consulting, Civil and Structural Engineers, 1979: "Rampart River Flooding Relief – A Feasibility Study"

(c) 3rd January 2014 flood

According to information supplied by LCC, tidal flooding on 3rd January 2014 reportedly affected coastal areas in Blackrock and Dundalk Port, causing road flooding and some damage to properties.

Review of the daily rainfall records collected from the two meteorological stations in the vicinity of the study area (Omeath and Riverstown) indicates a relatively dry period for the first 10 days of January 2014, with the (maximum) cumulative precipitation recorded on 3rd January being 1.3mm and 7mm on 5th January 2014; which is not exceptional.

Blackrock

In Blackrock, flooding was attributed to a combination of high tides and surge raising water levels which resulted in overtopping of the seawall along Main Street (R172), causing flooding to sections of the road (c. 500m) and three adjacent properties (1 residential and 2 commercial). Further flooding was also reported at this location on 5th and 6th January 2014. The flood depth on 3rd January 2014 was approximately 300mm and the high tide for Dundalk Bay along shore road in Blackrock was recorded as 3.219mAOD. The predicted high tide level for Dundalk Bay was 3.0m on 5th and 6th January 2014, and the flood depth approximately 150mm to 300mm, respectively.

Flooding was also observed further north, between Dundalk and Blackrock, at The Loakers and Connollys Corner along the shore road of the R172. The flood depth was reported as being approximately 300mm on 3rd January and approximately 100mm to 150mm on 6th January 2014 (no flooding recorded on 5th January 2014).

According to a note on the Flood Event Report, flooding at the above locations has occurred during February 2002 and also during the 1970's and 1980's.

Dundalk

Flooding at the Dundalk Port area on 3rd January 2014, was attributed to overtopping due to a combination of high tide, low air pressure and wind direction. It affected c.200m of the Main Inner Relief Road (N52) from St Helena's Road to Quay Street (see flood extends map in Appendix A), with traffic disruptions and damages to two industrial buildings and one public house. According to photographic evidence supplied by LCC, flooding appears to also have affected Coes Road to the south, however no further details have been supplied. The recorded high tide level on Georges Quay was 3.45mAOD, with the flood depths ranging from 450mm[4] on the Quay (off the main road) to 250mm on the road.

Further flooding was also reported at this location on 5th and 6th January 2014. The recorded high tide level on the top of the road kerb opposite Georges Quay was 3.35mAOD (5th January 2014) and 3.30mAOD (6th January 2014), with the flood depth ranging from 450mm on the Quay (off the main road) to 250mm on the road.

According to a note on the Flood Event Report, the area is prone to 'occasional' flooding. The last time this has occurred during 2002 with an estimated tide level of 3.65mAOD.

[4] The Flooding Event Report completed for the event on 3rd January 2014 states a rather excessive figure of 4.5m flood depth at the location of the Quay. However, this is understood to be a typographical error and that the depth was 0.45m as suggested by the reports on 5th and 6th January 2014.

Some flooding was also observed at Fairgreen Road (c.200m), west of Tain Bridge, with flood depths ranging between 250mm and 150mm on 3rd January 2014 and between 150mm and 100mm on 5th January 2014 (no flooding reported on 6th January 2014) that made road temporarily impassable. A note on Flood Event Report identifies 'surface depression' as the cause of flooding and suggests that the presence of road gullies allows for water to back up resulting in substantial difference in tide and flood levels.

(d) 14th November 2014 flood

The Register of Significant Flood Events supplied by LLC indicates that a fluvial flood event on 14th November 2014 affected a number of locations in Louth, with the following falling within the study area:

- 'Dundalk': Water breached the banks at the low side of river causing flooding of four industrial units in Mounthamilton Industrial Estate and three residential properties along Ardee Road.
- 'Louth': Water levels in river rose and water breached the bank at the low points flooding two properties along Regan's Terrace in Dundalk.

Further information concerning this flood event has not been supplied. The daily rainfall records collected from the two meteorological stations in the vicinity of the study area (Omeath and Riverstown) indicate that the (maximum) cumulative precipitation on 14th November 2014 was in the order of 19.6mm; which is not exceptional.

In addition to the information listed above, the Council supplied evidence of a flood event on 13th November 2014, including time-stamped photographs of flooded areas and a register outlining affected locations. The photographs were captured between 10:00 and 11:00 on the morning of 13th November 2014 and show flooding on Ardee Road (R171) and adjacent residential properties and also in Bay Estate on the corner of Hazelwood Avenue with Cypress Gardens road and Hazel Close. The time these photographs were taken, coincides with the peak of the flood as this was recorded at Ballyhaise station.

The list of locations affected by flooding on the 13th November 2014 within the study area are the following:

- Ardee Road (R171) (3 residential and 5 commercial properties affected);
- Bay Estate;
- Dowadallshill, Newry Road;
- 91 Doolargy, Muirtheimhne Mor;
- Failte House, Long Avenue/Hill Street;
- Avenue Road (2 residential properties); and
- Century Bar, Roden Street.

Review of the daily rainfall records at Omeath and Riverstown indicates that the event on 13th November 2014 was more significant compared to the one on 14th November 2014, with a (maximum) cumulative precipitation in the order of 48.1mm. Making use of the 'Design Rainfall Frequency' application available on opw.hydronet, the Annual Exceedance Probability (AEP) of such an event is estimated as 7.1% (rainfall frequency 14 years) for an ungauged point near Bay Estate and 6.5% (rainfall frequency 15 years) near Ardee Road.

(e) 27th January 2016 flood

LCC supplied information of a flood event on 27th January 2016, including photographs and location plans of affected areas. The evidence suggests that the following areas were affected within the study area:

- Bellews Bridge Road;
- Doylesfort Road;
- Mill Road (only CAD drawings of the area- no information on flooding).

The source of flooding for this event is not identified in the Register of Significant Flood Events supplied by LCC. Review of the daily rainfall records at Omeath and Riverstown indicates that cumulative precipitation on 27th January 2016 was not significant (maximum 1.4mm). It appears however, that it follows a relatively wet day on 26th January 2016, when the (maximum) cumulative precipitation recorded was in the order of 28.7mm. The Annual Exceedance Probability (AEP) of this event is estimated as 66.7% (rainfall frequency 2 years) for ungauged points near Mill Road in Castletown, Doylesfort Road in Dowdallshill and Bellews Bridge Road in Saltown. It is believed that flooding in the above areas was due to prolonged rainfall during the 26th and 27th January 2016, however this cannot be confirmed with the information available.

(f) 9th July 2016 flood

LCC supplied photographic evidence of a flood event on 9th July 2016 that affected Castletown Road at Railway Bridge making it impassable at this location. According to anecdotal evidence, this area appears to be prone to flooding. Some shallow flooding is also captured on Park Avenue in Townparks.

The source of flooding for this event is not identified in the Register of Significant Flood Events supplied by LCC. It is however believed that this is a fluvial flood event. Review of the daily rainfall records at Omeath and Riverstown appears to support this notion as it indicates that the maximum cumulative precipitation on 9th July 2016 was in the order of 30.3mm. The Annual Exceedance Probability (AEP) of this event is estimated as 58.8% (rainfall frequency 2 years) for an ungauged point near Castletown Road.

(g) Recent events

In addition to the events described above, LCC supplied photographs of a flood event that occurred on 13th January 2020 and affected Newry Road (R132) and Fairgreen Road east of the junction with R132. It is believed that flooding is attributed to a combination of large spring tides and strong onshore winds with the surge from storm Brendan, which passed Ireland on 13th January 2020 and placed the entire country under an ‘orange’ weather alert. This appears to be further supported by the daily rainfall data available from the two stations in the vicinity of the study area. Review of this record suggests that the maximum cumulative rainfall on the 13th January 2020 was in the order of 6.3mm; which is not exceptional.

According to comments received by LCC upon submission of the draft Hydrological Method Statement (HMS) report, a recent flood event appears to have affected Hardy’s Lane during

September 2020. OPW's past flood event report (reported by Nicholas O'Dwyer Ltd) states that flooding occurred at the downstream portion of the culverts and outfall pipes within Hardy's Lane on 2nd September 2020. This was because the stormwater from the drainage channels that feed into the culverts along Hardy's Lane were not able to drain fast enough and caused flooding downstream.

Interrogation of the rainfall data records from the meteorological stations available in the vicinity of the catchment (Table 3-2) does not indicate any significant rainfall depths during this period. The maximum cumulative rainfall depth was recorded at Omeath rainfall gauge on 1st September 2020 and was in the order of 21.7mm; which is not exceptional.

The assessment of daily rainfall data collected from the meteorological stations available in the vicinity of the study area, indicates heavy rainfalls have also occurred in recent years and these are summarised in Table 3-2. The most significant among them have occurred on the following dates:

- 2nd May, 11th September, 3rd December and 29th December 2015;
- 3rd March 2017;
- 28th July 2018; and
- 19th July 2019.

Information on the above events is not available and the AEP assessment is based on daily rainfall data alone (see further discussion in section 3.4, above).

4. Hydrometric Gauge Rating Reviews

4.1 Overview

We will carry out a full rating curve review for the two gauging stations at Ladyswell and Brewery Park as part of the hydraulic modelling task. This involves:

- Visiting the site;
- Procuring topographic survey to check the CFRAM topographic survey data and hydraulic model;
- Developing/reviewing hydraulic models based on the surveyed sections using MIKE11/MIKE FLOOD software;
- Calibrating the model (if possible) by adjusting Manning's roughness values and weir/bridge coefficients; and
- Using the model to simulate fluvial discharges up to and exceeding the estimated 1 in 1000 year flow.

4.2 Ladyswell (06036)

Ladyswell gauging station is located a few metres from Dublin Road (R132). Figure 4-1 shows the location, cross section and photos of the gauging station.

As discussed in Section 3.5(c), this station was previously operated by EPA and it was taken over by OPW in May 2019. The latest station has a short period of record. Available data for this gauging is:

- EPA (1978 to 1993): 15 minutes flow timeseries and spot gauging (flow only). Unfortunately, no water level data is available; and
- OPW (2018 to 2020): 15 minutes water level timeseries and a spot gauging on 17/06/2019.

Figure 4-1 shows 1D-2D CFRAM model ratings plots. The model results indicate an inconsistent relationship between water level and flow at the gauge across the three flood magnitudes we have presented model results for. None of the model results match closely with the sole spot flow gauging. This is most likely due to backwater from long culverts in the watercourse downstream of the gauge.

We have concerns regarding the schematisation of the CFRAM model at this location. The gauging station is located on the Dundalk River, about 14m upstream of Dublin Road (R132) culvert. CFRAM survey information shows that this culvert is connected to the Dundalk Blackwater River. The survey also noted that further downstream the Marshes Lower River is also connected to Dundalk Blackwater River, but no information is shown of this connection. In the model schematisation, however, the Dundalk River is only connected to Marshes Lower River via a long culvert (i.e. there is no connection between Dundalk River and Dundalk Blackwater River).

As part of this study, we will carry out a CCTV survey for culverts, topographic survey at the inlet and outlet of the culverts and the connections between Dundalk, Dundalk Blackwater and Marshes Lower Rivers. We will check, and update if necessary, the model schematisation once we receive the new CCTV and topographic survey data. This will be reported in the hydraulic modelling report.

Figure 4-1 – Location and cross section of Ladyswell gauging station (Top); Photos of gauge location (Bottom)

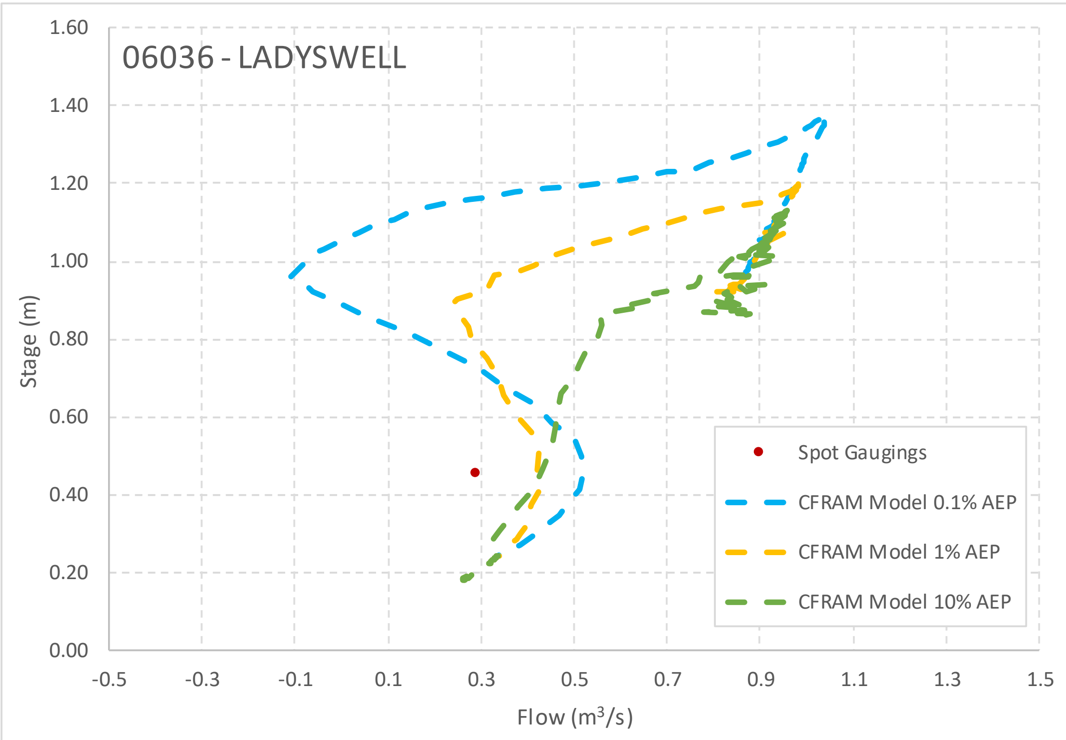


Figure 4-2 – Ladyswell gauging station ratings

4.3 Brewery Park (06013)

Brewery Park gauging station is located in the Brewery Business Park on Ardee Road, Dundalk. This station is located on the Dundalk River, about 740m upstream of Ladyswell gauging station. Figure 4-3 shows the location, cross section and photos of the gauging station.

The station was installed in July 2019 and operated by OPW. Data available for this gauging station is 15 minutes level timeseries from 2019 to 2020.

The 1D-2D CFRAM model ratings plots are shown on Figure 4-4. The results indicate that the relationship between water level and flow is consistent across the floods presented (in contrast to the Ladywell gauge). There is hysteresis evident, with water levels comparatively higher on the receding limb of the hydrograph.

As this gauging station is also located on the Dundalk River upstream of the Ladyswell gauging station, we will check this once we receive the new CCTV and topographic survey data.

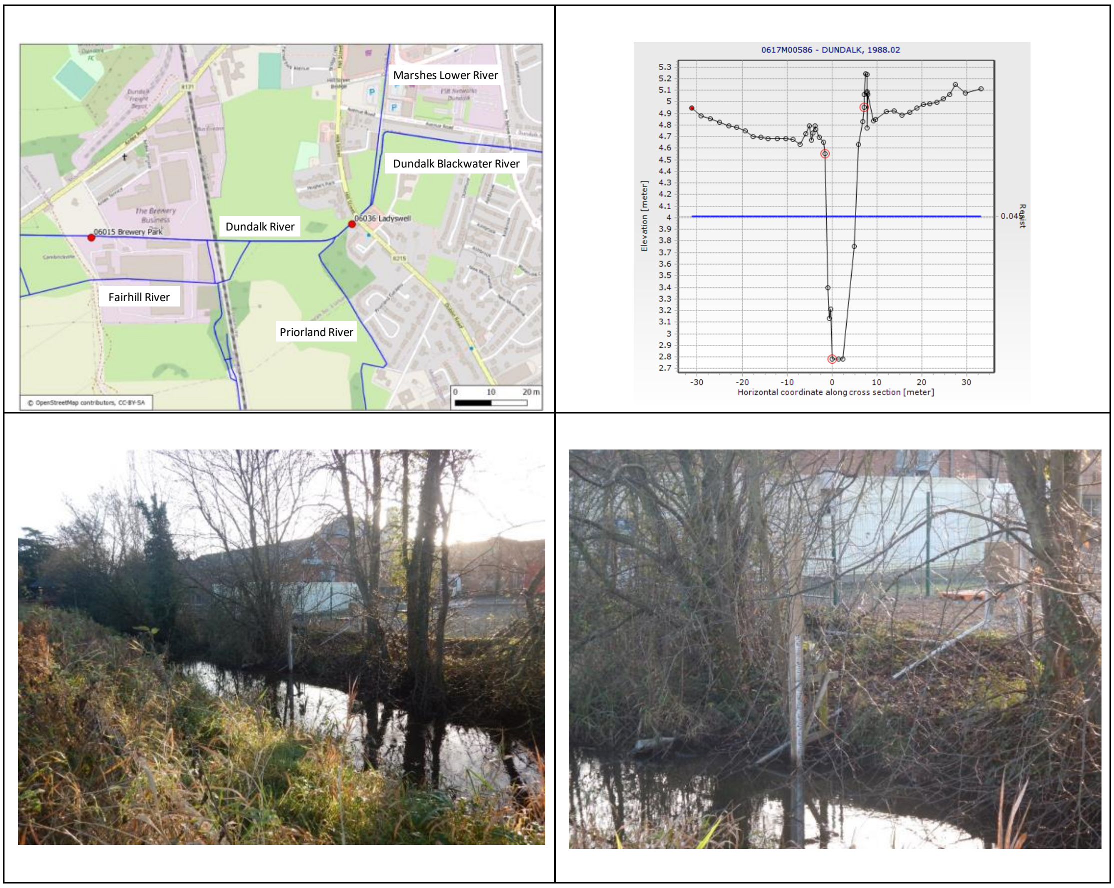


Figure 4-3 – Location and cross section of Brewery Park gauging station (Top); Photos of gauge location (Bottom)

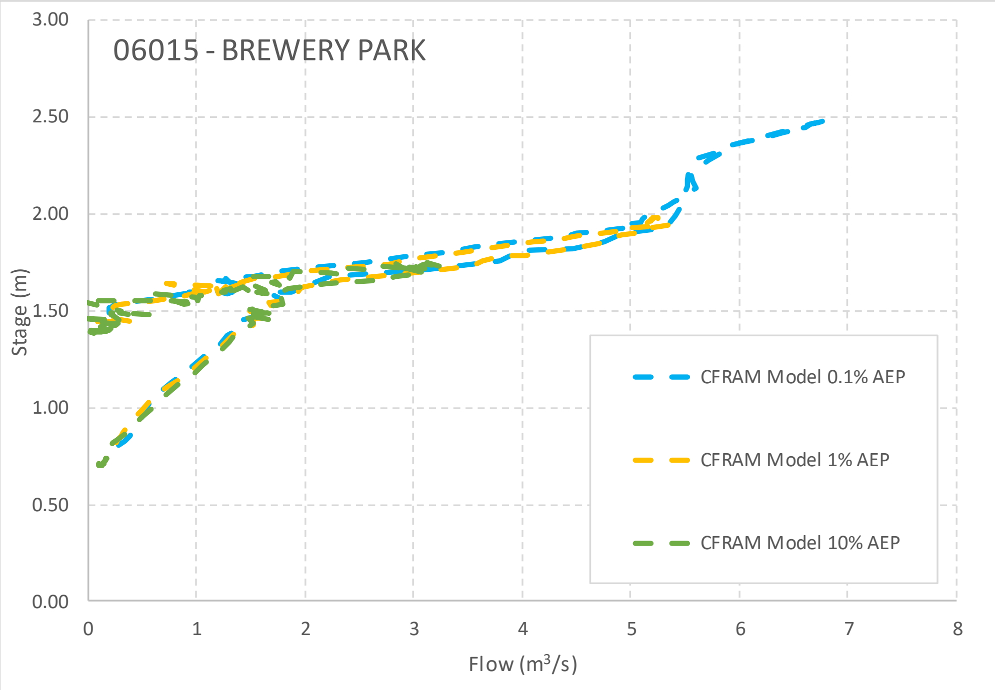


Figure 4-4 – Brewery Park gauging station ratings

4.4 Summary

The work that has been done so far indicates that it is not possible to generate consistent rating curves from model results for Ladyswell gauging station. This is possibly due to backwater from the long culverts downstream of the gauge. For Brewery park gauging station, however, there does appear to be a more consistent level-flow relationship so development of a rating curve from hydraulic model results is possible. We will check, and update if necessary, the model schematisation once we receive the new CCTV and topographic survey data. This will be reported in the hydraulic modelling report. Note that, due to the lack of flow gauging observations, the confidence that can be placed in any rating relationship will be low.

5. Design Flow Estimation

5.1 Overview

Our recommended approach for the hydrological assessment in this study is to use the FSU approach. Each step is described in more detail in the following sections:

- Index flood flow estimation (QMED) based on Physical Catchment Descriptors (FSU WP 2.3);
- Estimation of growth curve (FSU WP 2.2); and
- Derivation of hydrograph shape (FSU WP 3.1).

5.2 Index Flood Flow Estimation (QMED)

(a) Gauged data

As noted in Section 4, there is very limited gauged data available to inform the design flow estimation. As such, all the assessment points have been treated as ungauged locations.

(b) Ungauged locations

The index flood flow has been estimated using the following approach:

1. Estimate rural QMED from PCDs. The following equations were used for this calculation:
   - FSU 7-variable equation (primary method)
   - Institute of Hydrology Report 124 QBAR equation (for comparison, for small catchments only)
   - Flood Estimation Handbook (FEH) statistical method QMED equation (for comparison)
   - FSU 3-variable equation (for comparison)

2. Use a gauged pivotal site to adjust QMED. At the pivotal site, QMED is calculated from the gauged record and PCDs (FSU 7-variable equation) to derive an adjustment factor.

3. Use URBEXT value to make an urban adjustment to QMED, using the FSU 7-variable equation.

<u>Pivotal sites</u>

The preferred approach in FSU is to use the closest upstream or downstream gauging station on the same watercourse. This is not possible for this study area as there are no gauging stations with useable flow data available. Therefore, it is necessary to consider geographically or hydrologically similar stations:

- Table 5-1 presents the adjustment factors for nearby gauges on adjacent watercourses.

- Table 5-2 presents the adjustment factors for the hydrologically similar gauges recommended on the FSU Portal for the downstream end of the Castletown River.

- Table 5-3 presents the adjustment factors for the hydrologically similar gauges recommended on the FSU Portal for the downstream end of the Dundalk / Blackwater River.

This shows that there is a large variation in the potential adjustment factors in each of the tables – ranging from 0.56 (Roscrea) to 2.03 (Curralhir). Effectively this ranges from halving to doubling the unadjusted value.

The approach used in the CFRAM Hydrology Report was:

> *"Generally the geographically closest pivotal sites to the Model 4 catchments indicate a mixed pattern with catchments over 100km^2 indicating that the equation over estimates and catchments less than 100km^2 in area indicating under estimation."*
>
> *"A review of [the Castletown River] catchment against the full list of hydrologically similar sites indicates a strong trend towards over estimation with the average adjustment factor from the seven most hydrologically similar sites of 0.78. A review of the seven nearest sites geographically reveals an average adjustment factor of 1.12 but this is heavily influenced by the two small catchments to the north on the Flurry and Big Rivers (06030 and 06031) which are hydrologically quite different and in the case of the Curralhir station on the Flurry (06031) has high uncertainty within the adjustment factor. With these sites discounted the average of the geographically closest sites is reduced to 0.82. In light of this it is considered appropriate to apply an adjustment factor that considers the average of the geographically close and hydrologically similar sites of 0.8 to the Qmed flows in the Castletown River."*
>
> *"All of the other catchments are small (less than 25km^2) and all when reviewed against the full list of FSU hydrologically similar sites did not indicate a clear pattern towards under or over estimation against similar types of catchments nationally. Average adjustment factors for the seven most hydrologically similar pivotal sites to each catchment generally ranged from 0.96 to 1.04 but with one catchment with an average adjustment factor of 1.14 (Dundalk Blackwater). However the smaller pivotal sites within HA06 do indicate a strong trend towards under estimation and although there is some uncertainty in the data it is felt that these stations should be taken into account. As such adjustment factors for the smaller catchments have been derived from an average of the seven most hydrologically similar pivotal sites for each sub-catchment plus the three smaller HA06 pivotal sites 06030, 06031 and 06033 (maximum catchment area 55km2). This resulted in adjustment factors ranging from 1.18 to 1.24 and these have been applied to the ungauged PCD based estimates."*

Whilst the CFRAM approach is based on analysing and averaging the data from many gauges, it feels hard to justify retaining those adjustment factors given the evident spread between the gauges. The pattern between larger and smaller catchments does not appear as clear from the data in Table 5-1, Table 5-2 and Table 5-3. Further, the average adjustment factor in each of the three tables is close to 1 (1.05, 0.99 and 1.08 respectively).

Based on this, our recommended approach is not to apply a pivotal site adjustment to the QMED estimates derived from PCDs for any of the assessment locations.

Table 5-1 Potential pivotal sites – nearby geographically to Dundalk study area

Gauging Station	No.	Catchment area (km^2)	QMED gauged (m^3/s)	QMED PCDs (m^3/s)	Adjustment factor
Ballygoly	6030	10.4	8.6	5.02	1.71
Curralhir	6031	46.2	11.7	5.77	2.03
Muckno	6070	162.0	13.2	13.75	0.96
Clarebane	6012	162.8	14.5	14.24	1.02
Moyles Mill	6011	229.2	15.4	18.0	0.85
Aclint	06026	148.5	12.3	20.6	0.60
Tallanstown	06014	270.4	21.5	32.6	0.66
Burley	06025	176.0	19.1	26.2	0.73
Charleville	06013	309.1	27.1	42.9	0.63
Coneyburrow Br.	06033	55.2	18.6	14.2	1.31

Table 5-2 Potential pivotal sites – hydrologically similar to Castletown River (FSU Portal)

Gauging Station	No.	Catchment area (km^2)	QMED gauged (m^3/s)	QMED PCDs (m^3/s)	Adjustment factor
Clobanna	16051	34.2	2.9	3.46	0.82
Common's Road*	10021	32.5	7.4	6.72	1.09
Cushina	14009	68.4	6.8	6.09	1.12
Killeen Road	9035	37.1	11.7	8.64	1.35
Roscrea	25040	28.0	3.6	6.52	0.56

* Note that there have been changes to the Common's Road catchment and QMED in recent years so the values should be treated with caution

Table 5-3 Potential pivotal sites – hydrologically similar to Dundalk/Blackwater River (FSU Portal)

Gauging Station	No.	Catchment area (km^2)	QMED gauged (m^3/s)	QMED PCDs (m^3/s)	Adjustment factor
Carrickmines	10022	12.9	3.9	3.83	1.01
Naul	8002	33.4	5.4	3.81	1.42
Common's Road*	10021	32.5	7.4	6.72	1.09
Clobanna	16051	34.2	2.9	3.46	0.82
Ballyboghil	8012	26.0	4.4	4.21	1.03

* Note that there have been changes to the Common's Road catchment and QMED in recent years so the values should be treated with caution

(c) Comparison of index flood flow estimates

Appendix C tabulates the $QMED_{rural}$ estimates for each of the HEPs using the four methods (IoH124 not used for the Kilcurry River and Castletown River as it is only intended for small catchments). This comparison shows that:

- The flood estimates are generally reasonably similar.
- For the Castletown River, the FSU 7-variable equation typically gives around 30% higher flood estimates than the FSU 3-variable equation and around 5% higher than the FEH QMED equation.
- For the Dundalk / Blackwater River, the FSU 7-variable equation typically gives around 20% lower flood estimates than the FSU 3-variable equation and FEH QMED equation. Estimates from the IoH124 equation lie midway between the two FSU equations.
- Between the other watercourses, there is not a consistent pattern with the FSU 7-variable equation sometimes giving higher and sometimes lower estimates than the other equations. The IoH124 equation results are often very different to the other methods.

(d) Summary and recommended flows

Appendix D shows the adjustments made to the $QMED_{rural}$ estimate (FSU 7-variable equation, from PCDs) using URBEXT for each HEP.

5.3 Growth Curve

(a) Approach

Growth curves for selected locations were developed in accordance with the methodologies set out in the FSU studies.

The FSU web portal provides an application, the Flood Frequency Module, for the estimation of flood growth factors. Depending on whether the subject site is at a gauged or an ungauged location, and based on the record length available for the selected subject site, there are three approaches to determine the flood growth curves and growth factors.

1. For a gauged catchment, with a record length equal to or longer than the target return period, the gauged data is plotted on a flood frequency diagram and the most suitable probability distribution is fitted against it to produce a flood growth curve. This is referred to as single site-site analysis.
2. If a subject site is situated at an ungauged location, a pooled flood frequency analysis is performed. Hydrologically similar gauged locations are selected to form a pooling group to the ungauged subject site, creating a longer time-series of observed flood data. A suitable probability distribution is then fitted against L-moment ratio plots of the pooling group stations.
3. At gauged locations, with a record length shorter than the target return period, a combination of the single-site and pooled analysis is applied. This combined analysis grants the advantage of reducing of the standard error of estimate of QT subject to the condition that the growth curve is applicable to all pooled stations, and thus assuming homogeneity of the pooling group.

Forming of Pooling Groups

Pooling groups have been selected based on the Region-of-Influence approach. This is also referred to as Euclidean distance analysis scheme, which can be described as a measure of hydrological similarity in terms of size-wetness-permeability. The 5T rule applies for the selected target return period of 100 years.

Note:

- Only gauging stations rated between A-C are included in the FSU application, and available to form pooling groups.
- The CFRAM study states that catchments of the Shannon and Erne hydrometric areas don't seem to be homogeneous with Eastern, South-Eastern and North-Eastern HAs.
- The pooling groups for the selected locations are all heterogeneous (H>2). Where applicable some gauging stations were omitted in favour of others, L-skewness appeared to be vital in terms of increasing homogeneity.

Selection of statistical distribution

M. C. Peel et al. (2001)[5] suggest that:

> *"Distribution selection for homogeneous data is best based on the sample average [of L-moment-ratios] and not on a line of best-fit through the data points. For heterogeneous data, the line of best-fit is useful for distribution selection when data are drawn from a single distribution function with a large range of parent shape parameter values. In practice, however, there are no means of knowing how a real heterogeneous regional sample is constructed and whether it complies with this condition."*

Comparison approach

For comparison with the FSU Portal outputs, growth curves are also presented for the growth curve factors used in the CFRAM study.

(b) Comparison of growth curves

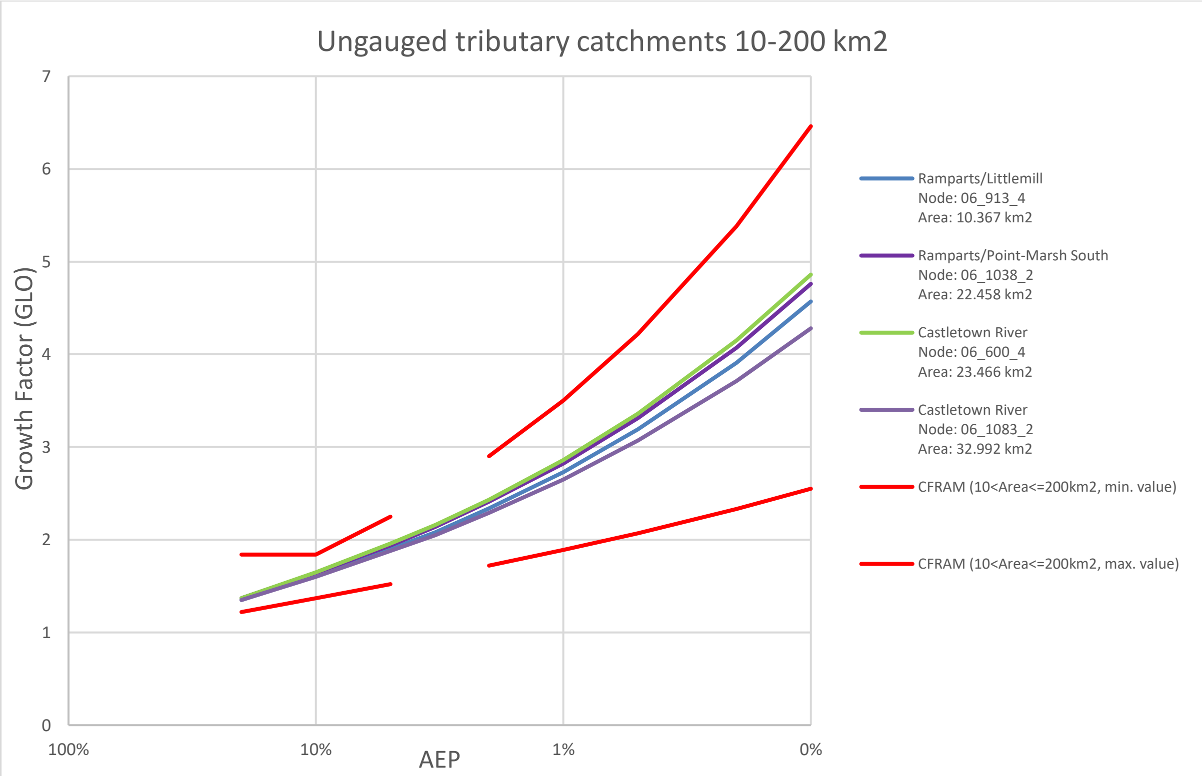
Table 5-4 to Table 5-5 show the range of derived growth curves at ungauged tributary catchments along the watercourses in Dundalk. The results from the preferred approach and distribution (combined/pooled approach, General Logistic distribution, discordant stations removed) are shown in bold for each location.

Based on these comparisons:

---

[5] Murray C. Peel, Q. J. Wang, Richard M. Vogel & Thomas A. McMahon (2001) The utility of L-moment ratio diagrams for selecting a regional probability distribution, Hydrological Sciences Journal, 46:1, 147-155, DOI: 10.1080/02626660109492806

- We tested excluding discordant stations from the default pooling groups to reduce heterogeneity. Generally, this has only a small impact on the growth factors. Excluding gauges from the Shannon and Erne hydrometric areas as suggested in the CFRAM report, did not increase homogeneity.
- For the larger ungauged tributaries (>10km^2) our preferred growth factors lie within the minimum and maximum range used in CFRAM.



- For the smaller ungauged tributaries (<10km^2) our preferred growth factors are smaller than used in CFRAM (up to 22% lower).

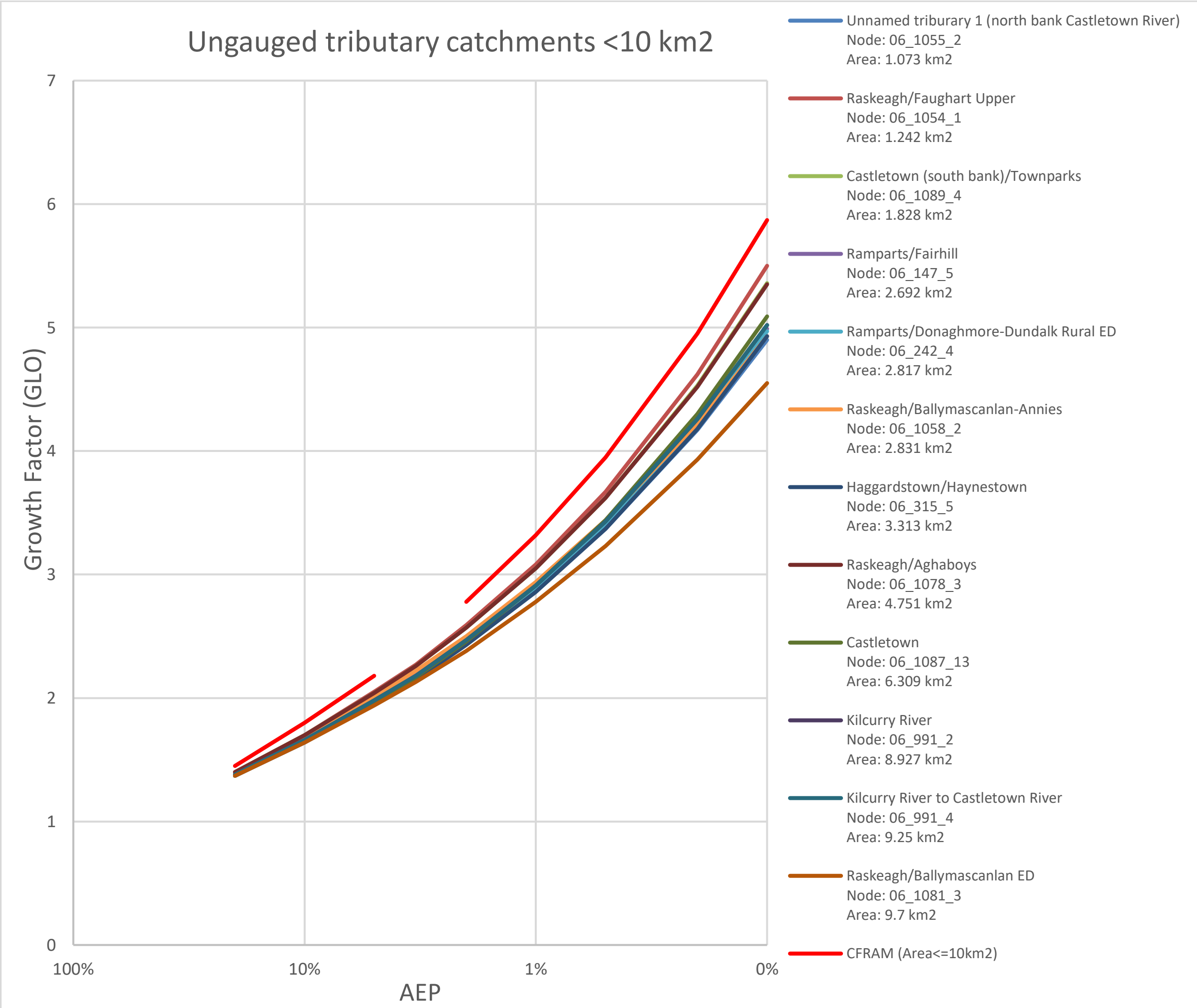


Table 5-4 Growth curve results -ungauged tributary catchments (<10 km^2)

Location	Approach	Dist.	20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
Stranacarry (north bank Castletown River) Node: 06_1055_2 Area: 1.1 km^2	Pooled FSU	GEV	1.42	1.72	2.02	2.20	2.44	2.78	3.14	3.64	4.05
		GLO	1.38	1.66	1.97	2.18	2.45	2.88	3.37	4.16	4.87
		LN3	1.54	1.93	2.31	2.53	2.82	3.22	3.63	4.20	4.65
	Pooled FSU, stations 08012/25034 excluded	GEV	1.41	1.70	2.01	2.19	2.43	2.78	3.15	3.67	4.10
		GLO	**1.37**	**1.65**	**1.96**	**2.16**	**2.44**	**2.87**	**3.37**	**4.17**	**4.90**
		LN3	1.55	1.93	2.32	2.55	2.84	3.25	3.68	4.27	4.74
Aghaboys (u/s) Node: 06_1054_1 Area: 1.2 km^2	Pooled FSU	GEV	1.42	1.73	2.04	2.23	2.47	2.82	3.19	3.72	4.15
		GLO	1.39	1.67	1.99	2.20	2.48	2.92	3.43	4.24	4.98
		LN3	1.56	1.95	2.34	2.58	2.88	3.29	3.72	4.31	4.78
	Pooled FSU, stations 08012/25034 excluded	GEV	1.43	1.76	2.10	2.31	2.59	3.00	3.44	4.09	4.63
		GLO	**1.40**	**1.70**	**2.05**	**2.27**	**2.59**	**3.08**	**3.67**	**4.62**	**5.50**
		LN3	1.62	2.07	2.53	2.81	3.17	3.67	4.21	4.95	5.55
Acarreagh Node:	Pooled FSU	GEV	1.42	1.73	2.04	2.23	2.47	2.82	3.19	3.72	4.15
		GLO	1.39	1.67	1.99	2.20	2.48	2.92	3.43	4.24	4.98

Location	Approach	Dist.	20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
06_1089_4 Area: 1.8 km^2		LN3	1.56	1.95	2.34	2.58	2.88	3.29	3.72	4.31	4.78
	Pooled FSU, stations 08009/25034 excluded	GEV	1.44	1.76	2.09	2.30	2.57	2.96	3.38	3.99	4.50
		GLO	**1.40**	**1.70**	**2.04**	**2.26**	**2.57**	**3.05**	**3.62**	**4.53**	**5.36**
		LN3	1.60	2.04	2.48	2.74	3.08	3.56	4.06	4.76	5.32
Killally/ Fairhill tributary Node: 06_147_5 Area: 2.7 km^2	Pooled FSU	GEV	1.42	1.73	2.04	2.23	2.47	2.82	3.19	3.72	4.15
		GLO	1.39	1.67	1.99	2.20	2.48	2.92	3.43	4.24	4.98
		LN3	1.56	1.95	2.34	2.58	2.88	3.29	3.72	4.31	4.78
	Pooled FSU, station 08009/ 08012/ 09011/ 25034/ 36031 excluded	GEV	1.42	1.73	2.04	2.23	2.48	2.83	3.20	3.73	4.17
		GLO	**1.38**	**1.67**	**1.99**	**2.20**	**2.48**	**2.92**	**3.44**	**4.25**	**4.99**
		LN3	1.56	1.96	2.35	2.59	2.89	3.31	3.74	4.34	4.82
Donaghmore Node: 06_242_4 Area: 2.8 km^2	Pooled FSU	GEV	1.42	1.73	2.04	2.23	2.47	2.82	3.19	3.72	4.15
		GLO	1.39	1.67	1.99	2.20	2.48	2.92	3.43	4.24	4.98
		LN3	1.56	1.95	2.34	2.58	2.88	3.29	3.72	4.31	4.78
	Pooled FSU, station 08009/ 08012/ 09011/ 25034 excluded	GEV	1.41	1.70	2.01	2.20	2.44	2.80	3.17	3.72	4.16
		GLO	**1.37**	**1.65**	**1.96**	**2.17**	**2.45**	**2.89**	**3.40**	**4.22**	**4.97**
		LN3	1.55	1.94	2.34	2.58	2.88	3.30	3.75	4.36	4.85
Ballynahattin (u/s) Node: 06_1058_2 Area: 2.8 km^2	Pooled FSU	GEV	1.42	1.71	2.00	2.17	2.39	2.70	3.02	3.45	3.80
		GLO	1.38	1.66	1.96	2.15	2.41	2.81	3.27	3.97	4.60
		LN3	1.52	1.87	2.22	2.42	2.68	3.03	3.39	3.88	4.26
	Pooled FSU, station 19046 excluded	GEV	1.44	1.75	2.06	2.25	2.49	2.83	3.19	3.68	4.08
		GLO	**1.40**	**1.69**	**2.01**	**2.22**	**2.50**	**2.94**	**3.44**	**4.22**	**4.93**
		LN3	1.56	1.95	2.33	2.56	2.84	3.24	3.65	4.21	4.65
Green Gates Node: 06_315_5 Area: 3.3 km^2	Pooled FSU	GEV	1.43	1.75	2.08	2.28	2.54	2.91	3.32	3.89	4.36
		GLO	1.40	1.70	2.03	2.25	2.54	3.01	3.55	4.42	5.22
		LN3	1.59	2.01	2.43	2.68	3.00	3.45	3.92	4.57	5.09
	Pooled FSU, station 08009/ 08012/ 25034 excluded	GEV	1.40	1.69	2.00	2.18	2.42	2.77	3.15	3.69	4.13
		GLO	**1.37**	**1.64**	**1.95**	**2.15**	**2.43**	**2.86**	**3.37**	**4.18**	**4.93**
		LN3	1.54	1.93	2.33	2.56	2.86	3.28	3.72	4.34	4.82
Aghaboys (d/s) Node: 06_1078_3 Area: 4.8 km^2	Pooled FSU	GEV	1.43	1.75	2.08	2.28	2.54	2.91	3.32	3.89	4.36
		GLO	1.40	1.70	2.03	2.25	2.54	3.01	3.55	4.42	5.22
		LN3	1.59	2.01	2.43	2.68	3.00	3.45	3.92	4.57	5.09
	Pooled FSU, station 25034 excluded	GEV	1.44	1.76	2.09	2.30	2.57	2.96	3.38	3.99	4.49
		GLO	**1.40**	**1.70**	**2.04**	**2.26**	**2.57**	**3.05**	**3.62**	**4.52**	**5.35**
		LN3	1.60	2.04	2.48	2.74	3.08	3.55	4.05	4.74	5.29
Castletown tributary	Pooled FSU	GEV	1.42	1.72	2.02	2.20	2.43	2.75	3.09	3.55	3.93
		GLO	1.38	1.67	1.98	2.17	2.44	2.85	3.33	4.07	4.74

Location	Approach	Dist.	20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
Node: 06_1087_13 Area: 6.3 km^2		LN3	1.53	1.90	2.27	2.48	2.75	3.12	3.51	4.03	4.45
	Pooled FSU, stations 08012/ 25023/ 25034 excluded	GEV	1.40	1.70	2.01	2.20	2.46	2.82	3.22	3.80	4.29
		GLO	**1.37**	**1.65**	**1.96**	**2.17**	**2.46**	**2.91**	**3.44**	**4.30**	**5.09**
		LN3	1.56	1.97	2.38	2.63	2.95	3.41	3.88	4.54	5.07
Kilcurry River Node: 06_991_2 Area: 8.9 km^2	Pooled FSU	GEV	1.42	1.72	2.02	2.20	2.43	2.75	3.09	3.55	3.93
		GLO	1.38	1.67	1.98	2.17	2.44	2.85	3.33	4.07	4.74
		LN3	1.53	1.90	2.27	2.48	2.75	3.12	3.51	4.03	4.45
	Pooled FSU, station 25034 excluded	GEV	1.41	1.71	2.02	2.21	2.46	2.82	3.21	3.76	4.21
		GLO	**1.38**	**1.66**	**1.98**	**2.18**	**2.47**	**2.91**	**3.43**	**4.26**	**5.02**
		LN3	1.56	1.96	2.36	2.60	2.91	3.34	3.79	4.41	4.91
Kilcurry River to Castletown River Node: 06_991_4 Area: 9.3 km^2	Pooled FSU	GEV	1.42	1.72	2.02	2.20	2.43	2.75	3.09	3.55	3.93
		GLO	1.38	1.67	1.98	2.17	2.44	2.85	3.33	4.07	4.74
		LN3	1.53	1.90	2.27	2.48	2.75	3.12	3.51	4.03	4.45
	Pooled FSU, station 25034 excluded	GEV	1.41	1.71	2.02	2.21	2.46	2.82	3.21	3.76	4.21
		GLO	**1.38**	**1.66**	**1.98**	**2.18**	**2.47**	**2.91**	**3.43**	**4.26**	**5.02**
		LN3	1.56	1.96	2.36	2.60	2.91	3.34	3.79	4.41	4.91
Ballynahattin (d/s) Node: 06_1081_3 Area: 9.7 km^2	Pooled FSU	GEV	1.40	1.66	1.92	2.07	2.26	2.52	2.78	3.13	3.40
		GLO	1.36	1.61	1.89	2.06	2.29	2.63	3.02	3.62	4.14
		LN3	1.47	1.78	2.07	2.24	2.46	2.75	3.05	3.44	3.75
	Pooled FSU, station 08012 excluded	GEV	1.41	1.69	1.98	2.15	2.37	2.67	2.99	3.42	3.77
		GLO	**1.37**	**1.64**	**1.94**	**2.13**	**2.38**	**2.78**	**3.23**	**3.93**	**4.55**
		LN3	1.51	1.86	2.20	2.40	2.66	3.01	3.37	3.86	4.24
	CFRAM (Area<=10km^2)	GLO	1.45	1.80	2.18		2.78	3.32	3.95	4.95	5.87

Table 5-5 Growth curve results -ungauged tributary catchments (10-200 km^2)

Location	Approach	Dist.	20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
Dundalk/ Blackwater (u/s) Node: 06_913_4 Area: 10.4 km^2	Pooled FSU	GEV	1.43	1.74	2.05	2.24	2.49	2.84	3.21	3.74	4.17
		GLO	1.39	1.68	2.00	2.21	2.50	2.94	3.45	4.27	5.01
		LN3	1.56	1.96	2.36	2.59	2.89	3.31	3.74	4.33	4.81
	Pooled FSU, stations 08009/ 08012/ 25034 excluded	GEV	1.38	1.66	1.94	2.11	2.33	2.64	2.97	3.44	3.81
		GLO	**1.35**	**1.61**	**1.90**	**2.08**	**2.34**	**2.73**	**3.19**	**3.91**	**4.57**
		LN3	1.50	1.85	2.20	2.41	2.67	3.04	3.42	3.95	4.36
Dundalk/ Blackwater (d/s) Node: 06_1038_2 Area: 22.5 km^2	Pooled FSU	GEV	1.42	1.72	2.02	2.20	2.43	2.76	3.11	3.58	3.97
		GLO	1.38	1.67	1.98	2.17	2.45	2.86	3.35	4.10	4.78
		LN3	1.54	1.91	2.28	2.50	2.77	3.16	3.55	4.09	4.51
	Pooled FSU, stations 08009/ 08012/ 25034 excluded	GEV	1.40	1.69	1.99	2.17	2.40	2.73	3.08	3.57	3.98
		GLO	**1.37**	**1.64**	**1.94**	**2.14**	**2.41**	**2.82**	**3.31**	**4.07**	**4.76**

Location	Approach	Dist.	20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
		LN3	1.53	1.90	2.27	2.49	2.77	3.16	3.57	4.12	4.56
Castletown River Node: 06_600_4 Area: 23.5 km^2	Pooled FSU	GEV	1.40	1.69	1.97	2.14	2.36	2.67	2.99	3.44	3.80
		GLO	1.37	1.64	1.93	2.12	2.38	2.77	3.23	3.94	4.58
		LN3	1.51	1.86	2.21	2.41	2.67	3.03	3.40	3.90	4.30
	Pooled FSU, station 25034 excluded	GEV	1.41	1.70	2.00	2.18	2.42	2.77	3.13	3.64	4.06
		GLO	**1.37**	**1.65**	**1.96**	**2.16**	**2.43**	**2.86**	**3.36**	**4.15**	**4.86**
		LN3	1.54	1.92	2.30	2.53	2.82	3.23	3.65	4.23	4.69
Castletown River Node: 06_1083_2 Area: 33.0 km^2	Pooled FSU	GEV	1.38	1.64	1.89	2.04	2.22	2.48	2.74	3.09	3.36
		GLO	1.35	1.59	1.86	2.02	2.25	2.59	2.97	3.56	4.07
		LN3	1.45	1.75	2.05	2.21	2.43	2.71	3.01	3.40	3.70
	Pooled FSU, stations 08009/ 25034 excluded	GEV	1.38	1.65	1.92	2.07	2.27	2.55	2.84	3.23	3.54
		GLO	**1.35**	**1.60**	**1.88**	**2.05**	**2.29**	**2.65**	**3.07**	**3.71**	**4.28**
		LN3	1.47	1.80	2.11	2.29	2.53	2.84	3.17	3.61	3.96
	CFRAM (10<Area<=200km^2, min. value)	GLO	1.22	1.37	1.52		1.72	1.89	2.07	2.33	2.55
	CFRAM (10<Area<=200km^2, max. value)	GLO	1.84	1.84	2.25		2.90	3.50	4.22	5.38	6.46

(c) Summary and recommended growth curves

Our recommended growth curves are summarised in Table 5-6. These are applied to the whole of each named watercourse. Smaller unnamed watercourses use the growth curve for the watercourse they discharge into.

Appendix E shows our recommended peak flows using these growth factors to multiply the QMED estimates.

Table 5-6 Recommended growth factors

Location	Based on	20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
Aghaboys	06_1054_1	1.40	1.70	2.05	2.27	2.59	3.08	3.67	4.62	5.50
Ballynahattin	06_1058_2	1.40	1.69	2.01	2.22	2.50	2.94	3.44	4.22	4.93
Kilcurry	06_991_2	1.38	1.66	1.98	2.18	2.47	2.91	3.43	4.26	5.02
Castletown	06_600_4	1.37	1.65	1.96	2.16	2.43	2.86	3.36	4.15	4.86
Stranacarry	06_1055_2	1.37	1.65	1.96	2.16	2.44	2.87	3.37	4.17	4.90
Castletown trib	06_1087_13	1.37	1.65	1.96	2.17	2.46	2.91	3.44	4.30	5.09
Acarreagh	06_1089_4	1.40	1.70	2.04	2.26	2.57	3.05	3.62	4.53	5.36
Donaghmore	06_242_4	1.37	1.65	1.96	2.17	2.45	2.89	3.40	4.22	4.97

Location	Based on	20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
Dundalk/ Blackwater	06_913_4	1.35	1.61	1.90	2.08	2.34	2.73	3.19	3.91	4.57
Killally / Fairhill trib	06_147_5	1.38	1.67	1.99	2.20	2.48	2.92	3.44	4.25	4.99
Green Gates	06_315_5	1.37	1.64	1.95	2.15	2.43	2.86	3.37	4.18	4.93

(d) Comparison with CFRAM peak flow estimates

Appendix F contains a comparison of peak flows derived in this current study with those adopted for the CFRAM study. In general:

- The peak flows for the largest catchments (Kilcurry River and Castletown River) are significantly larger for the current study than used in CFRAM. The index flood (2% AEP) estimates are larger and the growth curves applied to them are also steeper.

- The peak flows for the smaller catchments are lower for the current study than used in CFRAM. This applies to the Aghaboys, Ballynahattin, Stranacarry, Castletown tributary, Acarreagh watercourse, Donaghmore watercourse, Dundalk/Blackwater River, Ramparts/Marshes Lower watercourse and Blackrock watercourse. Only the Fairhill River, Priorland watercourse and Green Gates watercourse, of the smaller catchments, have higher peak flows for the current study than in CFRAM. Again, the differences stem from both the index flood and growth factors applied.

The differences between the flood estimates illustrate the uncertainty inherent in flood estimation for ungauged catchments such as these. We have made our best estimate based on available information and standard hydrological methods.

5.4 Hydrograph Shape

(a) Approach

Based on the results (growth factors and design peak flows) from the flood frequency analysis as described in 5.3, hydrograph shapes for the selected sites can be generated, using the FSU Hydrograph Width Module.

For ungauged locations a gauged hydrograph pivotal site is selected from a list of suggested hydrological similar candidates. Up to 10 flood event hydrographs will then be displayed for the pivotal/gauged site, with the possibility to adjust the timeframe that is being plotted. Following, a PCD adapted parametric model hydrograph is presented that can be modified to better fit the flood event hydrographs. The resulting characteristic hydrograph is then applied to the subject sites flood frequency estimates.

Note that several flood events show complex rather than favourable uniform hydrographs, and the automatically selected peaks don't always appear to be the largest peaks. Adjusting the characteristic hydrograph to better fit the flood event hydrographs is highly subjective. Some of the observed hydrographs in the FSU dataset have multiple or attenuated peaks, which can distort the analysis.

(b) Comparison of hydrograph shapes

Figure 5-1 to Figure 5-10 compare hydrograph shapes derived using the FSU Portal (unadjusted as the orange line, adjusted as the green line) to those used in the CFRAM model (red line). These show that:

- The adjusted FSU and CFRAM hydrographs in 5-8 match very closely.
- The adjusted FSU and CFRAM hydrographs in 5-4 and 5-5 match quite closely, specifically on the rising limb.
- For 5-1, 5-2, 5-3, 5-6, 5-7 and 5-9 – the CFRAM hydrographs show shorter durations/narrower hydrograph shapes, more so on the receding limb (with the adjusted FSU hydrographs in 5-1, 5-2 and 5-9 drawing closer to the CFRAM hydrograph).
- The CFRAM hydrograph in 5-10 lies between the unadjusted and adjusted FSU hydrographs.

Based on this comparison, we recommend implementing the adjusted FSU Portal hydrograph shapes in the model.

Appendix G contains a comparison of the Figure 5-9 hydrograph shape for the Dundalk / Blackwater River with observed water level data from the Ladyswell water level gauge. The three largest events in the 2018 to 2020 record are presented. This indicates that the design hydrograph shape may be underestimating runoff volume. However, note that the comparison is between flow and water level so other factors could be causing the difference. This will be explored further during the calibration phase of the hydraulic modelling and reported in the hydraulic modelling report.

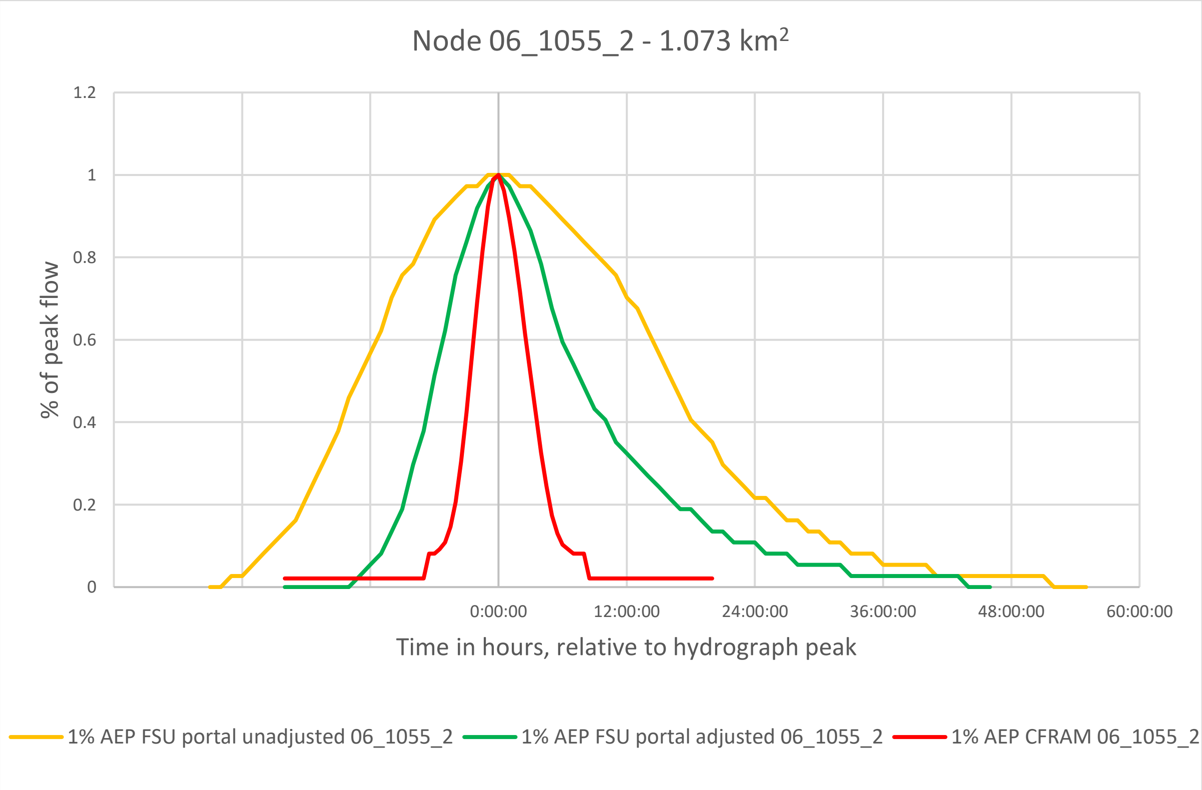


Figure 5-1 – Hydrograph shape comparison Node 06_1055_2

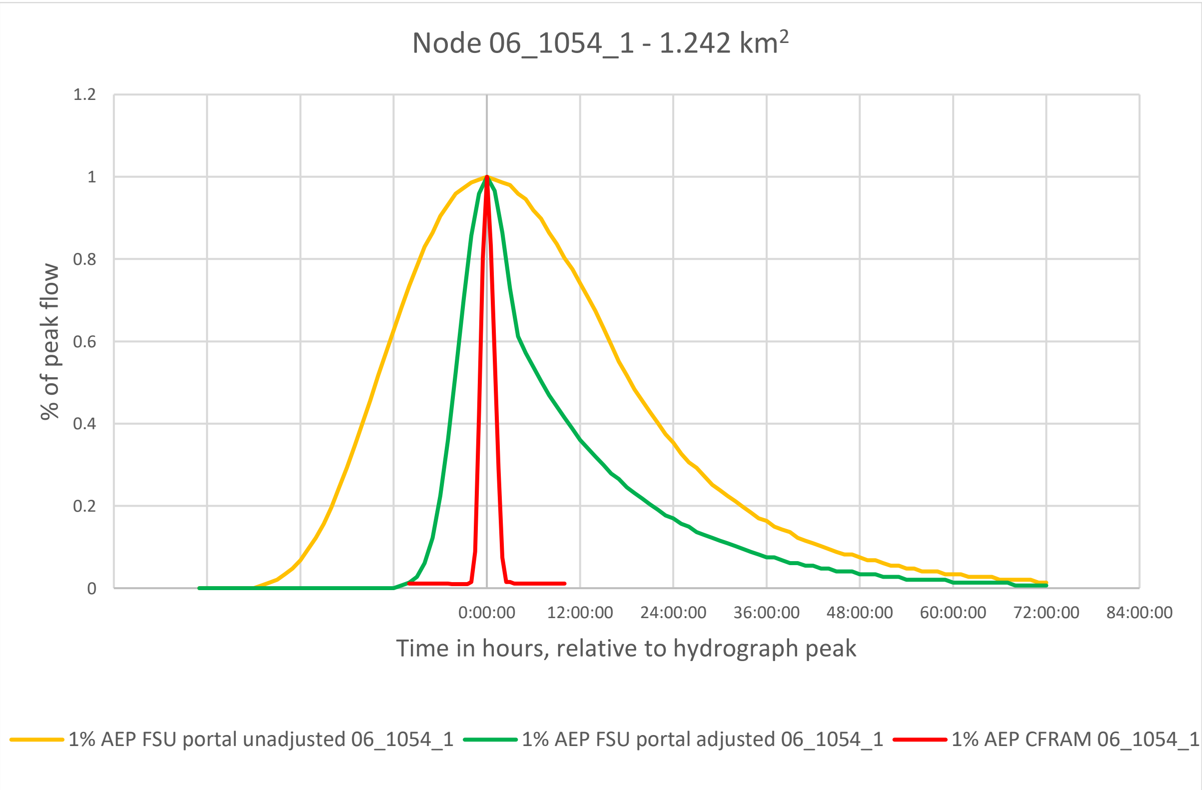


Figure 5-2 – Hydrograph shape comparison Node 06_1054_1

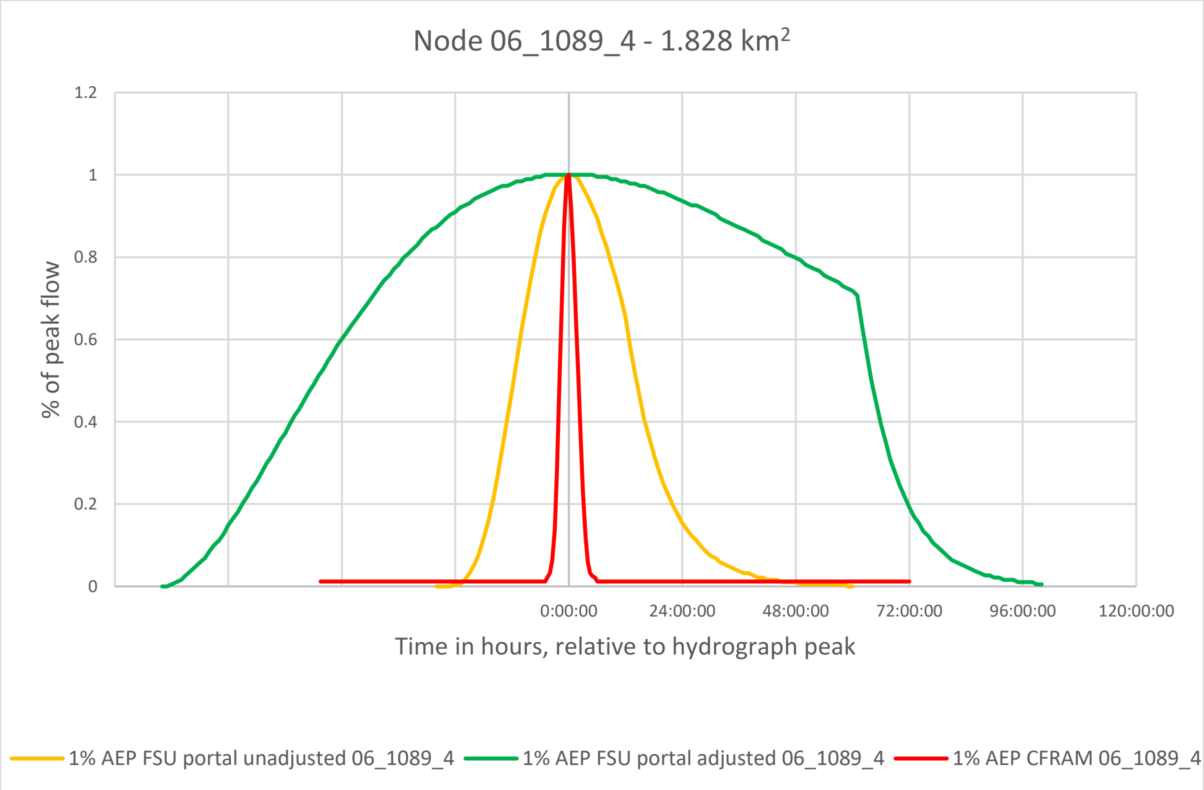


Figure 5-3 – Hydrograph shape comparison Node 06_1089_4

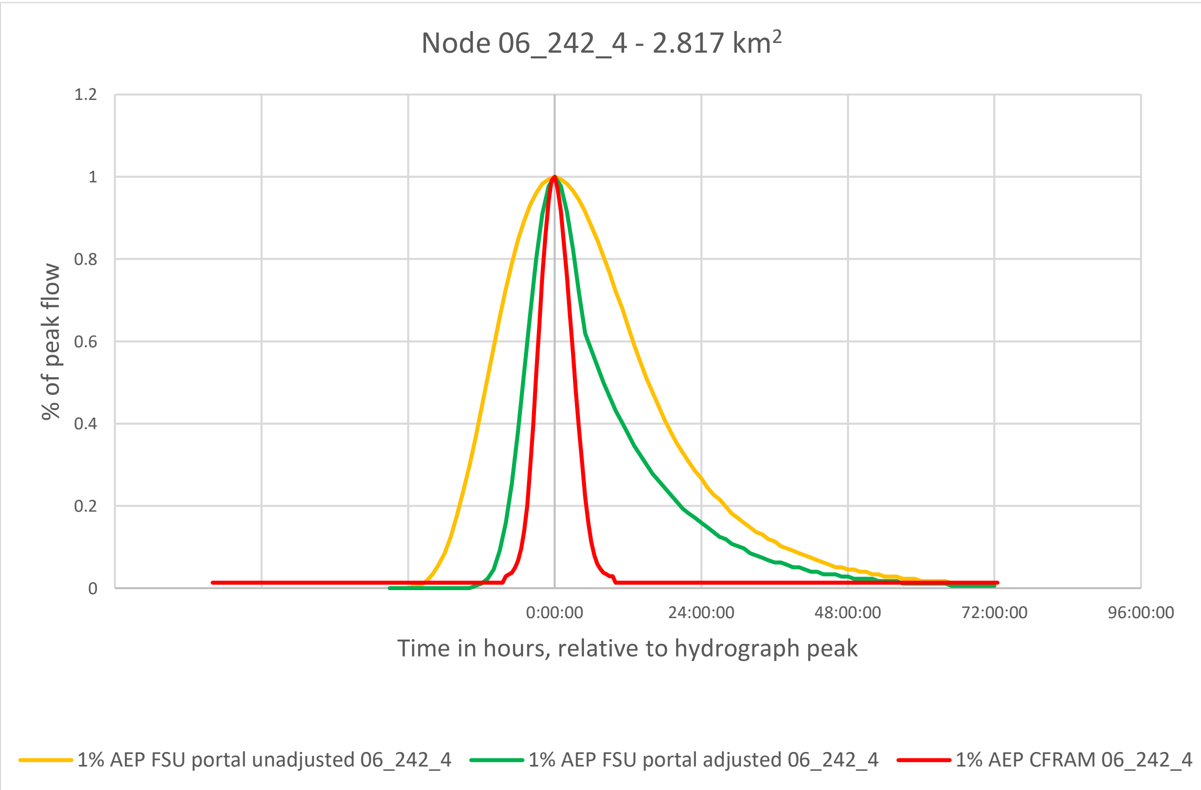


Figure 5-4 – Hydrograph shape comparison Node 06_242_4

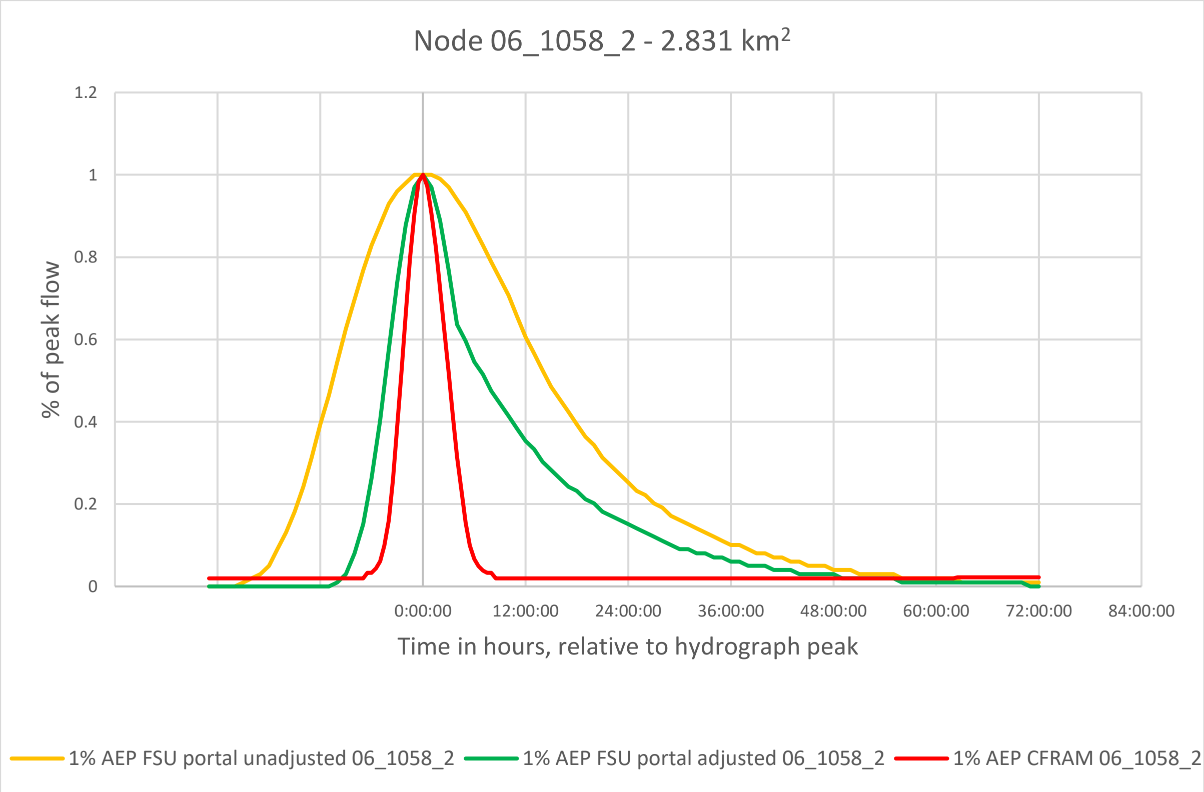


Figure 5-5 – Hydrograph shape comparison Node 06_1058_2

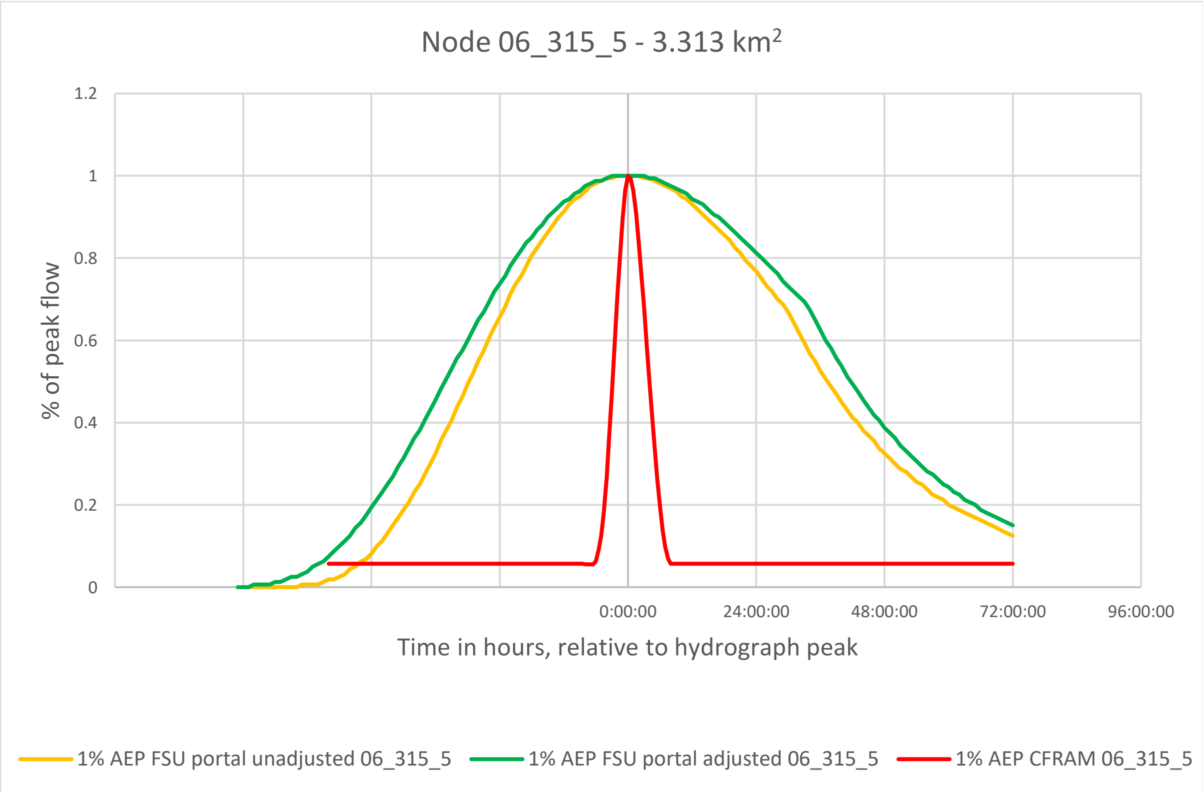


Figure 5-6 – Hydrograph shape comparison Node 06_315_5

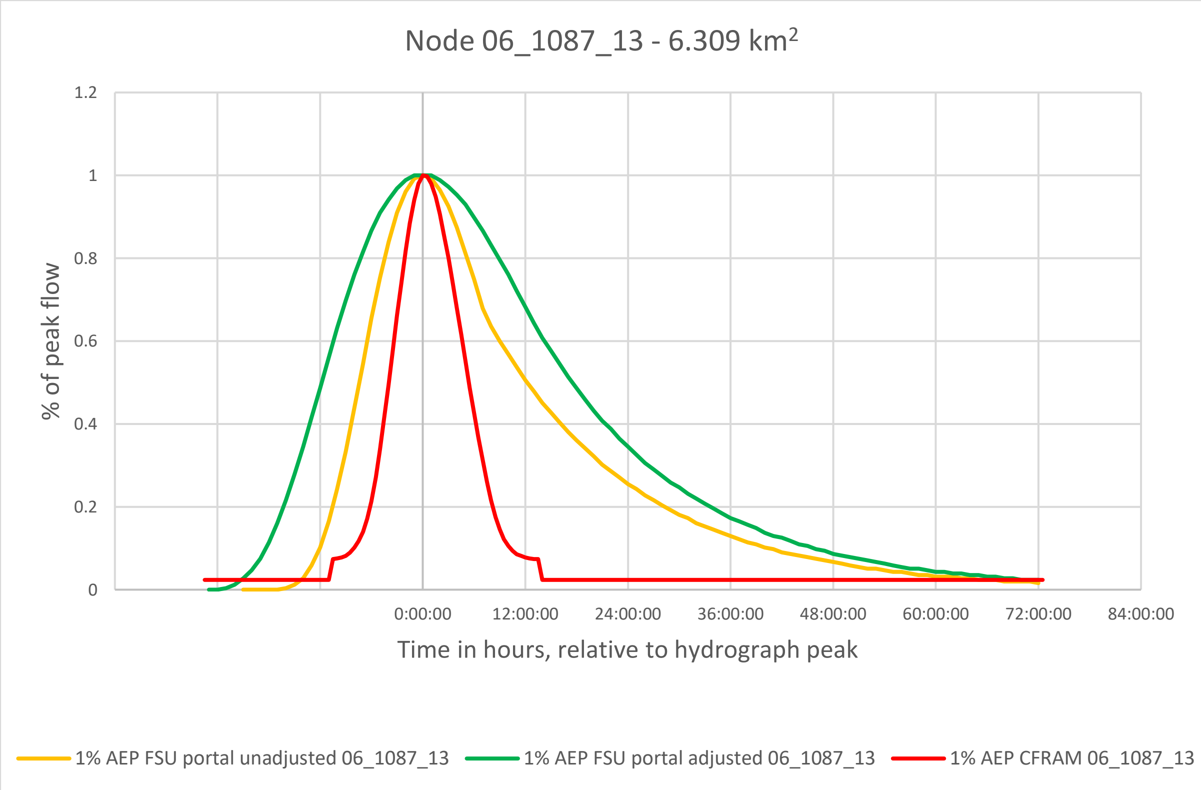


Figure 5-7 – Hydrograph shape comparison Node 06_1087_13

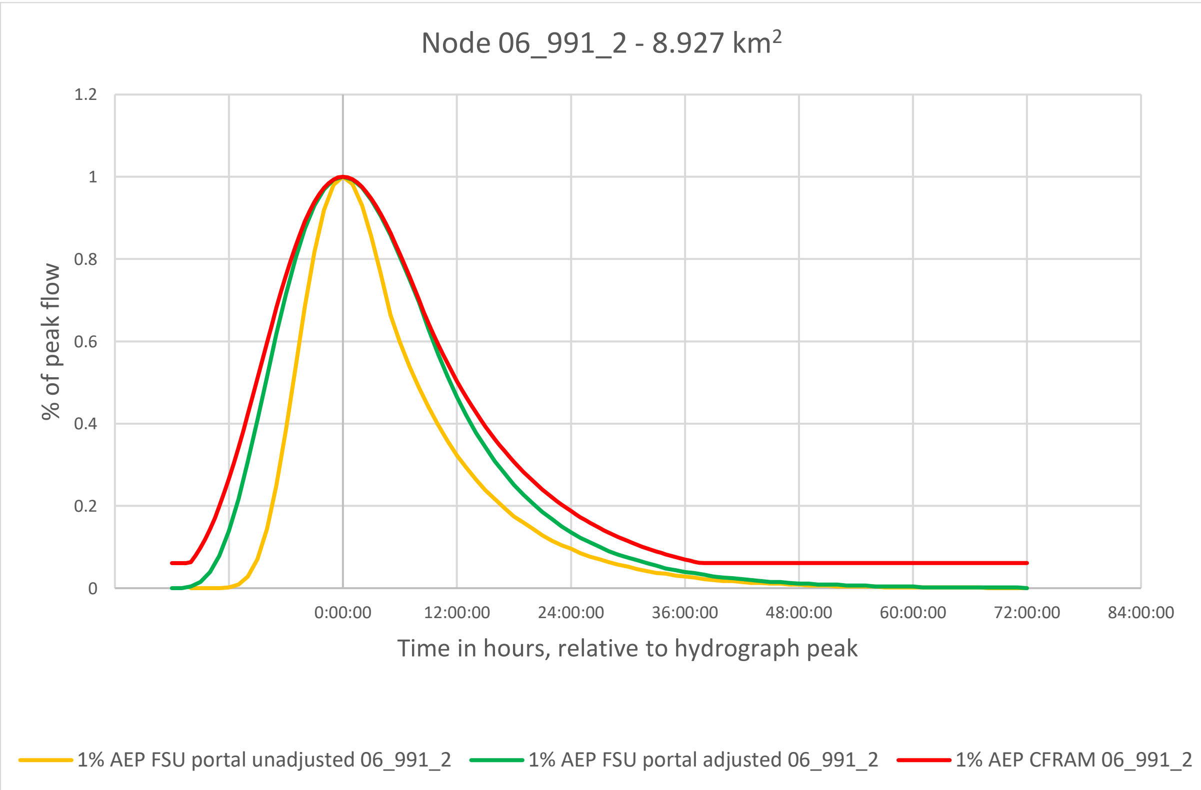


Figure 5-8 – Hydrograph shape comparison Node 06_991_2

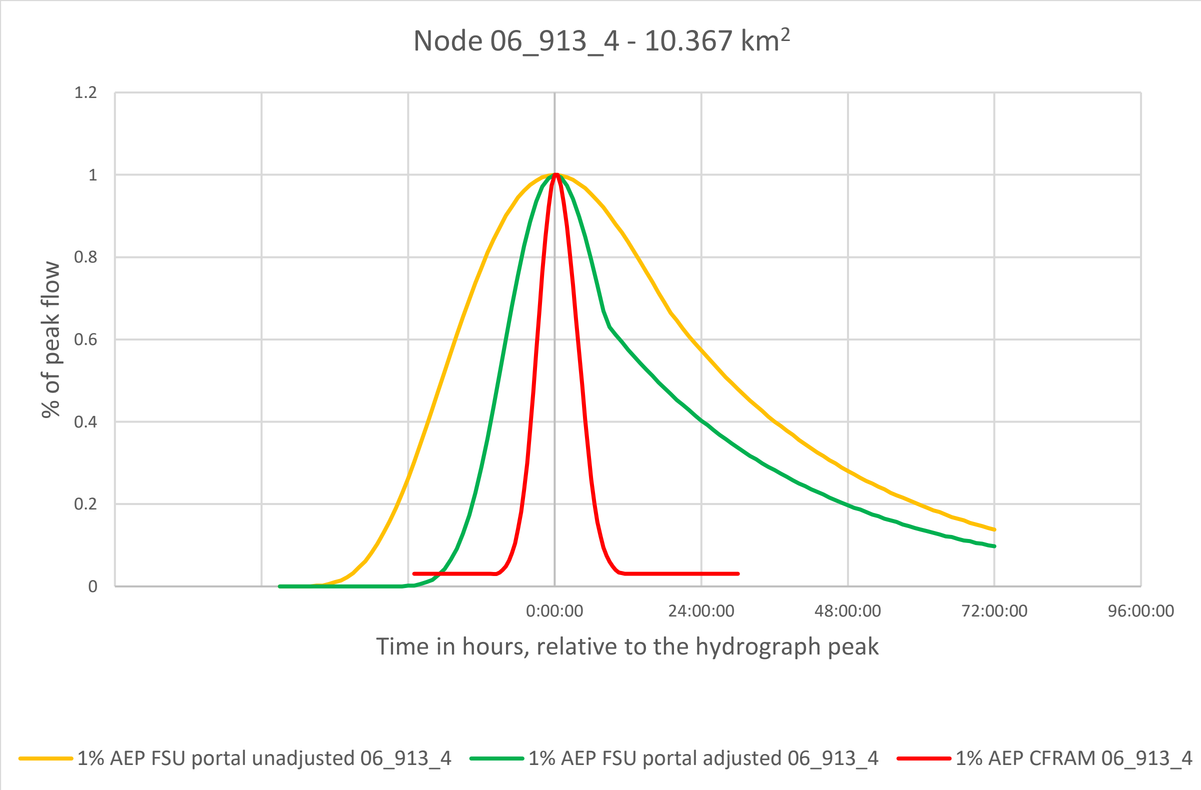


Figure 5-9 – Hydrograph shape comparison Node 06_913_4

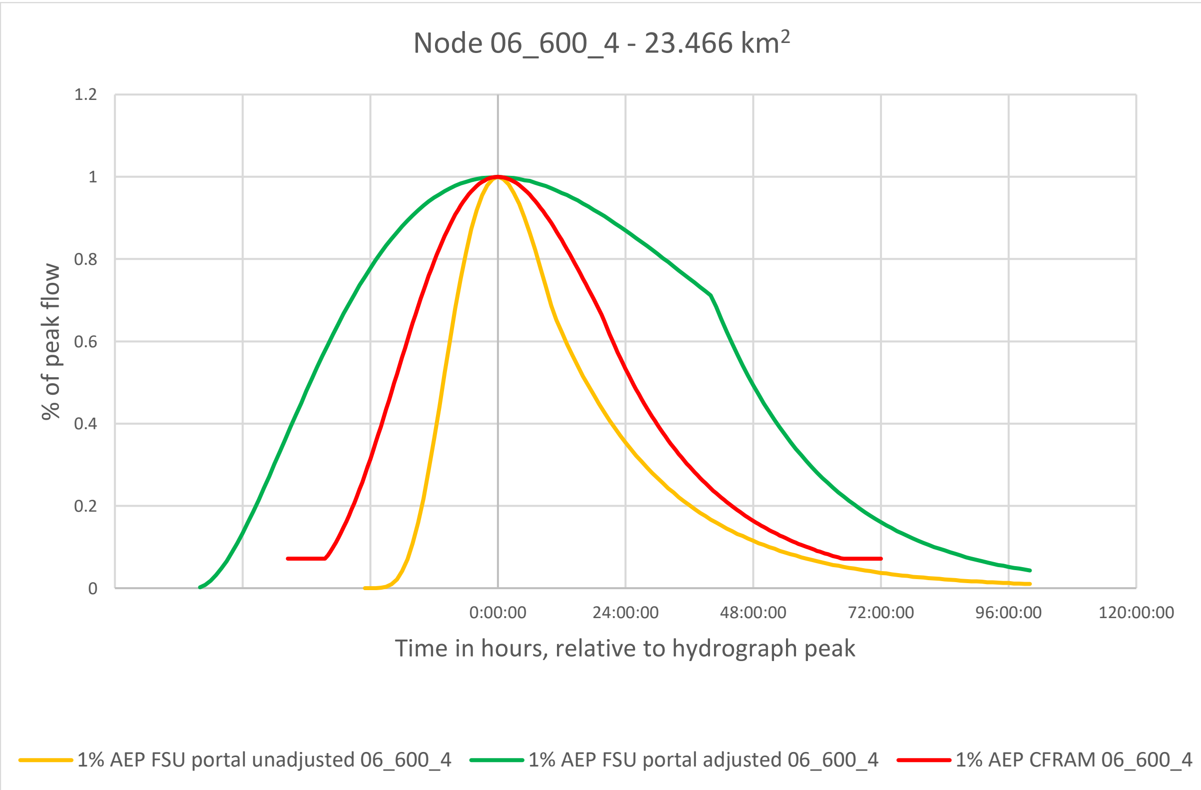


Figure 5-10 – Hydrograph shape comparison Node 06_600_4

5.5 Surface Water Contributions

(a) Approach

The estimation of rainfall depths and intensities for a range of design rainfall events has been undertaken using the FSU Portal. The "Point" selected for the estimation of design rainfall depths is located to the west of the rail line passing through the town and its co-ordinates are E:304000; N:306000. Results are tabulated for events with an Annual Exceedance Probability (AEP) of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1%.

In an attempt to evaluate the validity of the estimated rainfall depths, these figures are then compared to the maximum rainfall depths recorded at the meteorological stations available, located in the vicinity of the catchment.

(b) Rainfall data comparison

Table 5-7 below outlines the estimated rainfall depths in Dundalk for a number of storm durations ranging from 30 minutes to 24 hours (1440 minutes) and for events with an AEP of 50% (return frequency 2 years) up to 0.1% (return frequency 1000 years).

Table 5-7 Estimated (FSU) rainfall depths at Dundalk for storm events ranging from 30 minutes to 24 hours (1440 minutes).

Annual Exceedance Probability, AEP [%]	Rainfall depth [mm]						
	Storm duration [min]						
	30	60	90	120	240	480	1440
50	8.8	11.3	13	14.4	18.5	23.7	34.6
20	12.2	15.3	17.5	19.3	24.3	30.5	43.4
10	14.8	18.4	20.9	22.9	28.5	35.4	49.5
5	17.6	21.7	24.5	26.7	33	40.7	55.9
2	21.9	26.7	30	32.6	39.7	48.4	65.3
1	25.9	31.2	34.9	37.7	45.6	55.1	73.2
0.5	30.5	36.5	40.5	43.7	52.3	62.6	82.0
0.1	44.5	52.1	57.2	61.2	71.7	84.2	106.7

To cross-check the FSU Portal rainfall estimates:

- Table 5-8 compares FSU Portal rainfall depths with the maximum daily rainfall depths recorded at the meteorological stations in Riverstown and Omeath to the north of the catchment. The FSU Portal depths are for the grid point closest to each gauge (rather than Dundalk).
- Table 5-9, Table 5-10 and Table 5-11 compare FSU Portal rainfall depths with recorded rainfalls at the hourly rainfall gauges at Dublin Airport some 70km to the south, Dunsany about 65km to the south-west and Ballyhaise about 70km to the west of the

catchment, respectively, for a range of durations. Again, the FSU Portal depths are taken at the closest grid point to the gauge rather than Dundalk itself.

The results in Table 5-8 indicate that FSU Portal estimates are realistic. The maximum values recorded at the daily gauges typically lie between the 10% and 2% AEP, which seems plausible. This provides confidence in the estimated depths shown in Table 5-7, noting that predicted rainfalls at Dundalk are lower than at the two daily rain gauge locations.

The figures tabulated in Table 5-9 and Table 5-10 suggest that the maximum rainfall depths recorded at the hourly rainfall gauges to the south and south-west are higher, with AEPs for the recorded events lying between 10% and 0.5%. It is nevertheless noted, that the depths predicted at these gauges are significantly higher than those predicted at Dundalk (Table 5-7), suggesting that the rainfall regime is different. On the other hand, the rainfall depths estimated at Ballyhaise to the west (Table 5-11) appear to be comparable to those estimated at Dundalk (Table 5-7). The maximum rainfall depths recorded at this gauge appear to be significant for the shorter storm durations in the table ranging from 1% to 0.1% AEP. Maximum recorded rainfall depths for the longer storm periods are between 5% and 1% AEP.

Table 5-8 Estimated (FSU) rainfall depths for 24-hour storm events and maximum recorded daily rainfall depths at Riverstown and Omeath meteorological stations.

Annual Exceedance Probability, AEP [%]	Rainfall depth [mm]	
	24-hrs storm duration [hrs]	
	Riverstown	Omeath
50	43.4	44.9
20	54.6	55.6
10	62.5	63.1
5	70.7	70.8
2	82.6	82
1	92.8	91.5
0.5	104.2	101.9
0.1	136	130.9
Max recorded at station	**68.6**	**80.6**

Table 5-9 Estimated (FSU) rainfall depths for storm events ranging from 60 minutes to 24 hours and maximum recorded rainfall depths at Dublin Airport meteorological station.

Annual Exceedance Probability, AEP [%]	Rainfall depth [mm]				
	Storm duration [min]				
	60	120	240	480	1440
50	11.1	14.4	18.7	24.2	36.2
20	15.5	19.9	25.4	32.4	47.4
10	18.9	24	30.4	38.5	55.5
5	22.7	28.5	35.9	45.1	64.2
2	28.5	35.5	44.2	55.1	77.3
1	33.8	41.8	51.7	63.9	88.7
Max recorded at Dundalk Airport	**40.1**	**49.2**	**60.4**	**74.1**	**101.6**

Table 5-10 Estimated (FSU) rainfall depths for storm events ranging from 60 minutes to 24 hours and maximum recorded rainfall depths at Dunsany meteorological station.

Annual Exceedance Probability, AEP [%]	Rainfall depth [mm]				
	Storm duration [min]				
	60	120	240	480	1440
50	11.2	14.5	18.8	24.3	36.6
20	16	20.5	26.1	33.4	49.3
10	19.8	25	31.7	40.2	58.7
5	24	30.2	38	47.7	68.9
2	30.7	38.2	47.6	59.3	84.5
1	36.9	45.6	56.4	69.7	98.3
Max recorded at Dunsany	**32.3**	**33.7**	**43.6**	**46**	**65.5**

Table 5-11 Estimated (FSU) rainfall depths for storm events ranging from 60 minutes to 24 hours and maximum recorded rainfall depths at Ballyhaise meteorological station.

Annual Exceedance Probability, AEP [%]	Rainfall depth [mm]				
	Storm duration [min]				
	60	120	240	480	1440
50	11.3	14.5	18.5	23.7	35.3
20	15.5	19.4	24.4	30.8	44.5
10	18.5	23.1	28.7	35.8	50.9
5	21.9	27.1	33.4	41.2	57.6
2	27.2	33.1	40.3	49.2	67.5
1	31.8	38.4	46.4	56.1	75.9
Max recorded at Ballyhaise	**37.2**	**44.6**	**53.4**	**63.9**	**85.3**

(c) Summary

Assessment of the pluvial flooding will be implemented in the hydraulic modelling utilising the estimated rainfall depths from the FSU Portal above by:

- Applying the rainfall depths directly to the 2D flood model; and
- Assessing vulnerable areas / ponding of water.

5.6 Groundwater

Geological and groundwater maps, provided by the Geological Survey of Ireland (GSI), have been reviewed for the study area and specifically Ardee Rd. (R171) and Mounthammilton Estate west of Dundalk, to establish an understanding of the possible risk of groundwater flooding.

The underlying bedrock is the Clontail formation, a poorly productive aquifer, consisting of calcareous red-mica greywacke (Figure 5-11). The groundwater recharge within the study area ranges mainly between 51-100 mm (annual recharge) (Figure 5-12), a recharge cap of 100 mm is applied where the subsoil is not classified as made ground.

The subsoil permeability is mostly classified as 'medium' ('low' in the Dundalk costal area, 'high' where the Dundalk Gravel GWB is located as well as close to the Blackrock beaches/wetland) (Figure 5-13).

Groundwater vulnerability ranges mostly from 'moderate' to 'extreme' and 'Rock at or near Surface or Karst' (Figure 5-14) indicating groundwater depths from 0-3 m to greater than 10 m (extract shown below[6]). Specifically, the west of Dundalk including Ardee Rd/R171/Mounthammilton Estate shows high to extreme vulnerability and rock at or near surface or karst (associated medium permeability).

Depth to rock	Hydrogeological Requirements for Vulnerability Categories				
	Diffuse recharge			Point Recharge	Unsaturated Zone
	high permeability *(sand/gravel)*	**Moderate permeability** *(sandy subsoil)*	**low permeability** *(clayey subsoil, clay, peat)*	*(swallow holes, losing streams)*	*(sand & gravel aquifers only)*
0–3 m	Extreme	Extreme	Extreme	Extreme (30 m radius)	Extreme
3–5 m	High	High	High	N/A	High
5–10 m	High	High	Moderate	N/A	High
>10 m	High	Moderate	Low	N/A	High

i N/A = not applicable.
ii Release point of contaminants is assumed to be 1–2 m below ground surface.
iii Permeability classifications relate to the engineering behaviour as described by BS 5930.
iv Outcrop and shallow subsoil (i.e. generally <1.0 m) areas are shown as a sub-category of extreme vulnerability.
(amended from Deakin and Daly (1999) and DELG/EPA/GSI (1999))

There is no record of groundwater related historical flooding. No karst or karst features are present in the study area.

[6] Source: https://www.gsi.ie/en-ie/programmes-and-projects/groundwater-and-geothermal-unit/activities/understanding-ireland-groundwater/groundwater-vulnerability/Pages/Groundwater-vulnerability-and-pathways.aspx

Even though the subsoil permeability is classified as medium in most areas of Dundalk and Blackrock, the relatively low recharge in the area, indicates the presence of little groundwater. This is also reflected in the recorded groundwater vulnerabilities, which can be related to the recharge acceptance rate or the recharge potential.

This can be associated with low risk of groundwater flooding. In fact, as stated in the Louth groundwater body description by the GSI: "Due to the low permeability of some subsoil deposits (e.g. thicker till) and the aquifers, a high proportion of the effective rainfall will quickly discharge to the streams in the GWB. In addition, steeper slopes in the mountainous and drumlin areas and promote surface runoff. The relatively high stream density reflecting the higher proportion of surface runoff as opposed to aquifer recharge." [7]

In Ardee Rd/R171/Mounthammilton Estate, considering the topography (see google earth snapshot, Figure 5-15), as well as infrastructure (roads and small culvert), there is a risk for surface water/water from streams to be trapped in the lowland areas.

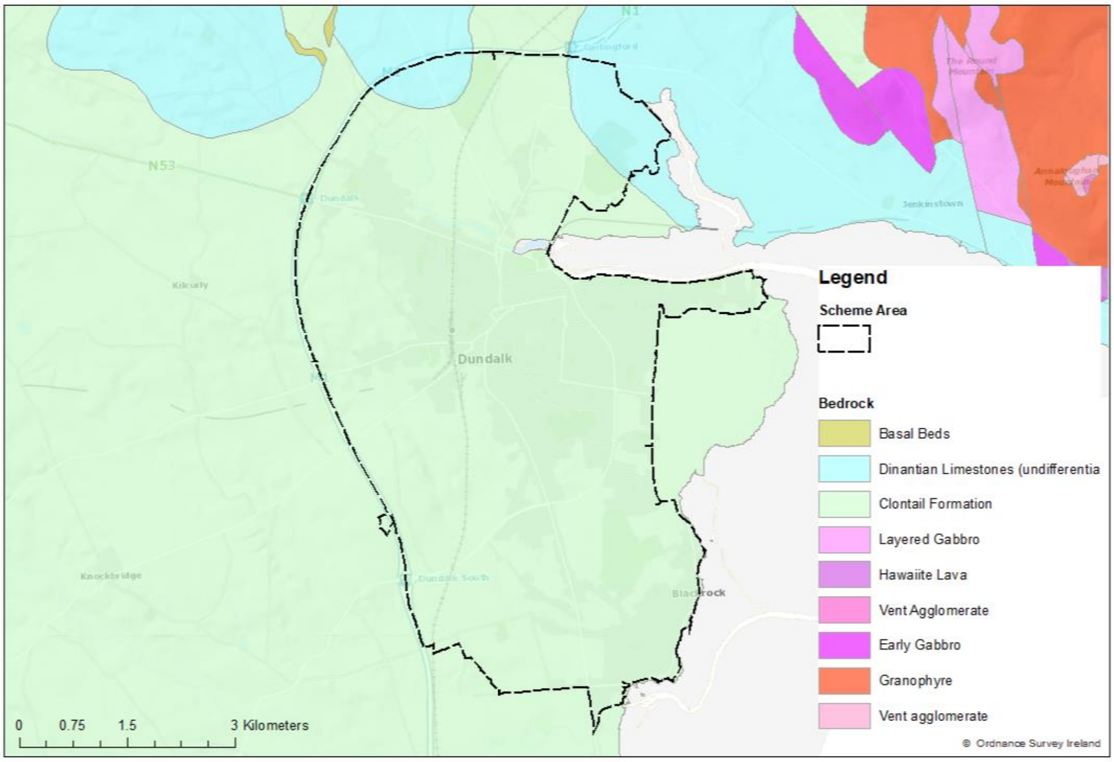


Figure 5-11 – Bedrock

[7] Source: https://secure.dccae.gov.ie/GSI_DOWNLOAD/Groundwater/Reports/GWB/LouthGWB.pdf

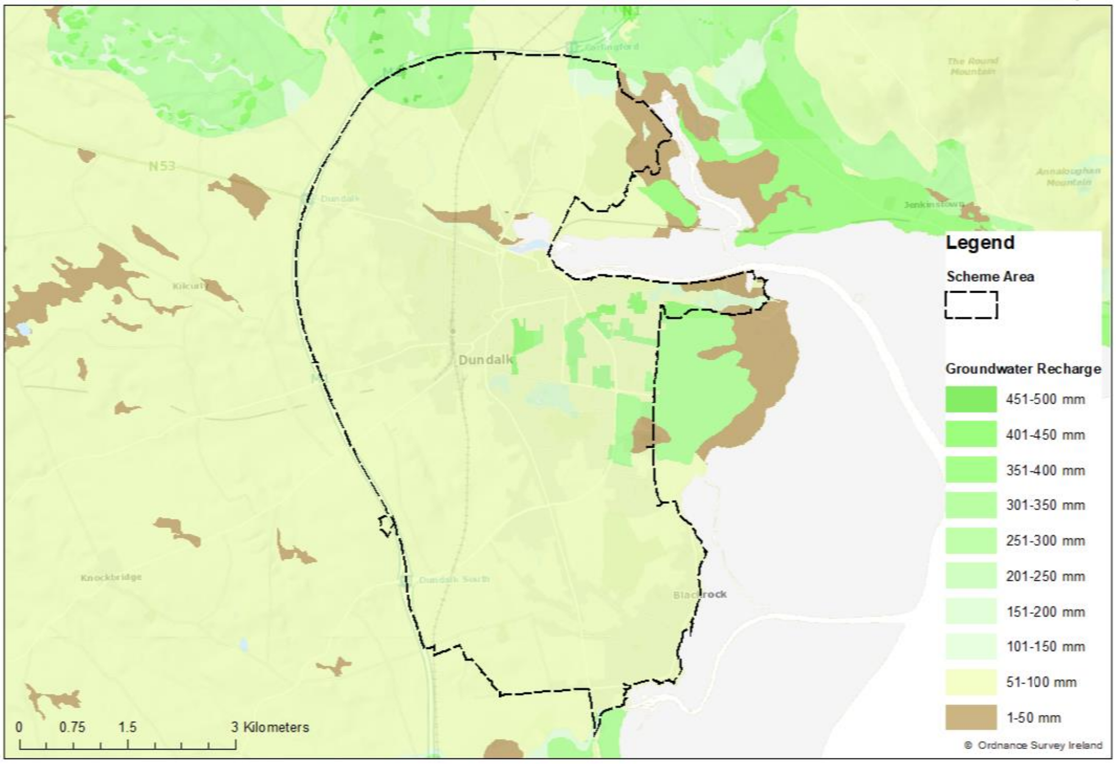


Figure 5-12 – Groundwater recharge

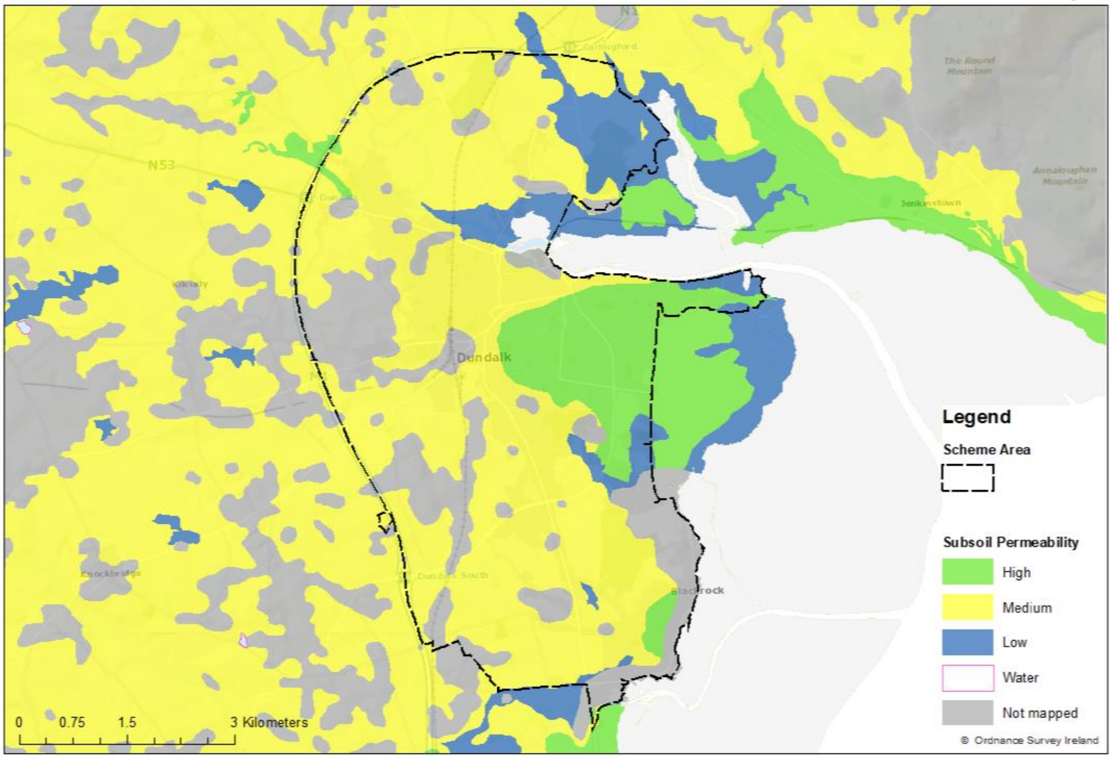


Figure 5-13 – Subsoil permeability

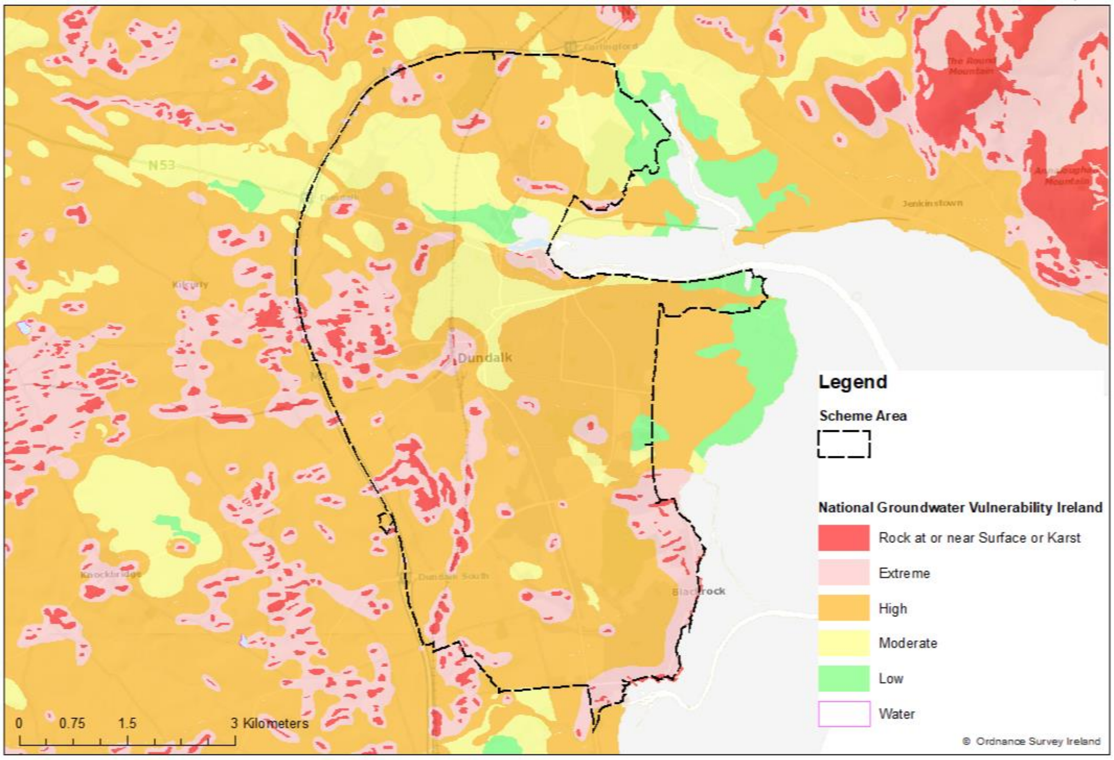


Figure 5-14 – Groundwater vulnerability

Figure 5-15 – Ardee Rd/R171/Mounthammilton Estate topography

5.7 Climate Change

(a) Flood flow adjustment

The design flood flows will be adjusted for the climate change scenarios based on Section 3.3.5 of the Brief:

- Mid-Range Future Scenario (MRFS) +20% to flood flows
- High End Future Scenario (HEFS) +30% to flood flows

(b) Urbanisation

An estimate of future development / urbanisation within the catchment has also been made. This can be tested, for comparison to the flow adjustments above, by amending URBEXT values in the index flood flow estimates from PCDs.

Investigating CORINE datasets since the first release in 1990 (baseline data) reveals, on a national scale (Corine Land Cover :: Environmental Protection Agency, Ireland (epa.ie)):

- Between 1990 – 2000:
  - Artificial surfaces increased in area from 1.5% to 1.9% of total national land cover. This was caused by urban sprawl and developments in infrastructure and sports facilities.
- Between 2000 – 2006:
  - The six years between 2000 and 2006 experienced a 0.3% increase in artificial surfaces. A growth in forestry from 12% to 12.6% was witnessed during the same period.
- Between 2006 – 2012:
  - From 2006 to 2012 the main landcover type change was afforestation (planting of forestry on previously un-forested land). This accounted for a 0.13% increase in the national area covered by forestry. Afforestation took place on agricultural and peatland areas, resulting in a 0.12% and 0.04% respective reduction in these landcover types nationally. In the same period the rate of increase in artificial areas reduced markedly down to just 0.04% of the national area. There was minimal new construction but there was significant completion of existing construction sites, in particular the completion of motorways (3,295 ha). Apart from these 'cross-type' changes, the change statistics were dominated by cyclical land management practises such as arable-pasture rotation (38.45% of total change) or clear-felling and re-planting of forestry (37.61% of total change). Whilst these changes are within their respective Level 1 landcover categories, they are still significant for applications such as greenhouse gas emissions analysis.
- Between 2012 – 2018:
  - No existing data commentary on the changes were found, however the CORINE 2012 – 2018 changes dataset revealed and land-use changes with the catchment
  - Filtering to only show the difference in artificial surfaces between 2012 and 2018 reveals Figure 5-16.
  - However, comparing the urban fabric data between the CORINE 2012 and 2018 datasets reveals a 125,000m^2 increase in artificial surfaces in Dundalk.

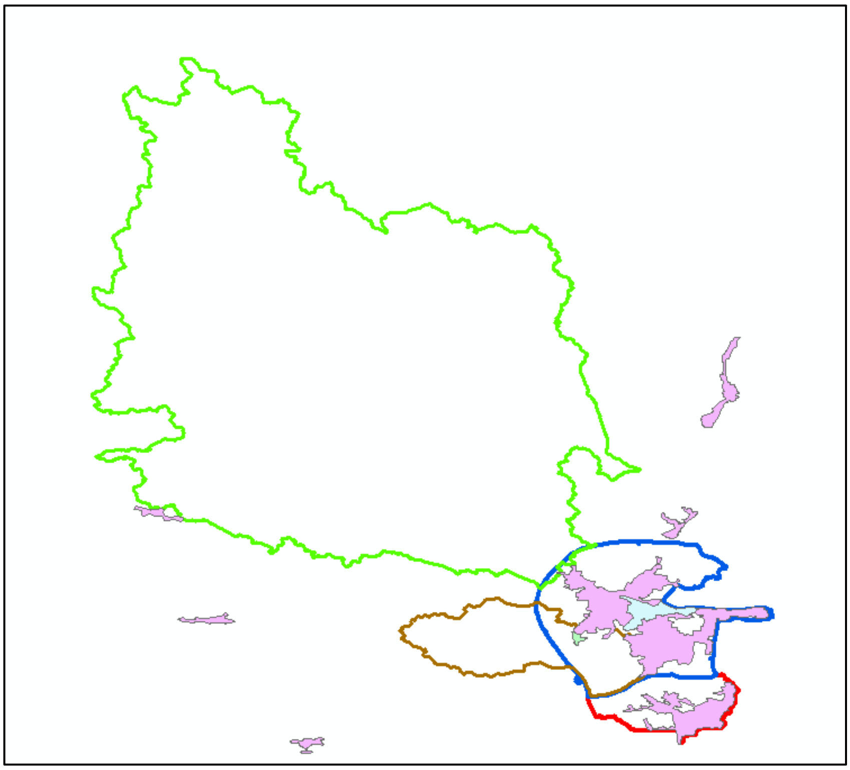


Figure 5-16 – Difference in artificial surfaces (2012-2018)

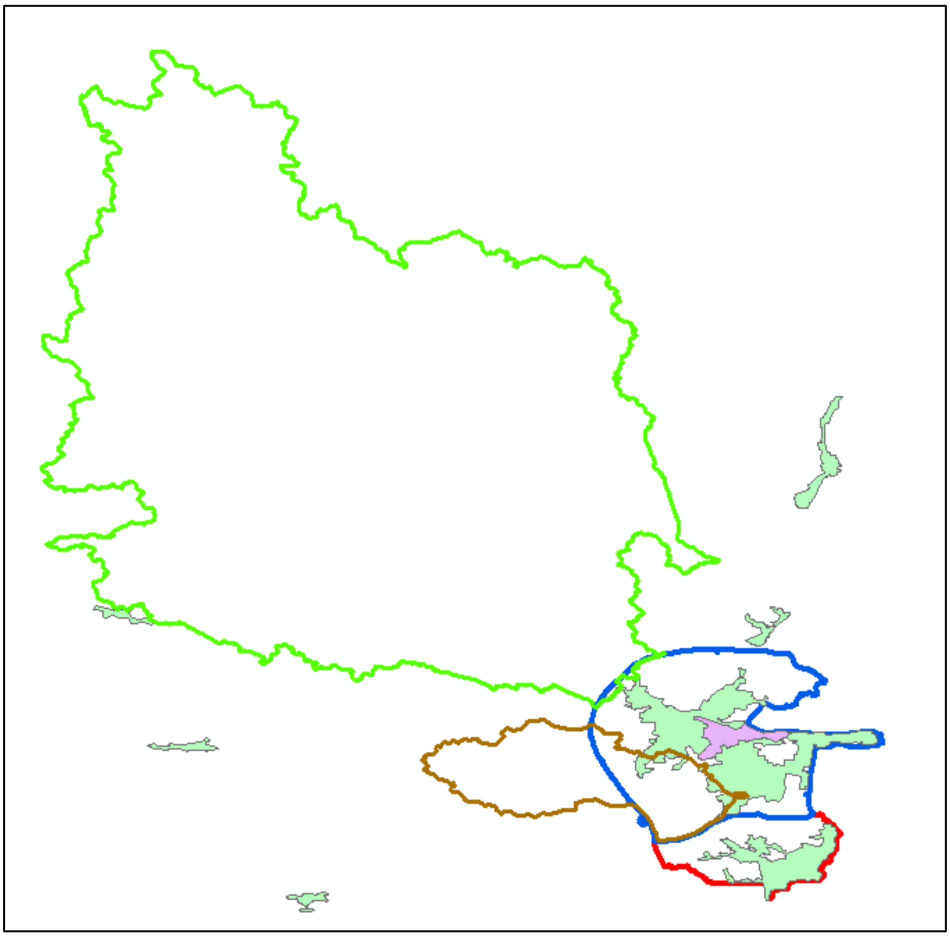


Figure 5-17 – CORINE 2018 dataset

The CORINE 2018 dataset, as shown in Figure 5-17, shows the current artificial surfaces areas

- Total artificial surfaces = 10,450,000m^2 (Dundalk), 2,925,000m^2 (Blackrock)
- Total Catchment Area for Dundalk = 225,725,000m^2 (Castletown); 142,968,000m^2 (Ramparts) + remaining Dundalk AFA boundary of 36,735,659m^2
- Total Catchment area for Blackrock ≈ 14,494,000m^2

Reviewing the current Development Plans in the catchment from (Volume 1A - Book of Maps (Regional Growth Centres, Self-Sustaining Growth Towns & Rural Policy Zones - Louth County Council (louthcoco.ie)) reveals the future artificial surface areas up to 2024 (shown in Table 5-12):

Table 5-12 Future artificial surface areas up to 2024

Area	Current Artificial Surface Area (m^2)	Future Artificial Surface Area (m^2)	% increase
Dundalk (inc. AFA plus + river catchments)	10,450,000	12,700,000	~22%
Blackrock	2,925,000	3,439,500	~18%

The total increase in % artificial surface coverage can then be calculated using the data in Table 5-13.

Table 5-13 Total increase in % artificial surface coverage

Catchment	Physical Surface Area (m^2)	Total Area (m^2)	% artificial surface coverage
2018 CORINE *Dundalk*	10,450,000	405,429,000	2.6%
2021-2027 Development Plans *Dundalk*	12,700,000	405,429,000	3.1%
2018 CORINE *Blackrock*	2,925,000	14,494,000	20.2%
2021-2027 Development Plans *Blackrock*	3,439,500	14,494,000	23.7%

Table 5-14 compares the % increase in artificial surface area over time:

Table 5-14 Percent increase in artificial surface area over time

Timescale	% increase in artificial surfaces	Notes	Reference
1990 - 2000	0.4%	Country Wide	Corine Land Cover :: Environmental Protection Agency, Ireland (epa.ie)
2000 - 2006	0.3%	Country Wide	Corine Land Cover :: Environmental Protection Agency, Ireland (epa.ie)
2006 - 2012	0.1%	Country Wide	Corine Land Cover :: Environmental Protection Agency, Ireland (epa.ie)

2012 – 2018	0.1%	Catchment Area	Corine Land Cover :: Environmental Protection Agency, Ireland (epa.ie)
2018 – 2021	0.1%	Catchment Area	Data Assumed from previous and future years growth
2021 – 2027 *Dundalk*	0.6% (rounded)	Catchment Area	Volume 1A - Book of Maps (Regional Growth Centres, Self-Sustaining Growth Towns & Rural Policy Zones - Louth County Council (louthcoco.ie)
2021 – 2027 *Blackrock*	3.5% (rounded)	Catchment Area	Volume 1A - Book of Maps (Regional Growth Centres, Self-Sustaining Growth Towns & Rural Policy Zones - Louth County Council (louthcoco.ie)

To get a figure for the future potential increase in urbanisation, the average of the previous figures can be taken, weighting them for the respective timescales to give an indicative figure of urbanisation increase:

$$Dundalk = \left(\frac{0.4}{10} + \frac{0.3}{6} + \frac{0.1}{6} + \frac{0.1}{6} + \frac{0.1}{3} + \frac{0.6}{6}\right) \div 6 = 0.04\%\ per\ year$$

$$Blackrock = \left(\frac{0.4}{10} + \frac{0.3}{6} + \frac{0.1}{6} + \frac{0.1}{6} + \frac{0.1}{3} + \frac{3.5}{6}\right) \div 6 = 0.15\%\ per\ year$$

As an example from the data above, taking the present day URBEXT as 0.221 (Dundalk / Blackwater River at downstream limit), with a 0.0004 increase each year, URBEXT would increase to 0.241 after 50 years and 0.261 after 100 years. This would be equivalent to 3.3% and 6.6% relative increases to the present day urban adjustment factor. These changes are relatively small compared to the MRFS and HEFS flow multipliers defined in 5.7(a). The equivalent numbers for Blackrock are much larger (14% and 28% increases in urban adjustment factor) but still less than the HEFS climate change flow multiplier.

(c) Summary

The future potential increases in urbanisation are relatively small compared to MRFS and HEFS flow multipliers. No further adjustment is necessary for increased urbanisation. We will use the flood flow adjustments defined in the brief (20% for MRFS, 30% for HEFS) to represent climate change.

5.8 Joint Probability

Joint probability will be tested in the hydraulic model and will be reported in the hydraulic report. This will be considered in relation to:

- Fluvial-fluvial. Assessing the relative timing of flood peaks in the different watercourses. In particular, the relative timing of the flood in the Castletown River and the smaller tributaries joining it.
- Fluvial-pluvial. This will focus on ensuring pluvial flooding does not accumulate behind new fluvial flood defences, based on the surface water contributions modelling.
- Tidal-pluvial. This will focus on ensuring pluvial flooding does not accumulate behind new coastal flood defences, based on the surface water contributions modelling.
- Fluvial – coastal/tidal water level. Table 5-15 outlines the fluvial – tidal combinations.

The fluvial – tidal combinations were selected based on the best practice approach recommended in Defra/Environment Agency report FD2308 (March 2005) and also experience from other projects. The Defra/EA approach involves using multiple combinations of fluvial and tidal events for each annual probability of interest. We selected one fluvial dominated and one tidal dominated event for each annual probability, with a lesser concurrent magnitude for the non-dominant case.

We are of the opinion that though the CFRAM Neagh Bann Hydraulics Report follows a simplified conservative approach whereby the 50% AEP design event is maintained for one mechanism while the whole range of probabilities for the other mechanism are tested and vice versa, using the Defra/EA recommended combination provides more realistic and representative joint probability combinations where the concurrent lesser event magnitude is influenced by the larger magnitude event. This is a key finding of the research underpinning the Defra/Environment Agency FD2308 report.

Table 5-15 Fluvial – tidal combinations

Flood	Fluvial		Tidal	
	Fluvial	Tidal	Fluvial	Tidal
2	2	MHWS	"1"	2
5	5	MHWS	"1"	5
10	10	MHWS	"1"	10
20	20	1	"1"	20
50	50	2	2	50
100	100	2	2	100
200	200	5	5	200
1000	1000	5	5	1000

6. Coastal Hydrology

6.1 Overview

The tender specification defines the coastal hydrological conditions. These include water levels and wave heights assessed in previous projects. This will provide the boundary conditions for the hydraulic modelling and overtopping assessments.

The extreme tide levels are derived from a regional model study using a disaggregated model of the storm surge and then combining it with the astronomic tides to provide the extreme levels. The models used in the Irish Coastal Wave and Water Level Modelling Study (ICWWS) 2018 were calibrated using gauge data in the wider area. This methodology allows the full range of AEPs to be estimated as sufficient gauge data is not available for the coast of Ireland. This did not use local tide gauge data due to the limited length of records.

To complement the Irish Coastal Protection Strategy Study (ICPSS) 2010 and later updated in ICWWS (2018) undertaken by RPS, this work includes an analysis of tide gauge records from Dundalk Port and Giles Quay which was undertaken to assess the latest local data. This also provided an extreme value analysis for the water level data recorded at Dundalk. This is reported in Appendix H.

6.2 Extreme Water Levels

The extreme water levels were assessed initially in the ICPSS (2010) and later updated in ICWWS (2018). Both Studies used the same estimation points along the North East (NE) coast, as shown in Figure 6-1. Of these NE3 is relevant to the Castletown River area and the NE4 values are relevant to the southern Blackrock frontages.

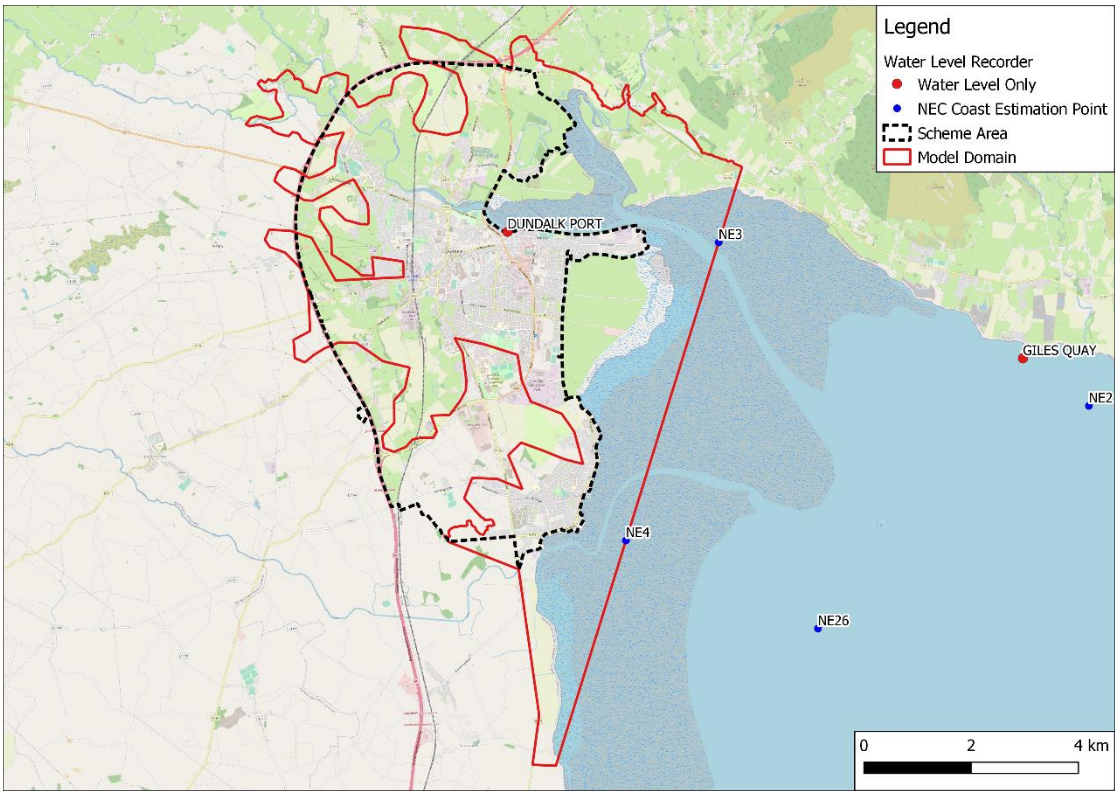


Figure 6-1 – Plan showing the location of extreme water level assessment points and tide gauges.

There are two tide gauges near the study site at Dundalk Port and Giles Quay. The Dundalk Port tide gauge record started in November 2015 and Giles Quay in October 2015. An extreme value analysis of these gauges was undertaken, following removal of erroneous records (see Appendix H, 'Extreme Water Level Analysis of Dundalk Port and Giles Quay Gauges',123160-BUK-ZZ-00-RP-HY-00007).

This work cleaned the recorded data and identified the recorded high-water levels at Dundalk Port which were then fitted to a Generalised Pareto Distribution (GPD) distribution and return periods estimated for extreme levels. These levels were consistently about 0.15m lower for the majority of return periods than that estimated in the ICWWS 2018. The data at Giles Quay was investigated but unfortunately this included an underlying noise that means there was insufficient confidence in the data to use in an extreme value analysis. Since the Extreme Value Analysis (July 2021) the gauge at Giles' Quay is no longer operational and has been removed.

For the range of return periods that will be modelled, there is sufficient information to pro-rata intermediate return periods or levels as required. This Study's approach is to use the ICWWS 2018 to OSGM015 given that

- the latter ICPSS (2010) outputs are now superseded by these ICWWS 2018 Phase 1 outputs, and
- to ensure conformity with the project deliverables and modelling which is built to OSGM015 geoid model.

The water levels to be used in the hydraulic modelling are presented in Table 6-1 below.

Table 6-1 Extreme water levels m OD Malin (OSGM15)[8] for Points NE3 and NE4

AEP	Point NE3	Point NE4
50%	3.28	3.20
20%	3.36	3.29
10%	3.43	3.35
5%	3.49	3.42
2%	3.57	3.51
1%	3.64	3.57
0.5% (target SoP)	3.70	3.64
0.1%	3.85	3.79

6.3 Sea Level Rise

In addition, the extreme water levels will be affected by sea level rise. Sea level rise has been occurring for some time and is visible in longer tide gauge records. Future sea-levels are predicted to increase, due to climate change which exceeds the counter effect of isostatic rebound following the last ice age.

The tender specification requests the investigation of two climate change scenarios as in Figure 6-2, which include a Mid-Range and High-End Future Scenario. Flood Risk Management Climate Change Sectoral Adaptation Plan (OPW, 2019) notes that these are not intended to represent any specific projection but could be taken to represent possible futures for 2100.

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

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

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

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

Figure 6-2 – Climate change scenarios given in Tender Specification.

[8] https://www.floodinfo.ie/publications/?t=46&k=ICWWS%202018%20Phase%201

These scenarios will be taken to test conditions at the end of the 50-year design life of the scheme i.e. the year 2071.

6.4 Water level hydrograph shape

To create the coastal water level boundary conditions a time series needs to be developed that includes the standard astronomic tidal cycle and the additional elevation of the water levels due to the surge. This is done by adding a surge shape and the astronomic conditions together. The astronomic tide curve has been obtained from the Admiralty Total Tide software for Dundalk (0625A), for use as part of this analysis. A comparison was undertaken between Soldiers Point (0625) and Dundalk (0625A) noting no difference in tidal curves.

The surge is a nominal unit height to enable it to be scaled to fit the extreme levels predicted for the site. The shape of the surge can last several days depending on the progress of the weather system causing the storm event.

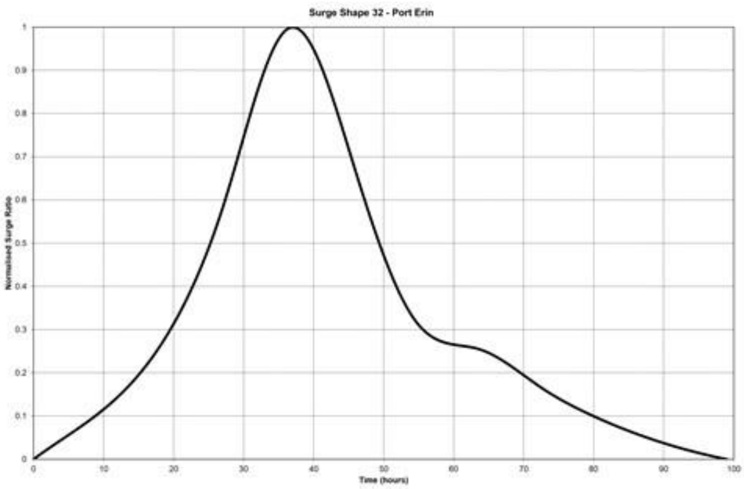


Figure 6-3 – Surge shape at Port Erin

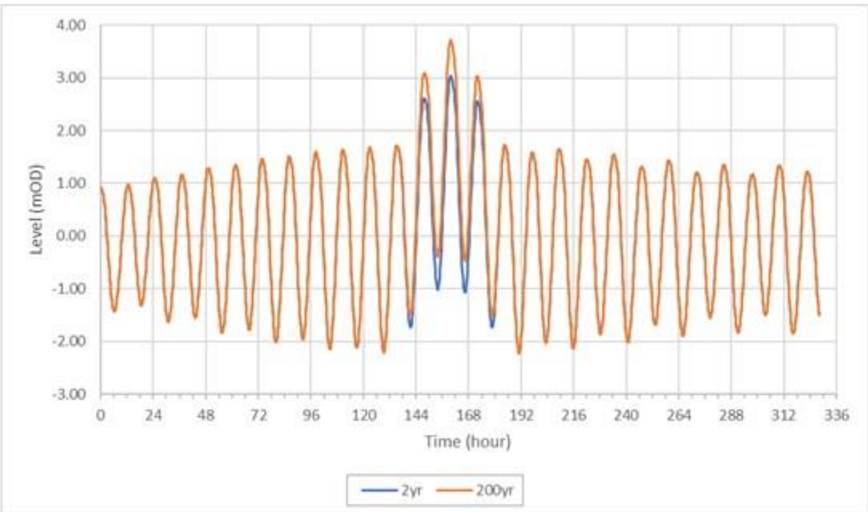


Figure 6-4 – Illustration of combined surge and astronomic tide conditions

The CFRAM study Section 6.2.3 of the Hydrology report appears to have used a simple assumed sinusoidal representation of the surge shape with a duration of 48hrs. We propose to use the surge shape developed from analysis of gauge data at Port Erin as part of the UK coastal design sea levels work in 2018[9] , Figure 6-3. This will be scaled in height to match the extreme sea levels discussed in Section 6.2 (Point NE3, Table 6-1). The astronomical tide that will be applied has been taken from Soldiers Point, having its peak at a level between MHWS and HAT (average). Further details will be discussed in the wave overtopping analysis included in the Hydraulic Report for this project.

In the absence of more detailed information applicable to the site area, we have used the surge shapes developed by the Environment Agency in the UK which are based on analysis of data from 43 tide gauge sites across the UK. The tide gauge closest to Dundalk is at Port Erin (number 32), which is the recommended 'Donor Site' for the coastline at the Isle of Man, and across the Irish Sea from Ballyhalbert to Warrenpoint in Northern Ireland. Having compared surge shape 32- Port Erin with the other two surge profiles available for Northern Ireland (42-Bangor, covering coastline from Ballycastle to Ballyhalbert; and 43 - Portrush, covering Londonderry to Ballycastle) we have concluded that the three profiles are similar. Surge shape 32 - Port Erin was selected on the basis that it has a wider shape, representative of a more prolonged high sea state compared to the other two, which is expected to yield more conservative results.

The water level timeseries similar to that in Figure 6-4 will then be used in boundary conditions for the hydraulic modelling and overtopping assessments.

6.5 Overtopping Assessment of Sea Defences

The Overtopping Assessment of Sea Defences Report (123160-BUK-ZZ-00-RP-MA-00007) was prepared by Binnies UK Limited as part of the hydraulic analysis of the Dundalk FRS in line with the Project Brief, aiming to support activities associated with the coastal flood models. The coastal processes applied for the overtopping assessment are discussed in detail in the aforementioned report (123160-BUK-ZZ-00-RP-MA-00007 Overtopping Assessment of Sea Defences).

[9] https://data.gov.uk/dataset/1e9a94b5-ffc6-460b-95a2-467f8291deac/coastal-design-sea-levels-coastal-flood-boundary-surge-shape-data-2018

7. Summary

This report describes design flood estimation to be used in hydraulic model for the Dundalk Flood Relief Scheme.

All available hydrology data including CFRAM hydrology has been reviewed. Further data since the CFRAM study has also been analysed.

Reported historical flooding in Dundalk and Blackrock has occurred from coastal and fluvial/pluvial flooding. Therefore, the flood relief scheme in Dundalk and Blackrock is a combination of coastal and fluvial/pluvial defences.

Preliminary hydrometric gauge rating reviews for two gauging stations on the Rampart River (Dundalk River) at Ladyswell and Brewery Park have been included in this report. The actual rating review will be carried out in the hydraulic modelling task.

Our recommended method for the hydrological assessment in this study is to use the FSU approach:

- Gauged flow: currently there is not sufficient hydrometric flow data available from the two gauges within the study area to use this in the design flood estimation assessment. Therefore, the entire study area is considered as ungauged for this hydrological assessment.
- Ungauged locations: The primary method is using the FSU 7-variable equation. Other approaches based on the IoH124 QBAR, FEH statistical method QMED and FSU 3-variable equations have been estimated and compared.
- The recommended growth curves and hydrographs shapes, derived using the FSU methods, are given in this report.

Assessment of the pluvial flooding will be implemented in the hydraulic modelling utilising the estimated rainfall depths from the FSU Portal above by: applying the rainfall depths directly to the 2D flood model; and assessing vulnerable areas / ponding of water.

We will use the flood flow adjustments defined in the brief (20% for MRFS, 30% for HEFS) to represent climate change. No further adjustment is necessary for increased urbanisation.

This hydrology report is accompanied by spatial data for catchments/sub-catchments and HEPS in accordance with the OPW FRS Engineering Spatial Data Specification Final Rev2.2 – April 2020[10]. Hydrological calculation with details of the methodologies applied is also included.

The coastal hydrology will be based, for each return period, on the extreme water levels from Phase 1 Technical Report – Appendix M of the Irish Coastal Wave and Water Level Modelling Study (ICWWS) 2018, since the latter ICPSS outputs are now superseded by these ICWWS 2018 Phase 1 outputs[11].

[10] https://www.gov.ie/en/publication/b15dd0-technical-specifications-and-guidance-notes/
[11] https://www.floodinfo.ie/publications/?t=46&k=ICWWS%202018%20Phase%201

APPENDICES

Appendix A: Comparison of Physical Catchment Descriptors

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km^2)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
	Aghaboys watercourse (from west into Ballymascanlan estuary)													
1	06_1059_Trib_RPS	3.88	0.628	927	1.000	1.641	22.949	0	0.1660	2.91	1016	1.612	24.818	0.0227
2	06_1054_1_RA	1.24	0.627	919	1.000	0.776	29.985	0	0.3686	1.39	1006	0.703	29.639	0.2050
3	06_1059_Trib_RPS_U									1.93	997	0.859	21.851	0.2790
4	06_1059_Trib_RPS_D									4.85	1007	1.313	24.818	0.1244
5	06_1078_2_B	4.59	0.647	926	1.000	1.494	21.210	0	0.1401	5.36	1002	1.280	23.410	0.1134
6	06_1078_3_RA	4.75	0.647	926	1.000	1.503	21.320	0	0.1354	5.40	1001	1.320	22.088	0.1126
	Ballynahattin watercourse (from west into Ballymascanlan estuary)													
7	06_1069_4_RPS	3.25	0.659	930	1.000	1.900	19.886	0	0.1033	5.06	1028	1.214	21.643	0.0000
8	06_1058_2_RA	2.83	0.700	910	1.000	1.134	20.322	0	0.0000	3.01	1002	1.054	22.667	0.0196
9	06_1058_3_B	3.30	0.702	910	1.000	1.124	17.629	0	0.0000	3.67	995	1.003	18.655	0.0161
10	06_1069_4_RPS_U									3.91	993	1.014	15.521	0.0164
11	06_1069_4_RPS_D									8.98	1018	1.129	15.521	0.0071
12	06_1080_2_B	7.26	0.685	920	1.000	1.497	12.188	0	0.0478	9.39	1019	1.151	13.080	0.0201
13	06_1080_3_B	7.77	0.685	919	1.000	1.464	10.037	0	0.0492	9.79	1015	1.158	10.740	0.0239
14	06_1081_1_B	9.22	0.692	919	1.000	1.295	8.829	0	0.0414	11.58	1009	1.032	9.033	0.0345
15	06_1081_3_B	9.67	0.692	919	1.000	1.286	7.849	0	0.0395	12.13	1008	1.029	8.216	0.0330
16	06_1081_D_RA	9.70	0.692	919	1.000	1.296	7.540	0	0.0394	13.08	1003	1.050	6.447	0.0306
	Kilcurry River (note: includes significant catchment area in Northern Ireland)													

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km^2)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
17	06_991_2_RA	8.93	0.667	894	1.000	2.086	8.513	0	0.0000	115.77	1060	1.008	10.805	0.0007
	Castletown River / Creggan River (note: includes significant catchment area in Northern Ireland)													
18	06_600_2_RA	22.61	0.627	884	0.994	1.292	7.102	0	0.0249	100.79	954	0.981	6.743	0.0027
19	06_600_4_RA_U1	23.47	0.627	884	0.994	1.278	7.090	0	0.0240	218.38	980	0.994	6.724	0.0022
20	06_600_4_RA_D									218.41	982	0.994	6.724	0.0026
21	06032_RA	32.99	0.644	887	0.996	1.509	6.853	0	0.0170	218.47	983	0.994	6.752	0.0026
22	06_1084_1_RA	33.00	0.644	887	0.996	1.509	6.853	0	0.0170	218.59	980	0.995	6.749	0.0027
23	06_1084_2_B	33.18	0.664	887	0.996	1.515	6.677	0	0.0170	219.16	970	0.995	6.752	0.0032
24	06_1055_2_RA_U									219.61	985	0.994	6.753	0.0032
25	06_1055_2_RA_D									220.69	973	0.996	6.753	0.0033
26	06_1085_2_B	35.43	0.664	888	0.996	1.482	6.327	0	0.0159	221.00	971	0.996	6.691	0.0033
27	06_1087_13_RA_U									221.06	974	0.997	6.633	0.0033
28	06_1087_13_RA_D									228.49	951	0.995	6.633	0.0052
29	06_DU15_B_U									228.51	951	0.996	6.556	0.0052
30	06_DU15_B_D									228.63	951	0.996	6.556	0.0052
31	06_1089_4_RA_U									228.64	951	0.996	6.551	0.0053
32	06_1089_4_RA_D									231.27	949	0.998	6.551	0.0115
33	06_DU16_B_U									231.31	949	0.999	6.512	0.0116
34	06_DU16_B_D									231.34	949	0.999	6.512	0.0116
35	06_DU06_B_U									231.38	949	1.000	6.376	0.0117
36	06_DU06_B_D									232.34	948	0.996	6.338	0.0158
37	06_DU17_B_U									232.35	948	0.996	6.284	0.0158
38	06_DU17_B_D									234.15	948	0.990	6.265	0.0200
39	06_DU07_B_U									234.20	948	0.991	6.244	0.0201

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km^2)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
40	06_DU07_B_D									234.75	947	0.989	6.244	0.0224
41	06_DDalk_D_RARPS									235.28	947	0.990	6.044	0.0225
	Unnamed watercourse 1 (from south into Castletown River)													
42	06_600_4_RA									0.02	896	2.666	20.176	0.0000
	Stranacarry watercourse (from north into Castletown River)													
43	06_1055_U									0.10	955	1.167	26.974	0.0000
44	06_1055_1_B	1.03	0.691	908	1.000	0.971	11.323	0	0.0000	0.66	941	1.442	12.529	0.0396
45	06_1055_2_RA	1.07	0.693	909	1.000	1.224	11.842	0	0.0000	1.07	939	1.221	11.813	0.0244
	Castletown tributary (from south into Castletown River)													
46	06_1087_U_RA									5.87	900	0.709	6.412	0.0004
47	06_1087_8_B	4.10	0.662	861	1.000	1.136	4.405	0	0.0000	6.19	899	0.752	5.850	0.0077
48	06_DU01_B_U									6.38	899	0.790	5.851	0.0119
49	06_DU01_B									0.26	876	0.779	5.788	0.0000
50	06_DU01_B_D									6.64	898	0.762	5.851	0.0115
51	06_1087_10_B	5.67	0.661	855	1.000	0.998	5.442	0	0.0023	6.82	898	0.823	6.600	0.0163
52	06_1087_11_B	5.99	0.662	856	1.000	1.027	6.852	0	0.0028	7.13	898	0.853	7.473	0.0405
53	06_1087_13_RA	6.31	0.661	858	1.000	1.075	7.913	0	0.0194	7.42	898	0.913	8.858	0.0624
	Unnamed watercourse 2 (from north into Castletown River)													
54	06_DU15_B									0.12	881	0.422	3.710	0.0000
	Acarreagh watercourse (from south into Castletown River)													
55	06_DU02_B									0.56	859	0.493	6.703	0.2314
56	06_DU03_B									0.28	862	0.176	5.251	1.0000
57	06_1089_U									0.04	876	2.382	4.863	0.0000
58	06_DU02_B_U									0.56	864	2.222	17.905	0.0017

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km^2)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
59	06_DU02_B_D									1.14	862	1.107	17.905	0.1175
60	06_1089_2_B	1.48	0.616	850	1.000	1.541	13.688	0	0.1651	1.57	862	1.337	13.213	0.3215
61	06_1089_3_B	1.79	0.616	853	1.000	1.559	9.982	0	0.2944	2.36	865	1.231	10.661	0.5304
62	06_1089_4_RA	1.83	0.616	854	1.000	1.601	9.850	0	0.3100	2.59	866	1.121	10.005	0.5567
	Unnamed watercourse 3 (from north into Castletown River)													
63	06_DU16_B									0.04	889	1.418	4.312	0.0000
	Unnamed watercourse 4 (from south into Castletown River)													
64	06_DU06_B									0.95	867	1.410	1.746	0.9992
	Unnamed watercourse 5 (from north into Castletown River)													
65	06_DU17_B									1.76	904	0.635	2.563	0.5465
	Unnamed watercourse 6 (from south into Castletown River)													
66	06_DU07_B									0.56	866	0.366	0.415	0.9929
	Donaghmore watercourse (from north into Blackwater River)													
67	06_242_U									0.63	869	1.310	5.150	0.0000
68	06_242_1_B	1.01	0.624	835	1.000	1.541	13.944	0	0.0000	1.09	867	1.391	16.080	0.0000
69	06_242_2_B	1.66	0.618	835	1.000	1.241	13.592	0	0.0000	1.40	867	1.472	15.853	0.0000
70	06_242_3_B	1.89	0.618	835	1.000	1.358	15.774	0	0.0000	1.90	864	1.323	15.701	0.0000
71	06_242_4_RPS	2.82	0.618	835	1.000	1.116	16.367	0	0.0122	2.50	862	1.248	16.529	0.0000
	Dundalk / Blackwater River													
72	06_913_U	9.14	0.618	836	1.000	0.606	3.741	0	0.0000	8.42	861	0.654	4.618	0.0000
73	06_913_3_B	10.21	0.644	836	1.000	0.591	4.237	0	0.0022	9.30	857	0.649	3.938	0.0000
74	06_913_4_RPS	10.37	0.644	836	1.000	0.629	5.264	0	0.0022	9.51	859	0.638	3.558	0.0000
75	06_242_4_RPS_U									9.90	851	0.669	5.262	0.0000
76	06_242_4_RPS_D	13.53	0.617	836	1.000	0.762	6.794	0	0.0042	12.40	855	0.789	5.262	0.0000

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km^2)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
77	06_DU04_B_U									12.69	854	0.783	6.868	0.0074
78	06_DU04_B_D	14.13	0.617	837	1.000	0.765	6.533	0	0.0098	13.43	854	0.755	6.868	0.0336
79	06_918_1_U	14.76	0.638	839	1.000	0.757	5.956	0	0.0307	17.30	841	0.811	6.246	0.0469
80	06_918_1_D									17.91	840	0.841	6.246	0.0650
81	06036_RPS									17.92	840	0.844	6.121	0.0656
82	06_930_2_B	18.30	0.638	843	1.000	0.849	5.723	0	0.0606	18.01	840	0.865	5.985	0.0701
83	06_930_3_B	18.46	0.638	843	1.000	0.868	5.634	0	0.0689	18.46	839	0.856	5.773	0.0930
84	06_930_4_B	18.67	0.637	844	1.000	0.885	5.146	0	0.0780	18.74	839	0.870	5.399	0.1066
85	06_DU09_B_U									18.84	839	0.876	5.285	0.1112
86	06_DU09_B_D									19.70	839	0.839	5.285	0.1500
87	06_930_5_B	18.87	0.638	844	1.000	0.902	4.981	0	0.0848	20.43	845	0.835	5.030	0.1805
88	06_DU10_B_U									20.89	847	0.836	4.748	0.1985
89	06_DU10_B_D									21.32	847	0.822	4.748	0.2136
90	06_DU11_B_U									21.33	846	0.833	4.579	0.2139
91	06_DU11_B_D									21.62	846	0.829	4.579	0.2191
92	06_1041_1_B_U	21.29	0.604	849	1.000	0.870	3.757	0	0.1589	21.65	848	0.836	4.486	0.2188
93	06_1041_1_B_D									22.12	848	0.837	4.486	0.2336
94	06_1041_2_B	21.54	0.604	851	1.000	0.883	3.713	0	0.1571	22.40	847	0.847	4.004	0.2334
95	06_1041_3_B	21.74	0.604	852	1.000	0.898	3.359	0	0.1565	22.58	846	0.864	3.819	0.2334
96	06_DU12_B_U									22.80	848	0.869	3.612	0.2370
97	06_DU12_B_D									24.06	849	0.910	3.612	0.2251
98	06_1038_D	22.46	0.604	856	1.000	1.032	3.155	0	0.1521	24.46	845	0.947	3.374	0.2215
	Fairhill River (from south into Blackwater River)													
99	06_438_2_B									0.24	835	1.896	0.182	0.0128

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km^2)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
100	06_DU05_B_U									0.27	834	3.824	3.181	0.0223
101	06_DU05_B_D									0.88	827	1.319	12.000	0.0069
102	06_438_3_B									0.98	829	1.013	9.416	0.0031
103	06_147_4_RPS_U									1.00	829	1.146	7.313	0.0219
104	06_147_4_RPS_D									3.67	822	0.831	7.313	0.0838
	Unnamed watercourse 7 (from south into Blackwater River)													
105	06_DU05_B									0.60	827	0.997	12.000	0.0000
	Unnamed watercourse 8 (from north into Blackwater River)													
106	06_DU04_B									0.72	844	0.022	7.357	0.4791
	Killally / Fairhill River tributary (from south into Blackwater River)													
107	06_Trib_Ddalk_1									0.28	824	0.180	30.357	0.0000
108	06_147_U									0.03	809	1.481	25.511	0.2117
109	06_Trib_Ddalk_U									0.19	819	0.263	11.733	0.5189
110	06_Trib_Ddalk_1_U									1.00	819	0.142	7.776	0.1681
111	06_Trib_Ddalk_1_D									1.04	820	0.177	7.776	0.1617
112	06_147_2_B	1.24	0.624	836	1.000	0.471	11.280	0	0.0659	1.60	816	0.355	9.150	0.1092
113	06_147_3_B	2.31	0.617	848	1.000	0.470	13.534	0	0.0402	2.12	815	0.513	7.980	0.1157
114	06_147_4_B	2.54	0.624	851	1.000	0.624	6.993	0	0.0365	2.48	817	0.639	7.557	0.0988
115	06_147_4_RPS									2.54	817	0.734	6.948	0.0968
	Priorland watercourse (from south into Blackwater River)													
116	06_918_U									0.21	818	0.243	16.444	0.7127
117	06_918_1									0.60	822	1.798	5.247	0.5995
	Unnamed watercourse 9 (from south into Blackwater River)													
118	06_DU09_B									1.07	824	0.534	0.683	1.0000

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km²)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km²)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
	Unnamed watercourse 10 (from south into Blackwater River)													
119	06_DU10_B									0.41	825	0.308	0.417	0.9517
	Unnamed watercourse 11 (from north into Blackwater River)													
120	06_DU11_B									0.13	832	0.373	2.476	0.9967
	Unnamed watercourse 12 (from north into Blackwater River)													
121	06_1041_1_B									0.44	860	0.137	4.571	0.9732
	Unnamed watercourse 13 (from south into Blackwater River)													
122	06_DU12_B									1.25	826	1.627	0.267	0.0033
	Ramparts / Marshes Lower watercourse (branch to north from Blackwater River)													
123	06_DU08_B									0.14	842	0.351	1.085	1.0000
124	06_DU08_B_U									0.23	841	3.333	1.021	0.7864
125	06_DU08_B_D									0.38	841	2.027	1.021	0.8702
126	06_318_I1									0.51	841	1.024	0.228	0.9044
127	06_318_I2									0.66	847	1.459	0.325	0.9252
128	06_318_I3									0.78	852	1.921	0.558	0.9366
129	06_318_D									0.83	852	2.217	0.405	0.9364
	Green Gates watercourse (into sea, south-west Blackrock)													
130	06_315_U_RA	1.14	0.646	843	1.000	0.132	20.834	0	0.1096	0.79	805	0.965	7.500	0.1216
131	06_315_2_B	1.43	0.634	843	1.000	0.454	4.433	0	0.1012	1.12	803	0.587	8.029	0.2755
132	06_315_3_B	2.62	0.666	843	1.000	0.439	5.064	0	0.0823	2.16	797	0.491	5.931	0.2035
133	06_315_4_B	3.04	0.630	843	1.000	0.543	3.381	0	0.1373	2.64	798	0.667	4.717	0.2993
134	06_315_5_RA	3.31	0.620	843	1.000	0.618	0.890	0	0.1716	2.85	797	0.712	4.301	0.3507
	Blackrock watercourse (into sea, Blackrock)													
135	06_0616A_U									0.35	794	0.290	5.991	0.3198

No.	Sub-catchment	FSU Physical Catchment Descriptors								PCDs from GIS check				
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	AREA (km^2)	SAAR (mm)	DRAIND	S1085 (m/km)	URBEXT
136	06_0616A_I1									1.59	792	0.929	4.613	0.4252
137	06_0616A_I2									1.86	791	1.069	3.615	0.4365
138	06_0616A_I3									2.43	789	1.030	4.592	0.5123
139	06_061A_D									2.52	789	1.195	4.180	0.5303
	Unnamed watercourse 14 (into sea, near Finnabair Industrial Park)													
140	06_DU14_B									0.29	799	0.171	2.606	0.6785
	Unnamed watercourse 15 (into sea, north of Finnabair Industrial Park)													
141	06_DU13_B_U									0.87	800	1.743	6.455	0.3287
142	06_DU13_B									1.08	808	1.641	7.628	0.7334
143	06_DU13_B_D									1.97	804	1.726	6.288	0.5550

Appendix B: Adopted Physical Catchment Descriptors

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
	Aghaboys watercourse (from west into Ballymascanlan estuary)									
1	06_1059_Trib_RPS	2.91	0.63	1016.30	1.00	1.61	24.82	0.00	0.02	0.23
2	06_1054_1_RA	1.39	0.63	1005.59	1.00	0.70	29.64	0.00	0.21	0.20
3	06_1059_Trib_RPS_U	1.93	0.63	997.12	1.00	0.86	21.85	0.00	0.28	0.22
4	06_1059_Trib_RPS_D	4.85	0.64	1006.80	1.00	1.31	24.82	0.00	0.12	0.23
5	06_1078_2_B	5.36	0.65	1001.83	1.00	1.28	23.41	0.00	0.11	0.24
6	06_1078_3_RA	5.40	0.65	1001.03	1.00	1.32	22.09	0.00	0.11	0.24
	Ballynahattin watercourse (from west into Ballymascanlan estuary)									
7	06_1069_4_RPS	5.06	0.66	1027.65	1.00	1.21	21.64	0.00	0.00	0.16
8	06_1058_2_RA	3.01	0.70	1001.86	1.00	1.05	22.67	0.00	0.02	0.24
9	06_1058_3_B	3.67	0.70	994.60	1.00	1.00	18.66	0.00	0.02	0.22
10	06_1069_4_RPS_U	3.91	0.70	992.61	1.00	1.01	15.52	0.00	0.02	0.22
11	06_1069_4_RPS_D	8.98	0.69	1017.83	1.00	1.13	15.52	0.00	0.01	0.20
12	06_1080_2_B	9.39	0.68	1018.82	1.00	1.15	13.08	0.00	0.02	0.21
13	06_1080_3_B	9.79	0.69	1015.47	1.00	1.16	10.74	0.00	0.02	0.21
14	06_1081_1_B	11.58	0.69	1009.17	1.00	1.03	9.03	0.00	0.03	0.23
15	06_1081_3_B	12.13	0.69	1008.23	1.00	1.03	8.22	0.00	0.03	0.23
16	06_1081_D_RA	13.08	0.69	1003.20	1.00	1.05	6.45	0.00	0.03	0.24
	Kilcurry River (note: includes significant catchment area in Northern Ireland)									
17	06_991_2_RA	115.77	0.67	1059.94	1.00	1.01	10.80	0.00	0.00	0.22
	Castletown River / Creggan River (note: includes significant catchment area in Northern Ireland)									

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
18	06_600_2_RA	100.79	0.63	954.47	0.99	0.98	6.74	0.00	0.00	0.20
19	06_600_4_RA_U1	218.38	0.63	979.87	0.99	0.99	6.72	0.00	0.00	0.20
20	06_600_4_RA_D	218.41	0.63	981.71	0.99	0.99	6.72	0.00	0.00	0.20
21	06032_RA	218.47	0.64	982.91	1.00	0.99	6.75	0.00	0.00	0.20
22	06_1084_1_RA	218.59	0.64	979.66	1.00	0.99	6.75	0.00	0.00	0.20
23	06_1084_2_B	219.16	0.66	970.49	1.00	0.99	6.75	0.00	0.00	0.20
24	06_1055_2_RA_U	219.61	0.66	984.57	1.00	0.99	6.75	0.00	0.00	0.20
25	06_1055_2_RA_D	220.69	0.66	973.24	1.00	1.00	6.75	0.00	0.00	0.20
26	06_1085_2_B	221.00	0.66	970.80	1.00	1.00	6.69	0.00	0.00	0.20
27	06_1087_13_RA_U	221.06	0.66	974.43	1.00	1.00	6.63	0.00	0.00	0.20
28	06_1087_13_RA_D	228.49	0.66	951.27	1.00	1.00	6.63	0.00	0.01	0.21
29	06_DU15_B_U	228.51	0.66	951.14	1.00	1.00	6.56	0.00	0.01	0.21
30	06_DU15_B_D	228.63	0.66	950.99	1.00	1.00	6.56	0.00	0.01	0.21
31	06_1089_4_RA_U	228.64	0.66	950.92	1.00	1.00	6.55	0.00	0.01	0.21
32	06_1089_4_RA_D	231.27	0.66	949.29	1.00	1.00	6.55	0.00	0.01	0.21
33	06_DU16_B_U	231.31	0.66	949.18	1.00	1.00	6.51	0.00	0.01	0.21
34	06_DU16_B_D	231.34	0.66	949.07	1.00	1.00	6.51	0.00	0.01	0.21
35	06_DU06_B_U	231.38	0.66	949.02	1.00	1.00	6.38	0.00	0.01	0.21
36	06_DU06_B_D	232.34	0.66	948.08	1.00	1.00	6.34	0.00	0.02	0.21
37	06_DU17_B_U	232.35	0.66	948.03	1.00	1.00	6.28	0.00	0.02	0.21
38	06_DU17_B_D	234.15	0.66	947.85	1.00	0.99	6.26	0.00	0.02	0.21
39	06_DU07_B_U	234.20	0.66	947.80	1.00	0.99	6.24	0.00	0.02	0.21
40	06_DU07_B_D	234.75	0.66	947.23	1.00	0.99	6.24	0.00	0.02	0.21
41	06_DDalk_D_RARPS	235.28	0.66	946.89	1.00	0.99	6.04	0.00	0.02	0.21

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
	Unnamed watercourse 1 (from south into Castletown River)									
42	06_600_4_RA	0.02	0.63	896.00	1.00	2.67	20.18	0.00	0.00	0.30
	Stranacarry watercourse (from north into Castletown River)									
43	06_1055_U	0.10	0.69	954.66	1.00	1.17	26.97	0.00	0.00	0.30
44	06_1055_1_B	0.66	0.69	940.82	1.00	1.44	12.53	0.00	0.04	0.30
45	06_1055_2_RA	1.07	0.69	939.02	1.00	1.22	11.81	0.00	0.02	0.30
	Castletown tributary (from south into Castletown River)									
46	06_1087_U_RA	5.87	0.66	900.39	1.00	0.71	6.41	0.00	0.00	0.30
47	06_1087_8_B	6.19	0.66	899.22	1.00	0.75	5.85	0.00	0.01	0.30
48	06_DU01_B_U	6.38	0.66	898.86	1.00	0.79	5.85	0.00	0.01	0.30
49	06_DU01_B	0.26	0.67	875.67	1.00	0.78	5.79	0.00	0.00	0.30
50	06_DU01_B_D	6.64	0.66	898.39	1.00	0.76	5.85	0.00	0.01	0.30
51	06_1087_10_B	6.82	0.66	898.34	1.00	0.82	6.60	0.00	0.02	0.30
52	06_1087_11_B	7.13	0.66	898.22	1.00	0.85	7.47	0.00	0.04	0.30
53	06_1087_13_RA	7.42	0.66	898.05	1.00	0.91	8.86	0.00	0.06	0.30
	Unnamed watercourse 2 (from north into Castletown River)									
54	06_DU15_B	0.12	0.66	880.93	1.00	0.42	3.71	0.00	0.00	0.30
	Acarreagh watercourse (from south into Castletown River)									
55	06_DU02_B	0.56	0.62	858.80	1.00	0.49	6.70	0.00	0.23	0.30
56	06_DU03_B	0.28	0.62	861.54	1.00	0.18	5.25	0.00	1.00	0.30
57	06_1089_U	0.04	0.62	875.96	1.00	2.38	4.86	0.00	0.00	0.30
58	06_DU02_B_U	0.56	0.62	864.35	1.00	2.22	17.90	0.00	0.00	0.30
59	06_DU02_B_D	1.14	0.62	861.62	1.00	1.11	17.90	0.00	0.12	0.30
60	06_1089_2_B	1.57	0.62	861.94	1.00	1.34	13.21	0.00	0.32	0.30

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
61	06_1089_3_B	2.36	0.62	864.85	1.00	1.23	10.66	0.00	0.53	0.30
62	06_1089_4_RA	2.59	0.62	866.20	1.00	1.12	10.01	0.00	0.56	0.30
	Unnamed watercourse 3 (from north into Castletown River)									
63	06_DU16_B	0.04	0.66	889.21	1.00	1.42	4.31	0.00	0.00	0.30
	Unnamed watercourse 4 (from south into Castletown River)									
64	06_DU06_B	0.95	0.66	867.38	1.00	1.41	1.75	0.00	1.00	0.30
	Unnamed watercourse 5 (from north into Castletown River)									
65	06_DU17_B	1.76	0.66	904.45	1.00	0.64	2.56	0.00	0.55	0.30
	Unnamed watercourse 6 (from south into Castletown River)									
66	06_DU07_B	0.56	0.66	865.89	1.00	0.37	0.41	0.00	0.99	0.30
	Donaghmore watercourse (from north into Blackwater River)									
67	06_242_U	0.63	0.62	869.10	1.00	1.31	5.15	0.00	0.00	0.30
68	06_242_1_B	1.09	0.62	866.79	1.00	1.39	16.08	0.00	0.00	0.30
69	06_242_2_B	1.40	0.62	866.87	1.00	1.47	15.85	0.00	0.00	0.30
70	06_242_3_B	1.90	0.62	863.86	1.00	1.32	15.70	0.00	0.00	0.30
71	06_242_4_RPS	2.50	0.62	862.09	1.00	1.25	16.53	0.00	0.00	0.30
	Dundalk / Blackwater River									
72	06_913_U	8.42	0.62	861.23	1.00	0.65	4.62	0.00	0.00	0.30
73	06_913_3_B	9.30	0.64	857.20	1.00	0.65	3.94	0.00	0.00	0.30
74	06_913_4_RPS	9.51	0.64	858.76	1.00	0.64	3.56	0.00	0.00	0.30
75	06_242_4_RPS_U	9.90	0.64	850.67	1.00	0.67	5.26	0.00	0.00	0.30
76	06_242_4_RPS_D	12.40	0.64	855.16	1.00	0.79	5.26	0.00	0.00	0.30
77	06_DU04_B_U	12.69	0.64	853.99	1.00	0.78	6.87	0.00	0.01	0.30
78	06_DU04_B_D	13.43	0.64	853.67	1.00	0.76	6.87	0.00	0.03	0.30

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
79	06_918_1_U	17.30	0.64	840.81	1.00	0.81	6.25	0.00	0.05	0.30
80	06_918_1_D	17.91	0.64	839.67	1.00	0.84	6.25	0.00	0.06	0.30
81	06036_RPS	17.92	0.64	839.62	1.00	0.84	6.12	0.00	0.07	0.30
82	06_930_2_B	18.01	0.64	839.57	1.00	0.87	5.98	0.00	0.07	0.30
83	06_930_3_B	18.46	0.64	839.44	1.00	0.86	5.77	0.00	0.09	0.30
84	06_930_4_B	18.74	0.64	839.35	1.00	0.87	5.40	0.00	0.11	0.30
85	06_DU09_B_U	18.84	0.64	839.33	1.00	0.88	5.29	0.00	0.11	0.30
86	06_DU09_B_D	19.70	0.64	839.15	1.00	0.84	5.29	0.00	0.15	0.30
87	06_930_5_B	20.43	0.64	844.59	1.00	0.84	5.03	0.00	0.18	0.30
88	06_DU10_B_U	20.89	0.62	846.66	1.00	0.84	4.75	0.00	0.20	0.30
89	06_DU10_B_D	21.32	0.61	847.46	1.00	0.82	4.75	0.00	0.21	0.30
90	06_DU11_B_U	21.33	0.61	846.42	1.00	0.83	4.58	0.00	0.21	0.30
91	06_DU11_B_D	21.62	0.60	846.40	1.00	0.83	4.58	0.00	0.22	0.30
92	06_1041_1_B_U	21.65	0.60	847.53	1.00	0.84	4.49	0.00	0.22	0.30
93	06_1041_1_B_D	22.12	0.60	847.72	1.00	0.84	4.49	0.00	0.23	0.30
94	06_1041_2_B	22.40	0.60	846.93	1.00	0.85	4.00	0.00	0.23	0.30
95	06_1041_3_B	22.58	0.60	846.31	1.00	0.86	3.82	0.00	0.23	0.30
96	06_DU12_B_U	22.80	0.60	847.55	1.00	0.87	3.61	0.00	0.24	0.30
97	06_DU12_B_D	24.06	0.60	848.83	1.00	0.91	3.61	0.00	0.23	0.30
98	06_1038_D	24.46	0.60	845.26	1.00	0.95	3.37	0.00	0.22	0.30
	Fairhill River (from south into Blackwater River)									
99	06_438_2_B	0.24	0.64	835.00	1.00	1.90	0.18	0.00	0.01	0.30
100	06_DU05_B_U	0.27	0.64	833.87	1.00	3.82	3.18	0.00	0.02	0.30
101	06_DU05_B_D	0.88	0.64	827.37	1.00	1.32	12.00	0.00	0.01	0.30

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
102	06_438_3_B	0.98	0.64	828.60	1.00	1.01	9.42	0.00	0.00	0.30
103	06_147_4_RPS_U	1.00	0.64	829.15	1.00	1.15	7.31	0.00	0.02	0.30
104	06_147_4_RPS_D	3.67	0.64	821.84	1.00	0.83	7.31	0.00	0.08	0.30
	Unnamed watercourse 7 (from south into Blackwater River)									
105	06_DU05_B	0.60	0.64	827.25	1.00	1.00	12.00	0.00	0.00	0.30
	Unnamed watercourse 8 (from north into Blackwater River)									
106	06_DU04_B	0.72	0.64	843.69	1.00	0.02	7.36	0.00	0.48	0.30
	Killally / Fairhill River tributary (from south into Blackwater River)									
107	06_Trib_Ddalk_1	0.28	0.62	823.67	1.00	0.18	30.36	0.00	0.00	0.30
108	06_147_U	0.03	0.62	808.52	1.00	1.48	25.51	0.00	0.21	0.30
109	06_Trib_Ddalk_U	0.19	0.62	818.75	1.00	0.26	11.73	0.00	0.52	0.30
110	06_Trib_Ddalk_1_U	1.00	0.62	819.00	1.00	0.14	7.78	0.00	0.17	0.30
111	06_Trib_Ddalk_1_D	1.04	0.62	819.70	1.00	0.18	7.78	0.00	0.16	0.30
112	06_147_2_B	1.60	0.62	816.41	1.00	0.36	9.15	0.00	0.11	0.30
113	06_147_3_B	2.12	0.62	815.40	1.00	0.51	7.98	0.00	0.12	0.30
114	06_147_4_B	2.48	0.62	816.60	1.00	0.64	7.56	0.00	0.10	0.30
115	06_147_4_RPS	2.54	0.62	816.91	1.00	0.73	6.95	0.00	0.10	0.30
	Priorland watercourse (from south into Blackwater River)									
116	06_918_U	0.21	0.64	818.16	1.00	0.24	16.44	0.00	0.71	0.30
117	06_918_1	0.60	0.64	822.14	1.00	1.80	5.25	0.00	0.60	0.30
	Unnamed watercourse 9 (from south into Blackwater River)									
118	06_DU09_B	1.07	0.64	824.27	1.00	0.53	0.68	0.00	1.00	0.30
	Unnamed watercourse 10 (from south into Blackwater River)									
119	06_DU10_B	0.41	0.61	825.38	1.00	0.31	0.42	0.00	0.95	0.30

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
	Unnamed watercourse 11 (from north into Blackwater River)									
120	06_DU11_B	0.13	0.60	832.00	1.00	0.37	2.48	0.00	1.00	0.30
	Unnamed watercourse 12 (from north into Blackwater River)									
121	06_1041_1_B	0.44	0.60	859.80	1.00	0.14	4.57	0.00	0.97	0.30
	Unnamed watercourse 13 (from south into Blackwater River)									
122	06_DU12_B	1.25	0.60	825.71	1.00	1.63	0.27	0.00	0.00	0.30
	Ramparts / Marshes Lower watercourse (branch to north from Blackwater River)									
123	06_DU08_B	0.14	0.60	842.12	1.00	0.35	1.08	0.00	1.00	0.30
124	06_DU08_B_U	0.23	0.60	841.03	1.00	3.33	1.02	0.00	0.79	0.30
125	06_DU08_B_D	0.38	0.60	841.29	1.00	2.03	1.02	0.00	0.87	0.30
126	06_318_I1	0.51	0.60	841.33	1.00	1.02	0.23	0.00	0.90	0.30
127	06_318_I2	0.66	0.60	847.04	1.00	1.46	0.33	0.00	0.93	0.30
128	06_318_I3	0.78	0.60	851.83	1.00	1.92	0.56	0.00	0.94	0.30
129	06_318_D	0.83	0.60	852.02	1.00	2.22	0.41	0.00	0.94	0.30
	Green Gates watercourse (into sea, south-west Blackrock)									
130	06_315_U_RA	0.79	0.65	804.75	1.00	0.96	7.50	0.00	0.12	0.30
131	06_315_2_B	1.12	0.63	803.39	1.00	0.59	8.03	0.00	0.28	0.30
132	06_315_3_B	2.16	0.67	797.23	1.00	0.49	5.93	0.00	0.20	0.30
133	06_315_4_B	2.64	0.63	797.81	1.00	0.67	4.72	0.00	0.30	0.30
134	06_315_5_RA	2.85	0.62	796.95	1.00	0.71	4.30	0.00	0.35	0.30
	Blackrock watercourse (into sea, Blackrock)									
135	06_0616A_U	0.35	0.62	793.82	1.00	0.29	5.99	0.00	0.32	0.30
136	06_0616A_I1	1.59	0.62	792.50	1.00	0.93	4.61	0.00	0.43	0.30
137	06_0616A_I2	1.86	0.62	791.48	1.00	1.07	3.61	0.00	0.44	0.30

No.	Sub-catchment	Adopted Physical Catchment Descriptors								
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ARTDRAIN2	URBEXT	SOIL
138	06_0616A_I3	2.43	0.62	788.96	1.00	1.03	4.59	0.00	0.51	0.30
139	06_061A_D	2.52	0.62	788.53	1.00	1.20	4.18	0.00	0.53	0.30
	Unnamed watercourse 14 (into sea, near Finnabair Industrial Park)									
140	06_DU14_B	0.29	0.62	799.00	1.00	0.17	2.61	0.00	0.68	0.30
	Unnamed watercourse 15 (into sea, north of Finnabair Industrial Park)									
141	06_DU13_B_U	0.87	0.62	799.68	1.00	1.74	6.45	0.00	0.33	0.30
142	06_DU13_B	1.08	0.62	807.96	1.00	1.64	7.63	0.00	0.73	0.30
143	06_DU13_B_D	1.97	0.62	804.39	1.00	1.73	6.29	0.00	0.55	0.30

Appendix C: QMED rural estimates with different methods

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
	Aghaboys watercourse (from west into Ballymascanlan estuary)												
1	06_1059_Trib_RPS	2.91	0.6285	1016	1.000	1.6120	24.818	0.0000	0.23	0.93	0.75	0.36	0.97
2	06_1054_1_RA	1.39	0.6272	1006	1.000	0.7028	29.639	0.0000	0.20	0.36	0.40	0.14	0.51
3	06_1059_Trib_RPS_U	1.93	0.6298	997	1.000	0.8590	21.851	0.0000	0.22	0.49	0.52	0.22	0.65
4	06_1059_Trib_RPS_D	4.85	0.6441	1007	1.000	1.3130	24.818	0.0000	0.23	1.35	1.09	0.56	1.38
5	06_1078_2_B	5.36	0.6465	1002	1.000	1.2801	23.410	0.0000	0.24	1.44	1.18	0.67	1.48
6	06_1078_3_RA	5.40	0.6468	1001	1.000	1.3198	22.088	0.0000	0.24	1.45	1.18	0.67	1.48
	Ballynahattin watercourse (from west into Ballymascanlan estuary)												
7	06_1069_4_RPS	5.06	0.6594	1028	1.000	1.2143	21.643	0.0000	0.16	1.34	1.11	0.27	1.40
8	06_1058_2_RA	3.01	0.7005	1002	1.000	1.0544	22.667	0.0000	0.24	0.73	0.65	0.40	0.72
9	06_1058_3_B	3.67	0.7019	995	1.000	1.0030	18.655	0.0000	0.22	0.82	0.75	0.39	0.84
10	06_1069_4_RPS_U	3.91	0.7012	993	1.000	1.0144	15.521	0.0000	0.22	0.84	0.79	0.41	0.88
11	06_1069_4_RPS_D	8.98	0.6860	1018	1.000	1.1289	15.521	0.0000	0.20	2.01	1.67	0.73	2.00
12	06_1080_2_B	9.39	0.6848	1019	1.000	1.1511	13.080	0.0000	0.21	2.05	1.74	0.84	2.10
13	06_1080_3_B	9.79	0.6852	1015	1.000	1.1580	10.740	0.0000	0.21	2.05	1.79	0.87	2.16
14	06_1081_1_B	11.58	0.6923	1009	1.000	1.0322	9.033	0.0000	0.23	2.19	2.02	1.22	2.39
15	06_1081_3_B	12.13	0.6922	1008	1.000	1.0295	8.216	0.0000	0.23	2.25	2.10	1.27	2.48
16	06_1081_D_RA	13.08	0.6923	1003	1.000	1.0499	6.447	0.0000	0.24	2.30	2.22	1.48	2.62
	Kilcurry River (note: includes significant catchment area in Northern Ireland)												
17	06_991_2_RA	115.77	0.6671	1060	1.000	1.0079	10.805	0.0000	0.22	21.45	15.07		20.55
	Castletown River / Creggan River (note: includes significant catchment area in Northern Ireland)												
18	06_600_2_RA	100.79	0.6273	954	0.994	0.9806	6.743	0.0000	0.20	15.58	13.44		17.25

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
19	06_600_4_RA_U1	218.38	0.6271	980	0.994	0.9939	6.724	0.0000	0.20	33.42	26.13		35.07
20	06_600_4_RA_D	218.41	0.6328	982	0.995	0.9940	6.724	0.0000	0.20	33.27	25.82		34.50
21	06032_RA	218.47	0.6444	983	0.996	0.9941	6.752	0.0000	0.20	32.90	25.14		33.20
22	06_1084_1_RA	218.59	0.6444	980	0.996	0.9949	6.749	0.0000	0.20	32.79	25.07		33.00
23	06_1084_2_B	219.16	0.6636	970	0.996	0.9947	6.752	0.0000	0.20	31.60	23.82		30.07
24	06_1055_2_RA_U	219.61	0.6637	985	0.996	0.9943	6.753	0.0000	0.20	32.25	24.16		30.95
25	06_1055_2_RA_D	220.69	0.6640	973	0.996	0.9956	6.753	0.0000	0.20	31.91	23.99		30.36
26	06_1085_2_B	221.00	0.6641	971	0.996	0.9964	6.691	0.0000	0.20	31.80	23.96		30.24
27	06_1087_13_RA_U	221.06	0.6641	974	0.996	0.9975	6.633	0.0000	0.20	31.93	24.05		30.47
28	06_1087_13_RA_D	228.49	0.6641	951	0.996	0.9952	6.633	0.0000	0.21	31.89	24.19		29.90
29	06_DU15_B_U	228.51	0.6641	951	0.996	0.9963	6.556	0.0000	0.21	31.83	24.19		29.90
30	06_DU15_B_D	228.63	0.6641	951	0.996	0.9959	6.556	0.0000	0.21	31.83	24.19		29.90
31	06_1089_4_RA_U	228.64	0.6641	951	0.996	0.9962	6.551	0.0000	0.21	31.83	24.19		29.90
32	06_1089_4_RA_D	231.27	0.6641	949	0.996	0.9984	6.551	0.0000	0.21	32.12	24.39		30.09
33	06_DU16_B_U	231.31	0.6641	949	0.996	0.9991	6.512	0.0000	0.21	32.10	24.39		30.09
34	06_DU16_B_D	231.34	0.6641	949	0.996	0.9989	6.512	0.0000	0.21	32.10	24.39		30.08
35	06_DU06_B_U	231.38	0.6641	949	0.996	0.9998	6.376	0.0000	0.21	31.98	24.39		30.08
36	06_DU06_B_D	232.34	0.6641	948	0.996	0.9958	6.338	0.0000	0.21	31.99	24.45		30.13
37	06_DU17_B_U	232.35	0.6641	948	0.996	0.9965	6.284	0.0000	0.21	31.94	24.45		30.13
38	06_DU17_B_D	234.15	0.6641	948	0.996	0.9898	6.265	0.0000	0.21	32.07	24.60		30.32
39	06_DU07_B_U	234.20	0.6641	948	0.996	0.9912	6.244	0.0000	0.21	32.07	24.61		30.32
40	06_DU07_B_D	234.75	0.6641	947	0.996	0.9891	6.244	0.0000	0.21	32.09	24.64		30.34
41	06_DDalk_D_RARPS	235.28	0.6641	947	0.996	0.9899	6.044	0.0000	0.21	31.96	24.68		30.38

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
	Unnamed watercourse 1 (from south into Castletown River)												
42	06_600_4_RA	0.02	0.6328	896	1.000	2.6656	20.176	0.0000	0.30	0.01	0.01	0.01	0.01
	Stranacarry watercourse (from north into Castletown River)												
43	06_1055_U	0.10	0.6912	955	1.000	1.1671	26.974	0.0000	0.30	0.03	0.04	0.03	0.04
44	06_1055_1_B	0.66	0.6912	941	1.000	1.4419	12.529	0.0000	0.30	0.16	0.18	0.16	0.18
45	06_1055_2_RA	1.07	0.6932	939	1.000	1.2213	11.813	0.0000	0.30	0.24	0.26	0.24	0.27
	Castletown tributary (from south into Castletown River)												
46	06_1087_U_RA	5.87	0.6621	900	1.000	0.7091	6.412	0.0000	0.30	0.86	1.11	1.04	1.21
47	06_1087_8_B	6.19	0.6621	899	1.000	0.7521	5.850	0.0000	0.30	0.91	1.16	1.09	1.26
48	06_DU01_B_U	6.38	0.6619	899	1.000	0.7896	5.851	0.0000	0.30	0.95	1.19	1.12	1.30
49	06_DU01_B	0.26	0.6690	876	1.000	0.7790	5.788	0.0000	0.30	0.04	0.08	0.06	0.08
50	06_DU01_B_D	6.64	0.6616	898	1.000	0.7624	5.851	0.0000	0.30	0.97	1.23	1.16	1.34
51	06_1087_10_B	6.82	0.6614	898	1.000	0.8226	6.600	0.0000	0.30	1.05	1.26	1.19	1.38
52	06_1087_11_B	7.13	0.6616	898	1.000	0.8534	7.473	0.0000	0.30	1.13	1.30	1.23	1.43
53	06_1087_13_RA	7.42	0.6615	898	1.000	0.9132	8.858	0.0000	0.30	1.24	1.35	1.28	1.48
	Unnamed watercourse 2 (from north into Castletown River)												
54	06_DU15_B	0.12	0.6641	881	1.000	0.4219	3.710	0.0000	0.30	0.02	0.04	0.03	0.04
	Acarreagh watercourse (from south into Castletown River)												
55	06_DU02_B	0.56	0.6162	859	1.000	0.4930	6.703	0.0000	0.30	0.09	0.17	0.12	0.18
56	06_DU03_B	0.28	0.6162	862	1.000	0.1764	5.251	0.0000	0.30	0.03	0.10	0.07	0.10
57	06_1089_U	0.04	0.6162	876	1.000	2.3824	4.863	0.0000	0.30	0.01	0.02	0.01	0.02
58	06_DU02_B_U	0.56	0.6162	864	1.000	2.2218	17.905	0.0000	0.30	0.17	0.17	0.12	0.18
59	06_DU02_B_D	1.14	0.6162	862	1.000	1.1071	17.905	0.0000	0.30	0.26	0.31	0.23	0.33
60	06_1089_2_B	1.57	0.6162	862	1.000	1.3369	13.213	0.0000	0.30	0.36	0.40	0.31	0.43

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
61	06_1089_3_B	2.36	0.6158	865	1.000	1.2313	10.661	0.0000	0.30	0.49	0.56	0.44	0.61
62	06_1089_4_RA	2.59	0.6160	866	1.000	1.1210	10.005	0.0000	0.30	0.52	0.61	0.48	0.67
	Unnamed watercourse 3 (from north into Castletown River)												
63	06_DU16_B	0.04	0.6641	889	1.000	1.4182	4.312	0.0000	0.30	0.01	0.02	0.01	0.02
	Unnamed watercourse 4 (from south into Castletown River)												
64	06_DU06_B	0.95	0.6641	867	1.000	1.4103	1.746	0.0000	0.30	0.15	0.24	0.20	0.24
	Unnamed watercourse 5 (from north into Castletown River)												
65	06_DU17_B	1.76	0.6641	904	1.000	0.6353	2.563	0.0000	0.30	0.23	0.41	0.36	0.44
	Unnamed watercourse 6 (from south into Castletown River)												
66	06_DU07_B	0.56	0.6641	866	1.000	0.3658	0.415	0.0000	0.30	0.04	0.15	0.12	0.15
	Donaghmore watercourse (from north into Blackwater River)												
67	06_242_U	0.63	0.6237	869	1.000	1.3095	5.150	0.0000	0.30	0.13	0.19	0.14	0.20
68	06_242_1_B	1.09	0.6237	867	1.000	1.3909	16.080	0.0000	0.30	0.27	0.29	0.22	0.31
69	06_242_2_B	1.40	0.6182	867	1.000	1.4719	15.853	0.0000	0.30	0.34	0.36	0.28	0.39
70	06_242_3_B	1.90	0.6180	864	1.000	1.3234	15.701	0.0000	0.30	0.44	0.47	0.36	0.51
71	06_242_4_RPS	2.50	0.6180	862	1.000	1.2482	16.529	0.0000	0.30	0.56	0.59	0.46	0.64
	Dundalk / Blackwater River												
72	06_913_U	8.42	0.6175	861	1.000	0.6542	4.618	0.0000	0.30	1.11	1.60	1.36	1.79
73	06_913_3_B	9.30	0.6436	857	1.000	0.6492	3.938	0.0000	0.30	1.13	1.63	1.48	1.74
74	06_913_4_RPS	9.51	0.6437	859	1.000	0.6381	3.558	0.0000	0.30	1.13	1.66	1.51	1.78
75	06_242_4_RPS_U	9.90	0.6434	851	1.000	0.6690	5.262	0.0000	0.30	1.26	1.70	1.55	1.81
76	06_242_4_RPS_D	12.40	0.6416	855	1.000	0.7891	5.262	0.0000	0.30	1.67	2.07	1.91	2.23
77	06_DU04_B_U	12.69	0.6414	854	1.000	0.7832	6.868	0.0000	0.30	1.78	2.11	1.94	2.27
78	06_DU04_B_D	13.43	0.6409	854	1.000	0.7551	6.868	0.0000	0.30	1.86	2.21	2.04	2.38

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
79	06_918_1_U	17.30	0.6381	841	1.000	0.8112	6.246	0.0000	0.30	2.33	2.71	2.51	2.89
80	06_918_1_D	17.91	0.6376	840	1.000	0.8413	6.246	0.0000	0.30	2.44	2.79	2.59	2.97
81	06036_RPS	17.92	0.6376	840	1.000	0.8435	6.121	0.0000	0.30	2.43	2.79	2.59	2.97
82	06_930_2_B	18.01	0.6376	840	1.000	0.8654	5.985	0.0000	0.30	2.46	2.80	2.60	2.99
83	06_930_3_B	18.46	0.6375	839	1.000	0.8562	5.773	0.0000	0.30	2.49	2.86	2.66	3.05
84	06_930_4_B	18.74	0.6375	839	1.000	0.8705	5.399	0.0000	0.30	2.51	2.90	2.69	3.09
85	06_DU09_B_U	18.84	0.6375	839	1.000	0.8756	5.285	0.0000	0.30	2.51	2.91	2.71	3.10
86	06_DU09_B_D	19.70	0.6375	839	1.000	0.8387	5.285	0.0000	0.30	2.58	3.02	2.81	3.22
87	06_930_5_B	20.43	0.6375	845	1.000	0.8352	5.030	0.0000	0.30	2.67	3.13	2.93	3.37
88	06_DU10_B_U	20.89	0.6247	847	1.000	0.8359	4.748	0.0000	0.30	2.75	3.29	3.00	3.63
89	06_DU10_B_D	21.32	0.6129	847	1.000	0.8219	4.748	0.0000	0.30	2.84	3.45	3.05	3.87
90	06_DU11_B_U	21.33	0.6126	846	1.000	0.8325	4.579	0.0000	0.30	2.83	3.45	3.05	3.87
91	06_DU11_B_D	21.62	0.6044	846	1.000	0.8285	4.579	0.0000	0.30	2.90	3.57	3.09	4.03
92	06_1041_1_B_U	21.65	0.6037	848	1.000	0.8359	4.486	0.0000	0.30	2.91	3.58	3.10	4.06
93	06_1041_1_B_D	22.12	0.6038	848	1.000	0.8367	4.486	0.0000	0.30	2.97	3.64	3.16	4.14
94	06_1041_2_B	22.40	0.6038	847	1.000	0.8473	4.004	0.0000	0.30	2.95	3.68	3.19	4.17
95	06_1041_3_B	22.58	0.6038	846	1.000	0.8645	3.819	0.0000	0.30	2.97	3.70	3.21	4.19
96	06_DU12_B_U	22.80	0.6038	848	1.000	0.8686	3.612	0.0000	0.30	2.97	3.74	3.24	4.24
97	06_DU12_B_D	24.06	0.6036	849	1.000	0.9099	3.612	0.0000	0.30	3.18	3.91	3.41	4.46
98	06_1038_D	24.46	0.6036	845	1.000	0.9473	3.374	0.0000	0.30	3.22	3.95	3.44	4.48
	Fairhill River (from south into Blackwater River)												
99	06_438_2_B	0.24	0.6434	835	1.000	1.8961	0.182	0.0000	0.30	0.03	0.08	0.05	0.07
100	06_DU05_B_U	0.27	0.6434	834	1.000	3.8236	3.181	0.0000	0.30	0.07	0.08	0.06	0.08
101	06_DU05_B_D	0.88	0.6434	827	1.000	1.3192	12.000	0.0000	0.30	0.19	0.22	0.17	0.22

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
102	06_438_3_B	0.98	0.6434	829	1.000	1.0134	9.416	0.0000	0.30	0.18	0.24	0.19	0.24
103	06_147_4_RPS_U	1.00	0.6434	829	1.000	1.1463	7.313	0.0000	0.30	0.18	0.25	0.20	0.24
104	06_147_4_RPS_D	3.67	0.6434	822	1.000	0.8307	7.313	0.0000	0.30	0.55	0.73	0.62	0.72
	Unnamed watercourse 7 (from south into Blackwater River)												
105	06_DU05_B	0.60	0.6434	827	1.000	0.9972	12.000	0.0000	0.30	0.12	0.16	0.12	0.16
	Unnamed watercourse 8 (from north into Blackwater River)												
106	06_DU04_B	0.72	0.6409	844	1.000	0.0217	7.357	0.0000	0.30	0.04	0.19	0.15	0.19
	Killally / Fairhill River tributary (from south into Blackwater River)												
107	06_Trib_Ddalk_1	0.28	0.6245	824	1.000	0.1803	30.357	0.0000	0.30	0.04	0.09	0.06	0.09
108	06_147_U	0.03	0.6245	809	1.000	1.4811	25.511	0.0000	0.30	0.01	0.02	0.01	0.01
109	06_Trib_Ddalk_U	0.19	0.6245	819	1.000	0.2627	11.733	0.0000	0.30	0.03	0.07	0.04	0.06
110	06_Trib_Ddalk_1_U	1.00	0.6245	819	1.000	0.1419	7.776	0.0000	0.30	0.09	0.26	0.19	0.25
111	06_Trib_Ddalk_1_D	1.04	0.6245	820	1.000	0.1768	7.776	0.0000	0.30	0.10	0.27	0.20	0.26
112	06_147_2_B	1.60	0.6245	816	1.000	0.3554	9.150	0.0000	0.30	0.20	0.38	0.29	0.38
113	06_147_3_B	2.12	0.6167	815	1.000	0.5131	7.980	0.0000	0.30	0.29	0.49	0.37	0.49
114	06_147_4_B	2.48	0.6245	817	1.000	0.6388	7.557	0.0000	0.30	0.36	0.55	0.43	0.55
115	06_147_4_RPS	2.54	0.6245	817	1.000	0.7336	6.948	0.0000	0.30	0.37	0.56	0.44	0.56
	Priorland watercourse (from south into Blackwater River)												
116	06_918_U	0.21	0.6376	818	1.000	0.2425	16.444	0.0000	0.30	0.03	0.07	0.05	0.06
117	06_918_1	0.60	0.6376	822	1.000	1.7984	5.247	0.0000	0.30	0.12	0.16	0.12	0.16
	Unnamed watercourse 9 (from south into Blackwater River)												
118	06_DU09_B	1.07	0.6375	824	1.000	0.5343	0.683	0.0000	0.30	0.10	0.27	0.21	0.26
	Unnamed watercourse 10 (from south into Blackwater River)												
119	06_DU10_B	0.41	0.6129	825	1.000	0.3079	0.417	0.0000	0.30	0.03	0.13	0.09	0.13

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
	Unnamed watercourse 11 (from north into Blackwater River)												
120	06_DU11_B	0.13	0.6044	832	1.000	0.3729	2.476	0.0000	0.30	0.02	0.05	0.03	0.05
	Unnamed watercourse 12 (from north into Blackwater River)												
121	06_1041_1_B	0.44	0.6038	860	1.000	0.1365	4.571	0.0000	0.30	0.04	0.14	0.10	0.15
	Unnamed watercourse 13 (from south into Blackwater River)												
122	06_DU12_B	1.25	0.6036	826	1.000	1.6274	0.267	0.0000	0.30	0.14	0.33	0.24	0.34
	Ramparts / Marshes Lower watercourse (branch to north from Blackwater River)												
123	06_DU08_B	0.14	0.6036	842	1.000	0.3505	1.085	0.0000	0.30	0.01	0.06	0.04	0.06
124	06_DU08_B_U	0.23	0.6036	841	1.000	3.3326	1.021	0.0000	0.30	0.05	0.08	0.05	0.08
125	06_DU08_B_D	0.38	0.6036	841	1.000	2.0266	1.021	0.0000	0.30	0.07	0.12	0.08	0.13
126	06_318_I1	0.51	0.6036	841	1.000	1.0245	0.228	0.0000	0.30	0.05	0.16	0.11	0.17
127	06_318_I2	0.66	0.6036	847	1.000	1.4594	0.325	0.0000	0.30	0.08	0.20	0.14	0.21
128	06_318_I3	0.78	0.6036	852	1.000	1.9209	0.558	0.0000	0.30	0.12	0.23	0.16	0.24
129	06_318_D	0.83	0.6036	852	1.000	2.2173	0.405	0.0000	0.30	0.12	0.24	0.17	0.26
	Green Gates watercourse (into sea, south-west Blackrock)												
130	06_315_U_RA	0.79	0.6455	805	1.000	0.9646	7.500	0.0000	0.30	0.13	0.20	0.15	0.18
131	06_315_2_B	1.12	0.6341	803	1.000	0.5871	8.029	0.0000	0.30	0.16	0.27	0.21	0.26
132	06_315_3_B	2.16	0.6661	797	1.000	0.4910	5.931	0.0000	0.30	0.25	0.43	0.37	0.39
133	06_315_4_B	2.64	0.6304	798	1.000	0.6671	4.717	0.0000	0.30	0.34	0.55	0.44	0.53
134	06_315_5_RA	2.85	0.6201	797	1.000	0.7116	4.301	0.0000	0.30	0.37	0.60	0.47	0.59
	Blackrock watercourse (into sea, Blackrock)												
135	06_0616A_U	0.35	0.6201	794	1.000	0.2896	5.991	0.0000	0.30	0.04	0.10	0.07	0.10
136	06_0616A_I1	1.59	0.6201	792	1.000	0.9292	4.613	0.0000	0.30	0.23	0.37	0.28	0.35
137	06_0616A_I2	1.86	0.6201	791	1.000	1.0694	3.615	0.0000	0.30	0.27	0.42	0.32	0.40

No.	Sub-catchment	Physical Catchment Descriptors								Qmed (rural)			
		AREA (km^2)	BFIsoils	SAAR (mm)	FARL	DRAIND	S1085 (m/km)	ART-DRAIN2	SOIL	FSU 7-variable	FSU 3-variable	IoH124	FEH
138	06_0616A_I3	2.43	0.6201	789	1.000	1.0299	4.592	0.0000	0.30	0.36	0.53	0.41	0.50
139	06_061A_D	2.52	0.6201	789	1.000	1.1952	4.180	0.0000	0.30	0.38	0.54	0.42	0.52
	Unnamed watercourse 14 (into sea, near Finnabair Industrial Park)												
140	06_DU14_B	0.29	0.6201	799	1.000	0.1709	2.606	0.0000	0.30	0.02	0.09	0.06	0.09
	Unnamed watercourse 15 (into sea, north of Finnabair Industrial Park)												
141	06_DU13_B_U	0.87	0.6201	800	1.000	1.7432	6.455	0.0000	0.30	0.18	0.23	0.17	0.22
142	06_DU13_B	1.08	0.6201	808	1.000	1.6407	7.628	0.0000	0.30	0.22	0.27	0.20	0.27
143	06_DU13_B_D	1.97	0.6201	804	1.000	1.7261	6.288	0.0000	0.30	0.38	0.45	0.35	0.44

Appendix D: Pivotal site and urban adjustments to QMED

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
	Aghaboys watercourse (from west into Ballymascanlan estuary)										
1	06_1059_Trib_RPS	0.93	0.023	1.03	0.96	None	-	-	-	1.00	0.96
2	06_1054_1_RA	0.36	0.205	1.32	0.47	None	-	-	-	1.00	0.47
3	06_1059_Trib_RPS_U	0.49	0.279	1.44	0.70	None	-	-	-	1.00	0.70
4	06_1059_Trib_RPS_D	1.35	0.124	1.19	1.61	None	-	-	-	1.00	1.61
5	06_1078_2_B	1.44	0.113	1.17	1.69	None	-	-	-	1.00	1.69
6	06_1078_3_RA	1.45	0.113	1.17	1.70	None	-	-	-	1.00	1.70
	Ballynahattin watercourse (from west into Ballymascanlan estuary)										
7	06_1069_4_RPS	1.34	0.000	1.00	1.34	None	-	-	-	1.00	1.34
8	06_1058_2_RA	0.73	0.020	1.03	0.75	None	-	-	-	1.00	0.75
9	06_1058_3_B	0.82	0.016	1.02	0.84	None	-	-	-	1.00	0.84
10	06_1069_4_RPS_U	0.84	0.016	1.02	0.86	None	-	-	-	1.00	0.86
11	06_1069_4_RPS_D	2.01	0.007	1.01	2.03	None	-	-	-	1.00	2.03
12	06_1080_2_B	2.05	0.020	1.03	2.11	None	-	-	-	1.00	2.11
13	06_1080_3_B	2.05	0.024	1.04	2.12	None	-	-	-	1.00	2.12
14	06_1081_1_B	2.19	0.035	1.05	2.31	None	-	-	-	1.00	2.31
15	06_1081_3_B	2.25	0.033	1.05	2.36	None	-	-	-	1.00	2.36
16	06_1081_D_RA	2.30	0.031	1.05	2.41	None	-	-	-	1.00	2.41
	Kilcurry River (note: includes significant catchment area in Northern Ireland)										

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
17	06_991_2_RA	21.45	0.001	1.00	21.47	None	-	-	-	1.00	21.47
	Castletown River / Creggan River (note: includes significant catchment area in Northern Ireland)										
18	06_600_2_RA	15.58	0.003	1.00	15.64	None	-	-	-	1.00	15.64
19	06_600_4_RA_U1	33.42	0.002	1.00	33.53	None	-	-	-	1.00	33.53
20	06_600_4_RA_D	33.27	0.003	1.00	33.40	None	-	-	-	1.00	33.40
21	06032_RA	32.90	0.003	1.00	33.03	None	-	-	-	1.00	33.03
22	06_1084_1_RA	32.79	0.003	1.00	32.92	None	-	-	-	1.00	32.92
23	06_1084_2_B	31.60	0.003	1.00	31.75	None	-	-	-	1.00	31.75
24	06_1055_2_RA_U	32.25	0.003	1.00	32.40	None	-	-	-	1.00	32.40
25	06_1055_2_RA_D	31.91	0.003	1.00	32.07	None	-	-	-	1.00	32.07
26	06_1085_2_B	31.80	0.003	1.00	31.96	None	-	-	-	1.00	31.96
27	06_1087_13_RA_U	31.93	0.003	1.00	32.08	None	-	-	-	1.00	32.08
28	06_1087_13_RA_D	31.89	0.005	1.01	32.13	None	-	-	-	1.00	32.13
29	06_DU15_B_U	31.83	0.005	1.01	32.08	None	-	-	-	1.00	32.08
30	06_DU15_B_D	31.83	0.005	1.01	32.08	None	-	-	-	1.00	32.08
31	06_1089_4_RA_U	31.83	0.005	1.01	32.08	None	-	-	-	1.00	32.08
32	06_1089_4_RA_D	32.12	0.011	1.02	32.67	None	-	-	-	1.00	32.67
33	06_DU16_B_U	32.10	0.012	1.02	32.65	None	-	-	-	1.00	32.65
34	06_DU16_B_D	32.10	0.012	1.02	32.65	None	-	-	-	1.00	32.65
35	06_DU06_B_U	31.98	0.012	1.02	32.54	None	-	-	-	1.00	32.54
36	06_DU06_B_D	31.99	0.016	1.02	32.74	None	-	-	-	1.00	32.74
37	06_DU17_B_U	31.94	0.016	1.02	32.69	None	-	-	-	1.00	32.69
38	06_DU17_B_D	32.07	0.020	1.03	33.03	None	-	-	-	1.00	33.03

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
39	06_DU07_B_U	32.07	0.020	1.03	33.03	None	-	-	-	1.00	33.03
40	06_DU07_B_D	32.09	0.022	1.03	33.17	None	-	-	-	1.00	33.17
41	06_DDalk_D_RARPS	31.96	0.022	1.03	33.03	None	-	-	-	1.00	33.03
	Unnamed watercourse 1 (from south into Castletown River)										
42	06_600_4_RA	0.01	0.000	1.00	0.01	None	-	-	-	1.00	0.01
	Stranacarry watercourse (from north into Castletown River)										
43	06_1055_U	0.03	0.000	1.00	0.03	None	-	-	-	1.00	0.03
44	06_1055_1_B	0.16	0.040	1.06	0.17	None	-	-	-	1.00	0.17
45	06_1055_2_RA	0.24	0.024	1.04	0.25	None	-	-	-	1.00	0.25
	Castletown tributary (from south into Castletown River)										
46	06_1087_U_RA	0.86	0.000	1.00	0.86	None	-	-	-	1.00	0.86
47	06_1087_8_B	0.91	0.008	1.01	0.92	None	-	-	-	1.00	0.92
48	06_DU01_B_U	0.95	0.012	1.02	0.96	None	-	-	-	1.00	0.96
49	06_DU01_B	0.04	0.000	1.00	0.04	None	-	-	-	1.00	0.04
50	06_DU01_B_D	0.97	0.011	1.02	0.99	None	-	-	-	1.00	0.99
51	06_1087_10_B	1.05	0.016	1.02	1.07	None	-	-	-	1.00	1.07
52	06_1087_11_B	1.13	0.041	1.06	1.20	None	-	-	-	1.00	1.20
53	06_1087_13_RA	1.24	0.062	1.09	1.35	None	-	-	-	1.00	1.35
	Unnamed watercourse 2 (from north into Castletown River)										
54	06_DU15_B	0.02	0.000	1.00	0.02	None	-	-	-	1.00	0.02
	Acarreagh watercourse (from south into Castletown River)										
55	06_DU02_B	0.09	0.231	1.36	0.12	None	-	-	-	1.00	0.12
56	06_DU03_B	0.03	1.000	2.79	0.08	None	-	-	-	1.00	0.08

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
57	06_1089_U	0.01	0.000	1.00	0.01	None	-	-	-	1.00	0.01
58	06_DU02_B_U	0.17	0.002	1.00	0.17	None	-	-	-	1.00	0.17
59	06_DU02_B_D	0.26	0.118	1.18	0.31	None	-	-	-	1.00	0.31
60	06_1089_2_B	0.36	0.322	1.51	0.54	None	-	-	-	1.00	0.54
61	06_1089_3_B	0.49	0.530	1.88	0.92	None	-	-	-	1.00	0.92
62	06_1089_4_RA	0.52	0.557	1.93	0.99	None	-	-	-	1.00	0.99
	Unnamed watercourse 3 (from north into Castletown River)										
63	06_DU16_B	0.01	0.000	1.00	0.01	None	-	-	-	1.00	0.01
	Unnamed watercourse 4 (from south into Castletown River)										
64	06_DU06_B	0.15	0.999	2.79	0.41	None	-	-	-	1.00	0.41
	Unnamed watercourse 5 (from north into Castletown River)										
65	06_DU17_B	0.23	0.546	1.91	0.43	None	-	-	-	1.00	0.43
	Unnamed watercourse 6 (from south into Castletown River)										
66	06_DU07_B	0.04	0.993	2.78	0.12	None	-	-	-	1.00	0.12
	Donaghmore watercourse (from north into Blackwater River)										
67	06_242_U	0.13	0.000	1.00	0.13	None	-	-	-	1.00	0.13
68	06_242_1_B	0.27	0.000	1.00	0.27	None	-	-	-	1.00	0.27
69	06_242_2_B	0.34	0.000	1.00	0.34	None	-	-	-	1.00	0.34
70	06_242_3_B	0.44	0.000	1.00	0.44	None	-	-	-	1.00	0.44
71	06_242_4_RPS	0.56	0.000	1.00	0.56	None	-	-	-	1.00	0.56
	Dundalk / Blackwater River										
72	06_913_U	1.11	0.000	1.00	1.11	None	-	-	-	1.00	1.11
73	06_913_3_B	1.13	0.000	1.00	1.13	None	-	-	-	1.00	1.13

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
74	06_913_4_RPS	1.13	0.000	1.00	1.13	None	-	-	-	1.00	1.13
75	06_242_4_RPS_U	1.26	0.000	1.00	1.26	None	-	-	-	1.00	1.26
76	06_242_4_RPS_D	1.67	0.000	1.00	1.67	None	-	-	-	1.00	1.67
77	06_DU04_B_U	1.78	0.007	1.01	1.80	None	-	-	-	1.00	1.80
78	06_DU04_B_D	1.86	0.034	1.05	1.95	None	-	-	-	1.00	1.95
79	06_918_1_U	2.33	0.047	1.07	2.50	None	-	-	-	1.00	2.50
80	06_918_1_D	2.44	0.065	1.10	2.68	None	-	-	-	1.00	2.68
81	06036_RPS	2.43	0.066	1.10	2.67	None	-	-	-	1.00	2.67
82	06_930_2_B	2.46	0.070	1.11	2.71	None	-	-	-	1.00	2.71
83	06_930_3_B	2.49	0.093	1.14	2.84	None	-	-	-	1.00	2.84
84	06_930_4_B	2.51	0.107	1.16	2.91	None	-	-	-	1.00	2.91
85	06_DU09_B_U	2.51	0.111	1.17	2.94	None	-	-	-	1.00	2.94
86	06_DU09_B_D	2.58	0.150	1.23	3.18	None	-	-	-	1.00	3.18
87	06_930_5_B	2.67	0.181	1.28	3.41	None	-	-	-	1.00	3.41
88	06_DU10_B_U	2.75	0.199	1.31	3.60	None	-	-	-	1.00	3.60
89	06_DU10_B_D	2.84	0.214	1.33	3.79	None	-	-	-	1.00	3.79
90	06_DU11_B_U	2.83	0.214	1.33	3.78	None	-	-	-	1.00	3.78
91	06_DU11_B_D	2.90	0.219	1.34	3.89	None	-	-	-	1.00	3.89
92	06_1041_1_B_U	2.91	0.219	1.34	3.90	None	-	-	-	1.00	3.90
93	06_1041_1_B_D	2.97	0.234	1.37	4.06	None	-	-	-	1.00	4.06
94	06_1041_2_B	2.95	0.233	1.36	4.03	None	-	-	-	1.00	4.03
95	06_1041_3_B	2.97	0.233	1.36	4.05	None	-	-	-	1.00	4.05
96	06_DU12_B_U	2.97	0.237	1.37	4.08	None	-	-	-	1.00	4.08

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
97	06_DU12_B_D	3.18	0.225	1.35	4.30	None	-	-	-	1.00	4.30
98	06_1038_D	3.22	0.221	1.35	4.33	None	-	-	-	1.00	4.33
	Fairhill River (from south into Blackwater River)										
99	06_438_2_B	0.03	0.013	1.02	0.03	None	-	-	-	1.00	0.03
100	06_DU05_B_U	0.07	0.022	1.03	0.07	None	-	-	-	1.00	0.07
101	06_DU05_B_D	0.19	0.007	1.01	0.19	None	-	-	-	1.00	0.19
102	06_438_3_B	0.18	0.003	1.00	0.18	None	-	-	-	1.00	0.18
103	06_147_4_RPS_U	0.18	0.022	1.03	0.19	None	-	-	-	1.00	0.19
104	06_147_4_RPS_D	0.55	0.084	1.13	0.62	None	-	-	-	1.00	0.62
	Unnamed watercourse 7 (from south into Blackwater River)										
105	06_DU05_B	0.12	0.000	1.00	0.12	None	-	-	-	1.00	0.12
	Unnamed watercourse 8 (from north into Blackwater River)										
106	06_DU04_B	0.04	0.479	1.79	0.06	None	-	-	-	1.00	0.06
	Killally / Fairhill River tributary (from south into Blackwater River)										
107	06_Trib_Ddalk_1	0.04	0.000	1.00	0.04	None	-	-	-	1.00	0.04
108	06_147_U	0.01	0.212	1.33	0.01	None	-	-	-	1.00	0.01
109	06_Trib_Ddalk_U	0.03	0.519	1.86	0.05	None	-	-	-	1.00	0.05
110	06_Trib_Ddalk_1_U	0.09	0.168	1.26	0.12	None	-	-	-	1.00	0.12
111	06_Trib_Ddalk_1_D	0.10	0.162	1.25	0.13	None	-	-	-	1.00	0.13
112	06_147_2_B	0.20	0.109	1.17	0.23	None	-	-	-	1.00	0.23
113	06_147_3_B	0.29	0.116	1.18	0.34	None	-	-	-	1.00	0.34
114	06_147_4_B	0.36	0.099	1.15	0.41	None	-	-	-	1.00	0.41
115	06_147_4_RPS	0.37	0.097	1.15	0.43	None	-	-	-	1.00	0.43

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
	Priorland watercourse (from south into Blackwater River)										
116	06_918_U	0.03	0.713	2.22	0.06	None	-	-	-	1.00	0.06
117	06_918_1	0.12	0.599	2.01	0.25	None	-	-	-	1.00	0.25
	Unnamed watercourse 9 (from south into Blackwater River)										
118	06_DU09_B	0.10	1.000	2.79	0.27	None	-	-	-	1.00	0.27
	Unnamed watercourse 10 (from south into Blackwater River)										
119	06_DU10_B	0.03	0.952	2.69	0.08	None	-	-	-	1.00	0.08
	Unnamed watercourse 11 (from north into Blackwater River)										
120	06_DU11_B	0.02	0.997	2.79	0.05	None	-	-	-	1.00	0.05
	Unnamed watercourse 12 (from north into Blackwater River)										
121	06_1041_1_B	0.04	0.973	2.74	0.11	None	-	-	-	1.00	0.11
	Unnamed watercourse 13 (from south into Blackwater River)										
122	06_DU12_B	0.14	0.003	1.00	0.15	None	-	-	-	1.00	0.15
	Ramparts / Marshes Lower watercourse (branch to north from Blackwater River)										
123	06_DU08_B	0.01	1.000	2.79	0.04	None	-	-	-	1.00	0.04
124	06_DU08_B_U	0.05	0.786	2.36	0.12	None	-	-	-	1.00	0.12
125	06_DU08_B_D	0.07	0.870	2.53	0.17	None	-	-	-	1.00	0.17
126	06_318_I1	0.05	0.904	2.60	0.14	None	-	-	-	1.00	0.14
127	06_318_I2	0.08	0.925	2.64	0.22	None	-	-	-	1.00	0.22
128	06_318_I3	0.12	0.937	2.66	0.31	None	-	-	-	1.00	0.31
129	06_318_D	0.12	0.936	2.66	0.33	None	-	-	-	1.00	0.33
	Green Gates watercourse (into sea, south-west Blackrock)										

No.	Sub-catchment	Qmed (rural, PCD)	Urban Adjustment			Qmed Adjustment Factor (Pivotal Site)					
			URBEXT	UAF	Qmed (urban) (m^3/s)	Pivotal Site Name	Pivotal Site Number	Qmed piv (gauged) (m^3/s)	Qmed piv (PCD) (m^3/s)	Adj. Factor	Qmed (adjusted) (m^3/s)
130	06_315_U_RA	0.13	0.122	1.19	0.16	None	-	-	-	1.00	0.16
131	06_315_2_B	0.16	0.276	1.43	0.23	None	-	-	-	1.00	0.23
132	06_315_3_B	0.25	0.204	1.32	0.33	None	-	-	-	1.00	0.33
133	06_315_4_B	0.34	0.299	1.47	0.50	None	-	-	-	1.00	0.50
134	06_315_5_RA	0.37	0.351	1.56	0.57	None	-	-	-	1.00	0.57
	Blackrock watercourse (into sea, Blackrock)										
135	06_0616A_U	0.04	0.320	1.51	0.06	None	-	-	-	1.00	0.06
136	06_0616A_I1	0.23	0.425	1.69	0.40	None	-	-	-	1.00	0.40
137	06_0616A_I2	0.27	0.436	1.71	0.47	None	-	-	-	1.00	0.47
138	06_0616A_I3	0.36	0.512	1.85	0.66	None	-	-	-	1.00	0.66
139	06_061A_D	0.38	0.530	1.88	0.72	None	-	-	-	1.00	0.72
	Unnamed watercourse 14 (into sea, near Finnabair Industrial Park)										
140	06_DU14_B	0.02	0.678	2.15	0.05	None	-	-	-	1.00	0.05
	Unnamed watercourse 15 (into sea, north of Finnabair Industrial Park)										
141	06_DU13_B_U	0.18	0.329	1.52	0.27	None	-	-	-	1.00	0.27
142	06_DU13_B	0.22	0.733	2.26	0.51	None	-	-	-	1.00	0.51
143	06_DU13_B_D	0.38	0.555	1.92	0.74	None	-	-	-	1.00	0.74

Appendix E: Recommended peak flows

No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
	Aghaboys watercourse (from west into Ballymascanlan estuary)											
1	06_1059_Trib_RPS	0.96	Aghaboys (u/s)	1.35	1.64	1.98	2.19	2.50	2.97	3.54	4.45	5.30
2	06_1054_1_RA	0.47	Aghaboys (u/s)	0.66	0.80	0.97	1.07	1.23	1.46	1.74	2.19	2.60
3	06_1059_Trib_RPS_U	0.70	Aghaboys (u/s)	0.98	1.19	1.43	1.59	1.81	2.15	2.56	3.23	3.84
4	06_1059_Trib_RPS_D	1.61	Aghaboys (u/s)	2.25	2.74	3.30	3.65	4.17	4.96	5.91	7.44	8.85
5	06_1078_2_B	1.69	Aghaboys (u/s)	2.37	2.88	3.47	3.84	4.38	5.21	6.21	7.82	9.30
6	06_1078_3_RA	1.70	Aghaboys (u/s)	2.38	2.89	3.48	3.85	4.40	5.23	6.23	7.84	9.34
	Ballynahattin watercourse (from west into Ballymascanlan estuary)											
7	06_1069_4_RPS	1.34	Ballynahattin (u/s)	1.88	2.27	2.70	2.98	3.36	3.95	4.62	5.67	6.63
8	06_1058_2_RA	0.75	Ballynahattin (u/s)	1.05	1.26	1.50	1.66	1.87	2.20	2.57	3.16	3.69
9	06_1058_3_B	0.84	Ballynahattin (u/s)	1.18	1.42	1.69	1.86	2.10	2.47	2.89	3.54	4.14
10	06_1069_4_RPS_U	0.86	Ballynahattin (u/s)	1.21	1.46	1.74	1.92	2.16	2.54	2.97	3.64	4.26
11	06_1069_4_RPS_D	2.03	Ballynahattin (u/s)	2.84	3.43	4.08	4.51	5.07	5.97	6.98	8.57	10.01
12	06_1080_2_B	2.11	Ballynahattin (u/s)	2.95	3.57	4.24	4.68	5.27	6.20	7.26	8.90	10.40
13	06_1080_3_B	2.12	Ballynahattin (u/s)	2.97	3.58	4.26	4.71	5.30	6.24	7.30	8.95	10.46
14	06_1081_1_B	2.31	Ballynahattin (u/s)	3.23	3.90	4.64	5.12	5.77	6.78	7.94	9.73	11.37
15	06_1081_3_B	2.36	Ballynahattin (u/s)	3.30	3.98	4.74	5.23	5.89	6.93	8.11	9.94	11.62
16	06_1081_D_RA	2.41	Ballynahattin (u/s)	3.37	4.07	4.84	5.35	6.02	7.09	8.29	10.17	11.88
	Kilcurry River (note: includes significant catchment area in Northern Ireland)											
17	06_991_2_RA	21.47	Kilcurry	29.63	35.65	42.52	46.81	53.04	62.49	73.66	91.48	107.80
	Castletown River / Creggan River (note: includes significant catchment area in Northern Ireland)											
18	06_600_2_RA	15.64	Castletown (u/s)	21.43	25.81	30.66	33.79	38.01	44.74	52.56	64.92	76.02

No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
19	06_600_4_RA_U1	33.53	Castletown (u/s)	45.93	55.32	65.71	72.42	81.47	95.88	112.65	139.13	162.94
20	06_600_4_RA_D	33.40	Castletown (u/s)	45.76	55.11	65.47	72.15	81.17	95.53	112.23	138.62	162.33
21	06032_RA	33.03	Castletown (u/s)	45.25	54.50	64.74	71.35	80.27	94.47	110.98	137.08	160.53
22	06_1084_1_RA	32.92	Castletown (u/s)	45.10	54.31	64.52	71.10	79.99	94.14	110.60	136.60	159.97
23	06_1084_2_B	31.75	Castletown (u/s)	43.49	52.38	62.22	68.57	77.15	90.80	106.67	131.75	154.29
24	06_1055_2_RA_U	32.40	Castletown (u/s)	44.39	53.46	63.51	69.99	78.74	92.67	108.87	134.47	157.48
25	06_1055_2_RA_D	32.07	Castletown (u/s)	43.94	52.92	62.86	69.27	77.93	91.72	107.76	133.09	155.86
26	06_1085_2_B	31.96	Castletown (u/s)	43.78	52.73	62.64	69.03	77.66	91.40	107.38	132.63	155.32
27	06_1087_13_RA_U	32.08	Castletown (u/s)	43.95	52.94	62.88	69.30	77.96	91.76	107.80	133.14	155.92
28	06_1087_13_RA_D	32.13	Castletown (u/s)	44.02	53.02	62.98	69.41	78.08	91.90	107.97	133.35	156.17
29	06_DU15_B_U	32.08	Castletown (u/s)	43.94	52.92	62.87	69.28	77.94	91.74	107.77	133.11	155.89
30	06_DU15_B_D	32.08	Castletown (u/s)	43.95	52.93	62.88	69.29	77.95	91.75	107.79	133.13	155.91
31	06_1089_4_RA_U	32.08	Castletown (u/s)	43.95	52.93	62.88	69.29	77.95	91.75	107.79	133.13	155.91
32	06_1089_4_RA_D	32.67	Castletown (u/s)	44.76	53.91	64.04	70.57	79.39	93.44	109.78	135.59	158.79
33	06_DU16_B_U	32.65	Castletown (u/s)	44.73	53.87	63.99	70.52	79.34	93.38	109.70	135.50	158.68
34	06_DU16_B_D	32.65	Castletown (u/s)	44.73	53.87	63.99	70.52	79.33	93.37	109.70	135.49	158.67
35	06_DU06_B_U	32.54	Castletown (u/s)	44.58	53.69	63.77	70.28	79.06	93.06	109.32	135.03	158.13
36	06_DU06_B_D	32.74	Castletown (u/s)	44.85	54.01	64.16	70.71	79.55	93.62	109.99	135.85	159.09
37	06_DU17_B_U	32.69	Castletown (u/s)	44.79	53.94	64.08	70.62	79.45	93.50	109.85	135.68	158.89
38	06_DU17_B_D	33.03	Castletown (u/s)	45.25	54.49	64.73	71.34	80.26	94.46	110.97	137.06	160.51
39	06_DU07_B_U	33.03	Castletown (u/s)	45.26	54.50	64.74	71.35	80.27	94.47	110.99	137.09	160.54
40	06_DU07_B_D	33.17	Castletown (u/s)	45.44	54.72	65.00	71.64	80.59	94.85	111.43	137.63	161.18
41	06_DDalk_D_RARPS	33.03	Castletown (u/s)	45.26	54.51	64.75	71.35	80.27	94.48	110.99	137.09	160.54

No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
	Unnamed watercourse 1 (from south into Castletown River)											
42	06_600_4_RA	0.01	Castletown (u/s)	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.04
	Stranacarry watercourse (from north into Castletown River)											
43	06_1055_U	0.03	Stranacarry	0.04	0.05	0.06	0.06	0.07	0.08	0.10	0.12	0.14
44	06_1055_1_B	0.17	Stranacarry	0.24	0.28	0.34	0.37	0.42	0.49	0.58	0.72	0.84
45	06_1055_2_RA	0.25	Stranacarry	0.34	0.41	0.48	0.53	0.60	0.71	0.83	1.03	1.21
	Castletown tributary (from south into Castletown River)											
46	06_1087_U_RA	0.86	Castletown tributary	1.18	1.42	1.69	1.87	2.12	2.50	2.96	3.70	4.38
47	06_1087_8_B	0.92	Castletown tributary	1.25	1.51	1.79	1.99	2.25	2.66	3.15	3.94	4.66
48	06_DU01_B_U	0.96	Castletown tributary	1.32	1.59	1.89	2.09	2.37	2.80	3.31	4.14	4.90
49	06_DU01_B	0.04	Castletown tributary	0.06	0.07	0.09	0.10	0.11	0.13	0.15	0.19	0.23
50	06_DU01_B_D	0.99	Castletown tributary	1.35	1.63	1.94	2.14	2.43	2.87	3.40	4.25	5.03
51	06_1087_10_B	1.07	Castletown tributary	1.47	1.77	2.10	2.32	2.63	3.12	3.68	4.60	5.45
52	06_1087_11_B	1.20	Castletown tributary	1.64	1.97	2.35	2.60	2.94	3.48	4.12	5.15	6.09
53	06_1087_13_RA	1.35	Castletown tributary	1.85	2.23	2.65	2.94	3.33	3.94	4.66	5.82	6.89
	Unnamed watercourse 2 (from north into Castletown River)											
54	06_DU15_B	0.02	Castletown (u/s)	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.07	0.08
	Acarreagh watercourse (from south into Castletown River)											
55	06_DU02_B	0.12	Acarreagh	0.16	0.20	0.24	0.26	0.30	0.35	0.42	0.52	0.62
56	06_DU03_B	0.08	Acarreagh	0.12	0.14	0.17	0.19	0.22	0.26	0.31	0.38	0.46
57	06_1089_U	0.01	Acarreagh	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.06
58	06_DU02_B_U	0.17	Acarreagh	0.24	0.29	0.35	0.39	0.44	0.52	0.62	0.78	0.92
59	06_DU02_B_D	0.31	Acarreagh	0.43	0.53	0.63	0.70	0.80	0.95	1.12	1.41	1.66
60	06_1089_2_B	0.54	Acarreagh	0.76	0.92	1.11	1.22	1.39	1.65	1.96	2.45	2.90

No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
61	06_1089_3_B	0.92	Acarreagh	1.29	1.57	1.89	2.09	2.38	2.82	3.35	4.19	4.96
62	06_1089_4_RA	0.99	Acarreagh	1.39	1.69	2.03	2.24	2.55	3.03	3.59	4.50	5.32
	Unnamed watercourse 3 (from north into Castletown River)											
63	06_DU16_B	0.01	Castletown (u/s)	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.04
	Unnamed watercourse 4 (from south into Castletown River)											
64	06_DU06_B	0.41	Castletown (u/s)	0.56	0.68	0.81	0.89	1.00	1.18	1.39	1.71	2.00
	Unnamed watercourse 5 (from north into Castletown River)											
65	06_DU17_B	0.43	Castletown (u/s)	0.59	0.71	0.85	0.93	1.05	1.24	1.45	1.79	2.10
	Unnamed watercourse 6 (from south into Castletown River)											
66	06_DU07_B	0.12	Castletown (u/s)	0.17	0.20	0.24	0.26	0.29	0.35	0.41	0.50	0.59
	Donaghmore watercourse (from north into Blackwater River)											
67	06_242_U	0.13	Donaghmore	0.17	0.21	0.25	0.28	0.31	0.37	0.43	0.54	0.63
68	06_242_1_B	0.27	Donaghmore	0.37	0.44	0.52	0.58	0.65	0.77	0.91	1.13	1.32
69	06_242_2_B	0.34	Donaghmore	0.47	0.57	0.68	0.75	0.84	1.00	1.17	1.46	1.71
70	06_242_3_B	0.44	Donaghmore	0.60	0.73	0.86	0.95	1.08	1.27	1.50	1.86	2.19
71	06_242_4_RPS	0.56	Donaghmore	0.77	0.93	1.10	1.22	1.38	1.63	1.91	2.38	2.80
	Dundalk / Blackwater River											
72	06_913_U	1.11	Dundalk/Blackwater (u/s)	1.50	1.79	2.11	2.31	2.60	3.03	3.55	4.35	5.08
73	06_913_3_B	1.13	Dundalk/Blackwater (u/s)	1.53	1.82	2.15	2.35	2.64	3.08	3.60	4.42	5.16
74	06_913_4_RPS	1.13	Dundalk/Blackwater (u/s)	1.52	1.82	2.14	2.35	2.64	3.08	3.60	4.41	5.16
75	06_242_4_RPS_U	1.26	Dundalk/Blackwater (u/s)	1.71	2.04	2.40	2.63	2.96	3.45	4.03	4.94	5.78
76	06_242_4_RPS_D	1.67	Dundalk/Blackwater (u/s)	2.25	2.69	3.17	3.47	3.90	4.55	5.32	6.52	7.62
77	06_DU04_B_U	1.80	Dundalk/Blackwater (u/s)	2.43	2.90	3.43	3.75	4.22	4.92	5.75	7.05	8.24
78	06_DU04_B_D	1.95	Dundalk/Blackwater (u/s)	2.63	3.14	3.71	4.06	4.57	5.33	6.22	7.63	8.92

No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
79	06_918_1_U	2.50	Dundalk/Blackwater (u/s)	3.37	4.02	4.75	5.20	5.85	6.82	7.97	9.77	11.42
80	06_918_1_D	2.68	Dundalk/Blackwater (u/s)	3.61	4.31	5.09	5.57	6.26	7.31	8.54	10.47	12.23
81	06036_RPS	2.67	Dundalk/Blackwater (u/s)	3.61	4.30	5.08	5.56	6.26	7.30	8.53	10.45	12.22
82	06_930_2_B	2.71	Dundalk/Blackwater (u/s)	3.66	4.37	5.16	5.65	6.35	7.41	8.66	10.61	12.41
83	06_930_3_B	2.84	Dundalk/Blackwater (u/s)	3.83	4.57	5.39	5.90	6.64	7.75	9.05	11.09	12.97
84	06_930_4_B	2.91	Dundalk/Blackwater (u/s)	3.93	4.69	5.53	6.06	6.81	7.95	9.29	11.38	13.31
85	06_DU09_B_U	2.94	Dundalk/Blackwater (u/s)	3.97	4.73	5.58	6.11	6.87	8.02	9.37	11.49	13.43
86	06_DU09_B_D	3.18	Dundalk/Blackwater (u/s)	4.29	5.11	6.03	6.60	7.43	8.67	10.13	12.41	14.51
87	06_930_5_B	3.41	Dundalk/Blackwater (u/s)	4.60	5.49	6.48	7.09	7.98	9.30	10.87	13.33	15.58
88	06_DU10_B_U	3.60	Dundalk/Blackwater (u/s)	4.86	5.80	6.84	7.49	8.42	9.83	11.49	14.08	16.45
89	06_DU10_B_D	3.79	Dundalk/Blackwater (u/s)	5.11	6.10	7.20	7.88	8.86	10.34	12.08	14.81	17.31
90	06_DU11_B_U	3.78	Dundalk/Blackwater (u/s)	5.10	6.08	7.18	7.86	8.84	10.31	12.05	14.77	17.26
91	06_DU11_B_D	3.89	Dundalk/Blackwater (u/s)	5.25	6.27	7.39	8.09	9.11	10.62	12.41	15.22	17.79
92	06_1041_1_B_U	3.90	Dundalk/Blackwater (u/s)	5.27	6.28	7.41	8.12	9.13	10.65	12.45	15.26	17.83
93	06_1041_1_B_D	4.06	Dundalk/Blackwater (u/s)	5.48	6.53	7.71	8.44	9.49	11.07	12.94	15.86	18.53
94	06_1041_2_B	4.03	Dundalk/Blackwater (u/s)	5.44	6.49	7.66	8.38	9.43	11.00	12.85	15.76	18.42
95	06_1041_3_B	4.05	Dundalk/Blackwater (u/s)	5.46	6.52	7.69	8.42	9.47	11.05	12.91	15.83	18.50
96	06_DU12_B_U	4.08	Dundalk/Blackwater (u/s)	5.50	6.56	7.74	8.48	9.54	11.12	13.00	15.93	18.62
97	06_DU12_B_D	4.30	Dundalk/Blackwater (u/s)	5.81	6.93	8.18	8.95	10.07	11.75	13.73	16.82	19.66
98	06_1038_D	4.33	Dundalk/Blackwater (u/s)	5.85	6.97	8.23	9.01	10.13	11.82	13.82	16.93	19.79
	Fairhill River (from south into Blackwater River)											
99	06_438_2_B	0.03	Dundalk/Blackwater (u/s)	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.11	0.13
100	06_DU05_B_U	0.07	Dundalk/Blackwater (u/s)	0.10	0.12	0.14	0.15	0.17	0.20	0.23	0.28	0.33
101	06_DU05_B_D	0.19	Dundalk/Blackwater (u/s)	0.25	0.30	0.36	0.39	0.44	0.51	0.60	0.73	0.85

No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
102	06_438_3_B	0.18	Dundalk/Blackwater (u/s)	0.24	0.29	0.34	0.37	0.42	0.49	0.57	0.70	0.82
103	06_147_4_RPS_U	0.19	Dundalk/Blackwater (u/s)	0.25	0.30	0.36	0.39	0.44	0.51	0.60	0.74	0.86
104	06_147_4_RPS_D	0.62	Dundalk/Blackwater (u/s)	0.83	0.99	1.17	1.28	1.44	1.68	1.96	2.41	2.81
	Unnamed watercourse 7 (from south into Blackwater River)											
105	06_DU05_B	0.12	Dundalk/Blackwater (u/s)	0.16	0.19	0.22	0.24	0.28	0.32	0.38	0.46	0.54
	Unnamed watercourse 8 (from north into Blackwater River)											
106	06_DU04_B	0.06	Dundalk/Blackwater (u/s)	0.09	0.10	0.12	0.13	0.15	0.17	0.20	0.25	0.29
	Killally / Fairhill River tributary (from south into Blackwater River)											
107	06_Trib_Ddalk_1	0.04	Killally / Fairhill tributary	0.05	0.06	0.08	0.09	0.10	0.11	0.13	0.16	0.19
108	06_147_U	0.01	Killally / Fairhill tributary	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.06	0.07
109	06_Trib_Ddalk_U	0.05	Killally / Fairhill tributary	0.07	0.08	0.10	0.11	0.12	0.14	0.16	0.20	0.24
110	06_Trib_Ddalk_1_U	0.12	Killally / Fairhill tributary	0.16	0.19	0.23	0.25	0.29	0.34	0.40	0.49	0.57
111	06_Trib_Ddalk_1_D	0.13	Killally / Fairhill tributary	0.18	0.21	0.25	0.28	0.32	0.37	0.44	0.54	0.64
112	06_147_2_B	0.23	Killally / Fairhill tributary	0.32	0.39	0.46	0.51	0.58	0.68	0.80	0.99	1.16
113	06_147_3_B	0.34	Killally / Fairhill tributary	0.47	0.57	0.68	0.75	0.85	1.00	1.17	1.45	1.70
114	06_147_4_B	0.41	Killally / Fairhill tributary	0.56	0.68	0.81	0.90	1.01	1.19	1.40	1.74	2.04
115	06_147_4_RPS	0.43	Killally / Fairhill tributary	0.59	0.72	0.86	0.95	1.07	1.26	1.48	1.83	2.15
	Priorland watercourse (from south into Blackwater River)											
116	06_918_U	0.06	Dundalk/Blackwater (u/s)	0.08	0.10	0.12	0.13	0.15	0.17	0.20	0.24	0.29
117	06_918_1	0.25	Dundalk/Blackwater (u/s)	0.33	0.40	0.47	0.51	0.58	0.68	0.79	0.97	1.13
	Unnamed watercourse 9 (from south into Blackwater River)											
118	06_DU09_B	0.27	Dundalk/Blackwater (u/s)	0.36	0.43	0.51	0.56	0.63	0.74	0.86	1.05	1.23
	Unnamed watercourse 10 (from south into Blackwater River)											
119	06_DU10_B	0.08	Dundalk/Blackwater (u/s)	0.11	0.14	0.16	0.17	0.20	0.23	0.27	0.33	0.38

No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
	Unnamed watercourse 11 (from north into Blackwater River)											
120	06_DU11_B	0.05	Dundalk/Blackwater (u/s)	0.06	0.07	0.09	0.10	0.11	0.13	0.15	0.18	0.21
	Unnamed watercourse 12 (from north into Blackwater River)											
121	06_1041_1_B	0.11	Dundalk/Blackwater (u/s)	0.15	0.18	0.22	0.24	0.27	0.31	0.36	0.45	0.52
	Unnamed watercourse 13 (from south into Blackwater River)											
122	06_DU12_B	0.15	Dundalk/Blackwater (u/s)	0.20	0.23	0.28	0.30	0.34	0.40	0.46	0.57	0.66
	Ramparts / Marshes Lower watercourse (branch to north from Blackwater River)											
123	06_DU08_B	0.04	Dundalk/Blackwater (u/s)	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.16	0.19
124	06_DU08_B_U	0.12	Dundalk/Blackwater (u/s)	0.16	0.19	0.22	0.24	0.28	0.32	0.38	0.46	0.54
125	06_DU08_B_D	0.17	Dundalk/Blackwater (u/s)	0.23	0.27	0.32	0.35	0.40	0.46	0.54	0.66	0.77
126	06_318_I1	0.14	Dundalk/Blackwater (u/s)	0.19	0.22	0.26	0.29	0.33	0.38	0.44	0.54	0.64
127	06_318_I2	0.22	Dundalk/Blackwater (u/s)	0.29	0.35	0.41	0.45	0.51	0.59	0.69	0.85	0.99
128	06_318_I3	0.31	Dundalk/Blackwater (u/s)	0.42	0.50	0.59	0.65	0.73	0.85	0.99	1.22	1.42
129	06_318_D	0.33	Dundalk/Blackwater (u/s)	0.44	0.53	0.63	0.68	0.77	0.90	1.05	1.29	1.50
	Green Gates watercourse (into sea, south-west Blackrock)											
130	06_315_U_RA	0.16	Green Gates	0.22	0.26	0.31	0.34	0.38	0.45	0.53	0.66	0.77
131	06_315_2_B	0.23	Green Gates	0.31	0.38	0.45	0.49	0.56	0.65	0.77	0.96	1.13
132	06_315_3_B	0.33	Green Gates	0.45	0.54	0.64	0.70	0.80	0.94	1.10	1.37	1.62
133	06_315_4_B	0.50	Green Gates	0.68	0.81	0.97	1.07	1.20	1.42	1.67	2.07	2.44
134	06_315_5_RA	0.57	Green Gates	0.79	0.94	1.12	1.23	1.40	1.64	1.94	2.40	2.83
	Blackrock watercourse (into sea, Blackrock)											
135	06_0616A_U	0.06	Green Gates	0.08	0.10	0.12	0.13	0.15	0.17	0.20	0.25	0.29
136	06_0616A_I1	0.40	Green Gates	0.54	0.65	0.77	0.85	0.96	1.13	1.34	1.66	1.96
137	06_0616A_I2	0.47	Green Gates	0.64	0.76	0.91	1.00	1.13	1.33	1.57	1.94	2.29

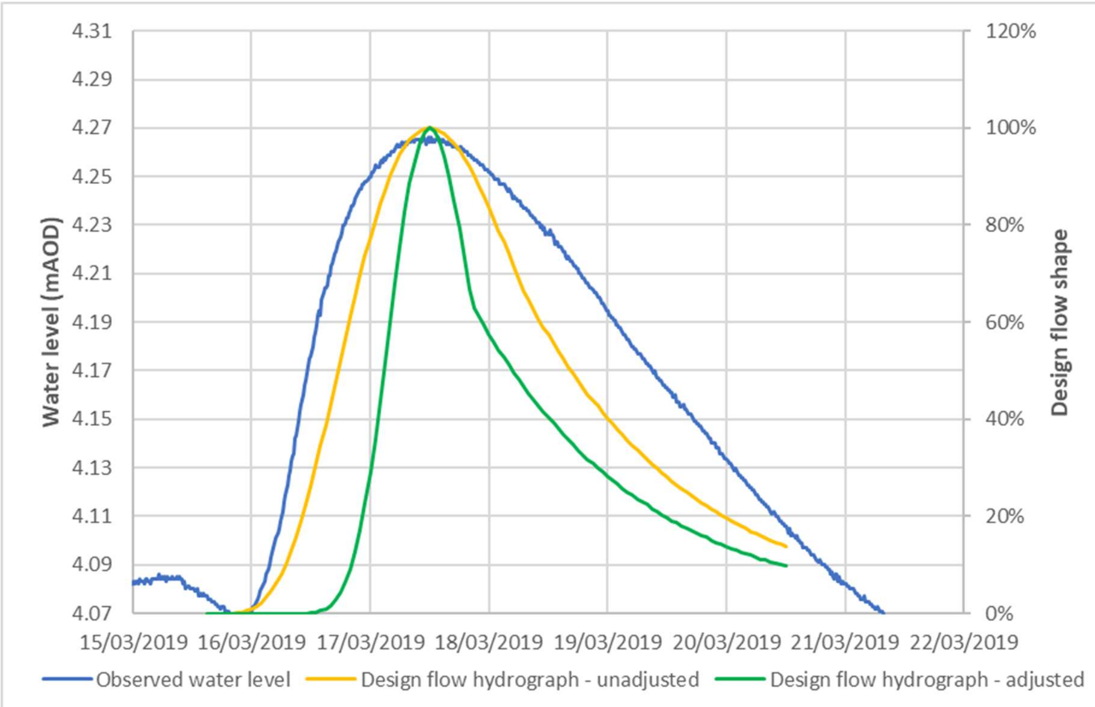
No.	Sub-catchment	Qmed (adjusted) (m^3/s)	Growth curve	Peak flow (m^3/s)								
				20%	10%	5%	3.3%	2%	1%	0.5%	0.2%	0.1%
138	06_0616A_I3	0.66	Green Gates	0.91	1.09	1.29	1.43	1.61	1.90	2.24	2.77	3.27
139	06_061A_D	0.72	Green Gates	0.99	1.19	1.41	1.55	1.76	2.07	2.44	3.02	3.56
	Unnamed watercourse 14 (into sea, near Finnabair Industrial Park)											
140	06_DU14_B	0.05	Green Gates	0.07	0.09	0.10	0.11	0.13	0.15	0.18	0.22	0.26
	Unnamed watercourse 15 (into sea, north of Finnabair Industrial Park)											
141	06_DU13_B_U	0.27	Green Gates	0.37	0.44	0.53	0.58	0.66	0.77	0.91	1.13	1.33
142	06_DU13_B	0.51	Green Gates	0.69	0.83	0.99	1.09	1.23	1.45	1.70	2.11	2.49
143	06_DU13_B_D	0.74	Green Gates	1.01	1.21	1.44	1.58	1.79	2.10	2.48	3.08	3.63

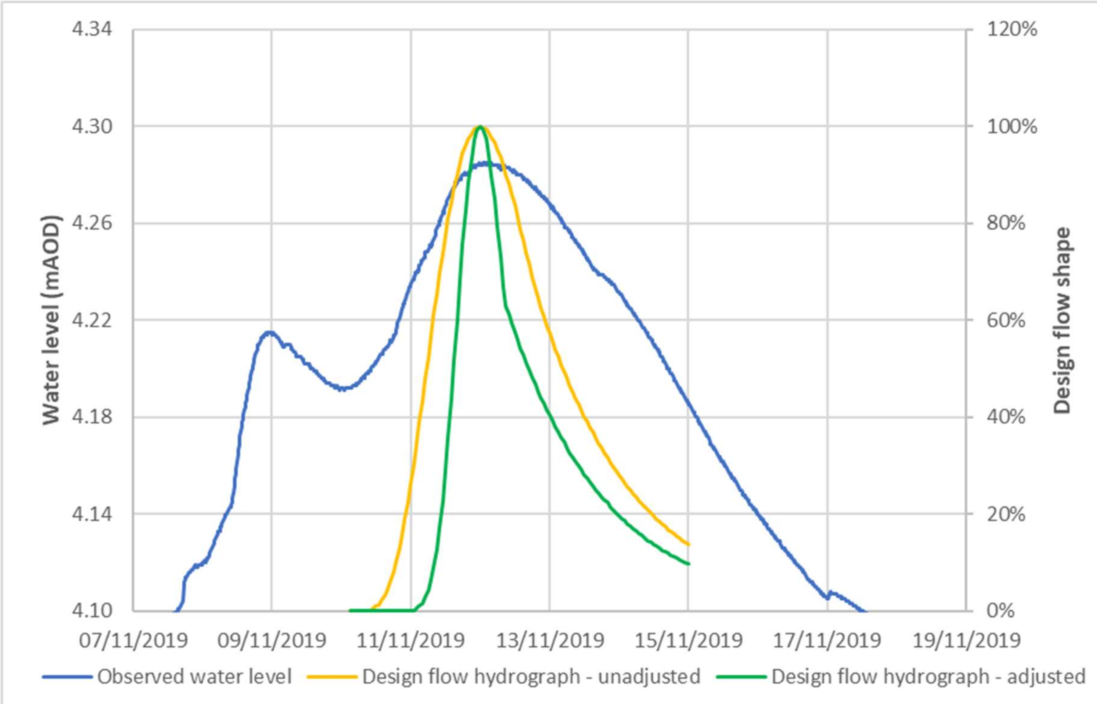
Appendix F: Recommended peak flows

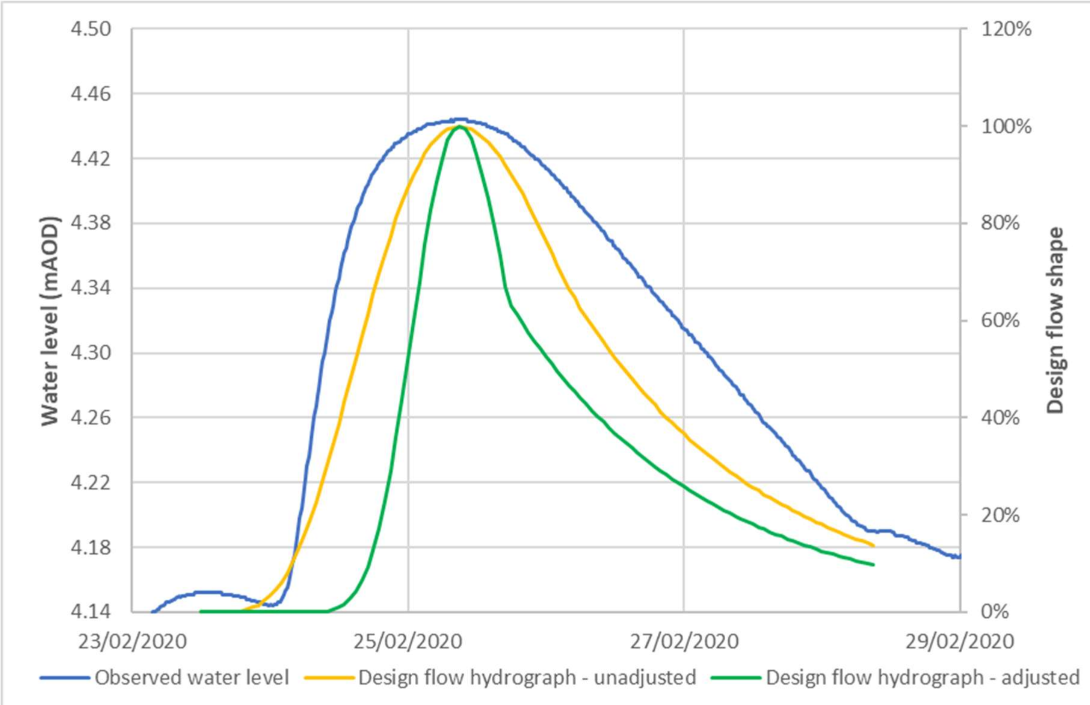
No.	Sub-catchment	Area (km^2)	Study	Peak flow (m^3/s)							
				50%	20%	10%	5%	2%	1%	0.5%	0.1%
	Aghaboys watercourse (from west into Ballymascanlan estuary)										
6	06_1078_3_RA	5.40	Current	1.70	2.38	2.89	3.48	4.40	5.23	6.23	9.34
	06_1078_3_RA	5.50	CFRAM	1.97	2.86	3.54	4.30	5.48	6.54	7.78	11.57
	Ballynahattin watercourse (from west into Ballymascanlan estuary)										
16	06_1081_D_RA	13.08	Current	2.41	3.37	4.07	4.84	6.02	7.09	8.29	11.88
	06_1081_D_RA	10.43	CFRAM	2.34	3.41	4.24	5.15	6.59	7.89	9.43	14.17
	Kilcurry River (note: includes significant catchment area in Northern Ireland)										
17	06_991_2_RA	115.77	Current	21.47	29.63	35.65	42.52	53.04	62.49	73.66	107.80
	06_991_2_RA	117.17	CFRAM	17.03	22.26	25.88	29.62	35.02	39.55	44.56	58.38
	Castletown River / Creggan River (note: includes significant catchment area in Northern Ireland)										
18	06_600_2_RA	100.79	Current	15.64	21.43	25.81	30.66	38.01	44.74	52.56	76.02
	06_600_2_RA	103.28	CFRAM	13.28	17.14	19.77	22.45	26.28	29.45	32.91	42.30
41	06_DDalk_D_RARPS	235.28	Current	33.03	45.26	54.51	64.75	80.27	94.48	110.99	160.54
	06_DDalk_D_RARPS	239.30	CFRAM	28.46	34.94	39.24	43.62	49.74	54.78	60.18	74.61
	Stranacarry watercourse (from north into Castletown River)										
45	06_1055_2_RA	1.07	Current	0.25	0.34	0.41	0.48	0.60	0.71	0.83	1.21
	06_1055_2_RA	2.31	CFRAM	0.56	0.81	1.00	1.21	1.54	1.84	2.19	3.26
	Castletown tributary (from south into Castletown River)										
53	06_1087_13_RA	7.42	Current	1.35	1.85	2.23	2.65	3.33	3.94	4.66	6.89
	06_1087_13_RA	7.43	CFRAM	1.51	2.20	2.72	3.30	4.21	5.02	5.98	8.89
	Acarreagh watercourse (from south into Castletown River)										
62	06_1089_4_RA	2.59	Current	0.99	1.39	1.69	2.03	2.55	3.03	3.59	5.32

No.	Sub-catchment	Area (km^2)	Study	Peak flow (m^3/s)							
				50%	20%	10%	5%	2%	1%	0.5%	0.1%
	06_1089_4_RA	2.70	CFRAM	1.10	1.59	1.97	2.39	3.05	3.64	4.33	6.44
	Donaghmore watercourse (from north into Blackwater River)										
71	06_242_4_RPS	2.50	Current	0.56	0.77	0.93	1.10	1.38	1.63	1.91	2.80
	06_242_4_RPS	2.78	CFRAM	0.72	1.05	1.30	1.58	2.01	2.40	2.85	4.24
	Dundalk / Blackwater River										
74	06_913_4_RPS	9.51	Current	1.13	1.52	1.82	2.14	2.64	3.08	3.60	5.16
	06_913_4_RPS	9.38	CFRAM	1.50	2.18	2.70	3.27	4.17	4.97	5.92	8.80
	Fairhill River (from south into Blackwater River)										
104	06_147_4_RPS_D	3.67	Current	0.62	0.83	0.99	1.17	1.44	1.68	1.96	2.81
	06_147_4_RPS_D	2.15	CFRAM	0.42	0.61	0.75	0.91	1.16	1.39	1.65	2.46
	Priorland watercourse (from south into Blackwater River)										
117	06_918_1	0.60	Current	0.25	0.33	0.40	0.47	0.58	0.68	0.79	1.13
	06_918_1	0.53	CFRAM	0.11	0.17	0.21	0.25	0.32	0.38	0.45	0.67
	Ramparts / Marshes Lower watercourse (branch to north from Blackwater River)										
129	06_318_D	0.83	Current	0.33	0.44	0.53	0.63	0.77	0.90	1.05	1.50
	06_318_D	0.96	CFRAM	0.43	0.62	0.77	0.93	1.19	1.42	1.69	2.51
	Green Gates watercourse (into sea, south-west Blackrock)										
134	06_315_5_RA	2.85	Current	0.57	0.79	0.94	1.12	1.40	1.64	1.94	2.83
	06_315_5_RA	2.79	CFRAM	0.43	0.62	0.77	0.93	1.19	1.42	1.69	2.51
	Blackrock watercourse (into sea, Blackrock)										
139	06_061A_D	2.52	Current	0.72	0.99	1.19	1.41	1.76	2.07	2.44	3.56
	06_061A_D	3.21	CFRAM	0.69	1.01	1.24	1.51	1.92	2.30	2.73	4.07

Appendix G: Design hydrograph shape check




Water level (mAOD)
4.34
4.30
4.26
4.22
4.18
4.14
4.10
Design flow shape
120%
100%
80%
60%
40%
20%
0%
07/11/2019
09/11/2019
11/11/2019
13/11/2019
15/11/2019
17/11/2019
19/11/2019
Observed water level
Design flow hydrograph - unadjusted
Design flow hydrograph - adjusted


4.50
4.46
4.42
4.38
4.34
4.30
4.26
4.22
4.18
4.14
Water level (mAOD)
120%
100%
80%
60%
40%
20%
0%
Design flow shape
23/02/2020
25/02/2020
27/02/2020
29/02/2020
Observed water level
Design flow hydrograph - unadjusted
Design flow hydrograph - adjusted

Appendix H: Extreme Water Level Analysis of Dundalk Port and Giles Quay Gauges

Binnies UK Ltd.
Nicholas O'Dwyer Ltd.

TECHNICAL NOTE

To:	Louth County Council - Flood Relief Projects Office	Date:	27th July 2021 20th June 2022
From:	Binnies UK Ltd.	Project No.:	123160
Subject:	Extreme Water Level Analysis of Dundalk Port and Giles Quay Gauges (Dundalk Hydrology Report - Appendix H)		

1. Purpose

This note provides a description of the assessment of extreme water levels performed on recorded gauge data at Dundalk Port and Giles Quay. It looks to complement additional local detail to the work undertaken in the RPS study (Irish Coastal Wave and Water Level Modelling Study 2018 Phase 1 Extreme Water Levels), which estimated extreme water levels in the Bay based on a regional surge model, prepared in 2018. The models used in the ICWWS 2018 were calibrated, when developed as part of the Irish Coastal Protection Strategy Study (ICPSS). Checks against local data and extremes in Dundalk were not undertaken. This assessment was recommended to ensure that these additional locally available data would be reviewed to consider any local effects, that may need to be considered for the design extreme water levels.

This note will be appended to the Dundalk Hydrology Report (123160-BUK-ZZ-00-RP-HY-00004).

2. Method

The approach to this assessment of the extremes comprises two stages. The first is to check the measured data records, assessing them for validity, removing erroneous data and then identifying the recorded high-water levels. The second stage then statistically fits the data to an extreme value distribution. The analysis has been entirely based on recorded total water levels. This contrasts with the approach undertaken by ICWWS 2018 which separated the astronomic or surge components and recombined to estimate the extremes, this updated the work undertaken in the Irish Coastal Protection Strategy Study in 2013.

2.1 Data cleaning and selection of high-water levels

The tide gauge data was downloaded from the OPW website (waterlevel.ie[1]) in CSV format and imported into excel. Water levels were plotted against time to visually check the data for their characteristic shapes. These patterns are associated with the regular rise and fall of the tide in a sinusoidal form each day and the regular variations associated with astronomic effects such spring and neap tides.

There are two approaches to selecting the high levels, either "peaks over a threshold" or a "block maximum" also referred to as annual maxima, taking the highest value in a set time period. For the analysis presented here we used the peaks over a threshold method to ensure seasonal effects would not impair the peak selection. This approach also allows the selection of multiple peaks in a short period of time for example peaks from consecutive winter storms, which might be missed using the block maxima method. The resulting peaks over threshold were further filtered to ensure only a single peak was taken from any one high tide as a neighbouring level may also be above the threshold and is not an independent event.

[1] https://waterlevel.ie/hydro-data/stations/06061/station.html?1646132393

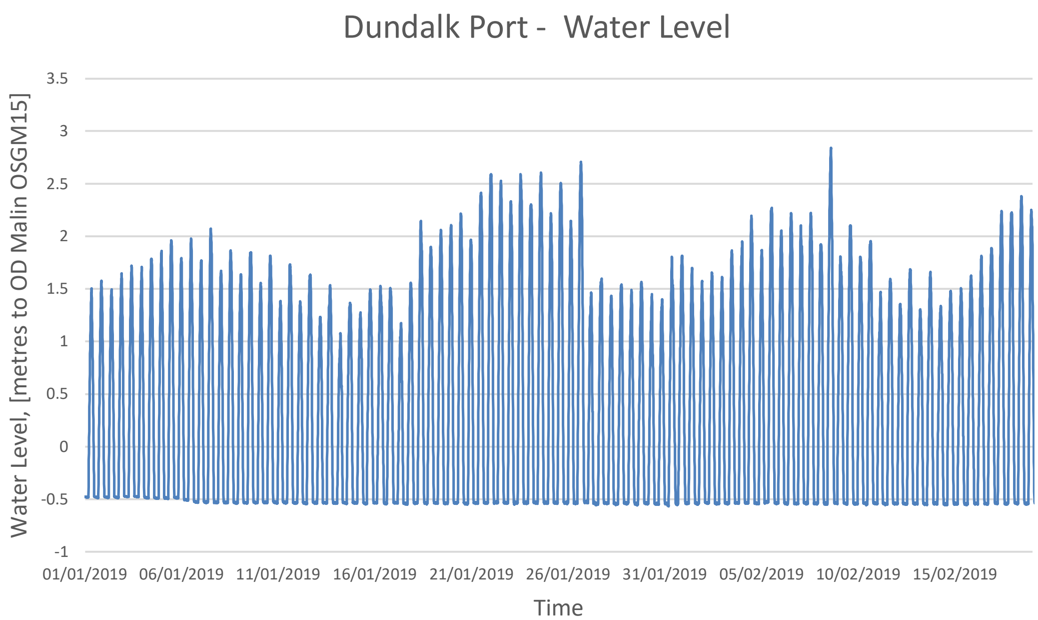


Figure 1: Dundalk Port water level, spring, and neap tides

2.2 Extreme Value Analysis

There are a variety of statistical distributions that simulate the character of extreme events. These are difficult to fit due to their rarity and seeking to predict events that have not been observed. Due to the limited data, there is some sensitivity in fitting the records and to making the choice of the appropriate distribution. Essentially it is the extreme tail of the distribution that needs to be fitted to the high levels, the ordinary events are removed as they can easily skew the shape of the tail. Common distributions include normal distribution and Weibull distribution. More specialist distributions include Generalised Extreme Value distribution and Generalised Pareto Distribution, both of which include shape parameters to adjust the fit to the data. These shape parameters are fitted using a method such as least squares or maximum likelihood estimates and have a corresponding goodness of fit and error bounds. Error bounds are useful to inform how statistically accurate the estimates are. Due to the method of selecting the high-water levels using the Peaks over Threshold the results were fitted to the Generalised Pareto Distribution.

3. Dundalk Port

3.1 Data cleaning

As described in section 2.1 the peaks over a threshold, in this case peaks over 2.8m, were identified in the tide gauge data records and cleaned to create the identified peaks as per table 5 appended. The cleaning process ensured that the peaks were true and not an erroneous recording and that adjacent water level records to the peak were also removed.

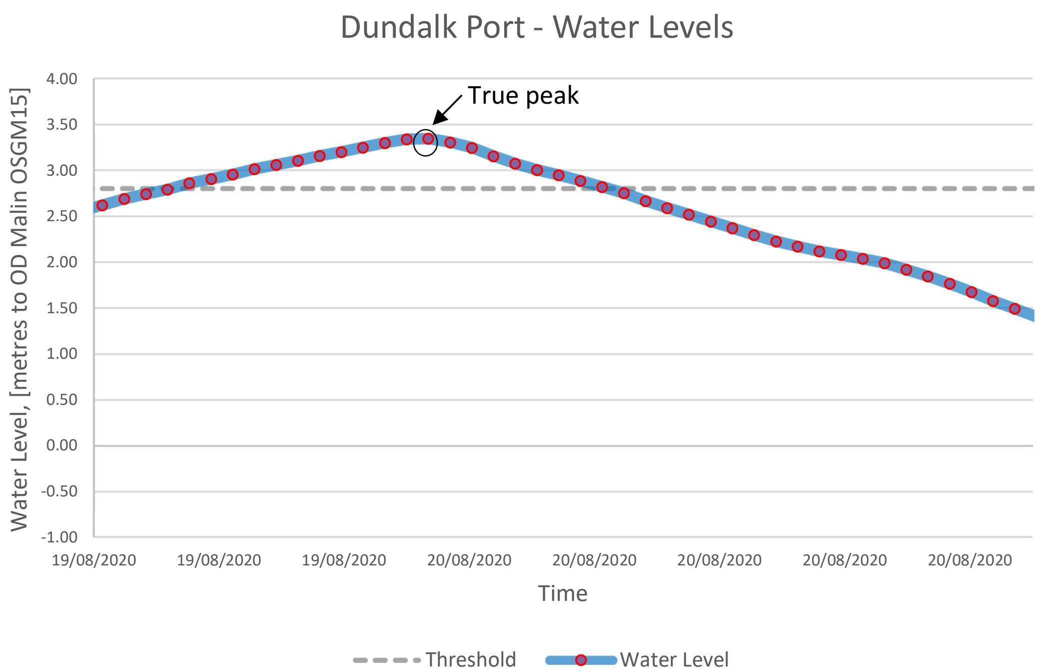


Figure 2: Selected peak, with highlighted true peak. Threshold of 2.80 mOD Malin (OSGM15)

The current gauge datum as listed for station 06061 Dundalk Port on waterlevel.ie, is Malin Head OSGM15 (https://waterlevel.ie/hydro-data/stations/06061/station.html?1646132393).

3.2 Extreme Value Assessment

The extreme value analysis was conducted using the statistics software R-Stats. The fitting of the distributions was undertaken using an algorithm developed by Emma Eastoe at the University of Lancaster in 2009 for the UK Environment Agency extreme boundary conditions project[2].

The threshold used for the assessment was set as 2.8 mOD, the same value used to identify the extremes. A choice must be made at this point on whether to increase this level and exclude more of the ordinary events. Figure 3 shows the measured water level plotted against the statistically defined level (using Generalised Pareto Distribution). The closer the data plots to the 1:1 line (black) the better the fit. In this case the majority of the records agree fairly consistently with the model. If there was a bias in this fit to the lower levels with the higher levels sitting dominantly on one side of the line, it would indicate the need to adjust the threshold. However, in this case, raising the threshold would not change the fit and only serve to exclude useful data. Therefore, the threshold of 2.8 mOD is deemed to be reasonable. This produced 53 no. measured high-water levels (see Appendix H1). The red dashed lines show the 95 percentile confidence intervals on the distribution fitting.

The peaks have been taken for extreme tide over the threshold, this does mean that during a meteorological storm event there may be several peaks identified over subsequent tides. Statistically these are considered to be independent events. There are different methods for the selection of the peaks, these vary by the type of statistical distributions used.

[2] Further details can be found in An Introduction to Statistical Modelling of Extreme Values Stuart Coles ISBN 978-1-85233-459-8

Figure 4 shows the measured and modelled probabilities for the water levels. This gives an indication of the goodness of fit of the distribution to the data and how symmetric or close to the line the data fits, this appears to be a reasonable fit. The red dashed lines show the 95 percentile confidence intervals.

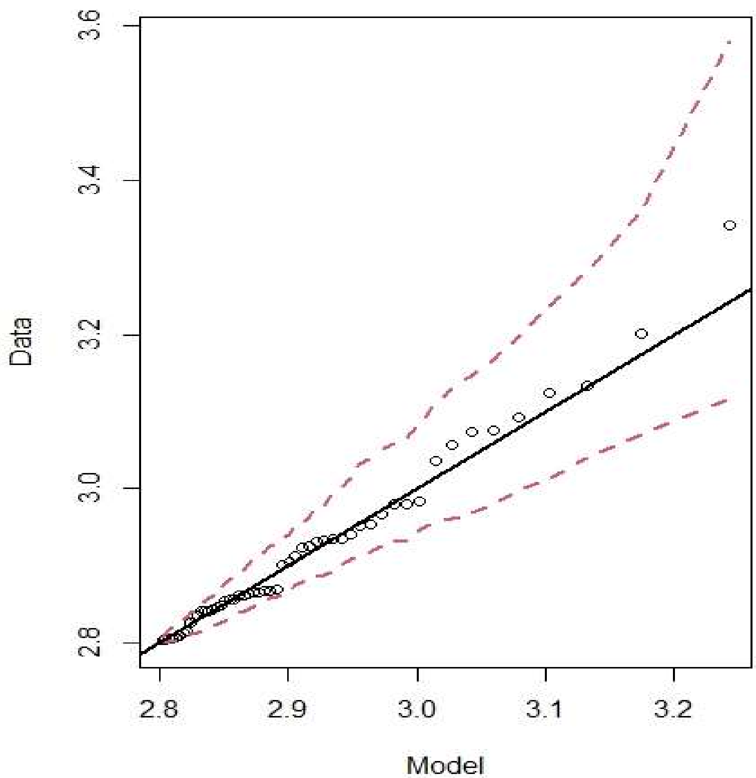


Figure 3: Quantile-quantile plot of water levels – x-axis showing the water level from the statistical distribution, y-axis showing the measured water level data.

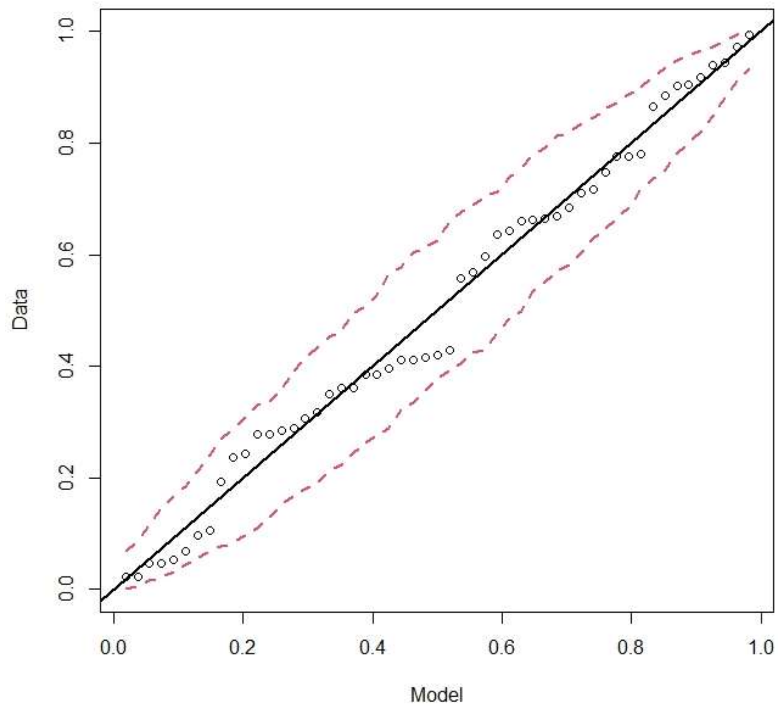


Figure 4: Probability-probability plot of water levels x-axis shows the probabilities form the statistical distribution and the y axis shows the probabilities from the measured data.

Estimation of return period based on the distribution fit (Appendix H2) is shown in Figure 4 and is dependent on the duration of the record identified. These are given in Table 1, which is based on the complete series starting in 1/11/2015 and finishing in 1/5/21 totalling 5.5 years with a slight reduction due to gaps in the record.

Table 1: Extreme value estimates based on gauge data at Dundalk Port

AEP	Return Period	MLE[3] Water level [metres to OD Malin OSGM15]	Standard error
100%	1	3.05	0.031
50%	2	3.12	0.043
20%	5	3.22	0.067
10%	10	3.28	0.092
5%	20	3.34	0.123
2%	50	3.42	0.172
1%	100	3.48	0.213
0.5% (target SoP)	200	3.53	0.257
0.1%	1000	3.65	0.372

The cleaned record duration is relatively short with 5.5 years, which reduces the confidence in predicting the higher extremes that are poorly represented in the measured data set. While this is progressively less accurate, a common rule of thumb in determining return periods is to use 2 to 3 times the length

[3] https://en.wikipedia.org/wiki/Maximum_likelihood_estimation

of the measured record. However, there is often no better data to inform the work and therefore whilst not perfect this is the best available data.

4. Giles Quay

4.1 Data cleaning

Giles Quay water levels generally show the expected pattern, fitting with the tidal cycles and spring neap cycles. Some data, however, is clearly erroneous, resulting in step-like pattern. Other errors and noise occur in the data, these manifest in the low tide periods, seemingly when the gauge dries out, which should give a consistent minimum. However, this is not the case as the minimum appears to be drifting and thus indicating an error at times with the recorded datum. There also appears to be a separate random noise overlying the whole record, small in magnitude compared to the tidal cycle but still significant enough to affect the quality of extremes, see Figure 5. It was not possible to determine the cause of the noise. This error didn't appear to fit with any possible environmental effect such as wave reflection or seaweed or sediment. It seemed more like a background interference with the recording rather than the measurement, therefore, it is difficult to comment more on this aspect.

The cleaning process of the data was attempted using several different approaches to understand what may cause the errors which included moving averages to remove regular cycles and see the underlying trends, plotting at differing temporal scales, visually searching through data graphs to see patterns in the records, such as the varying drying levels.

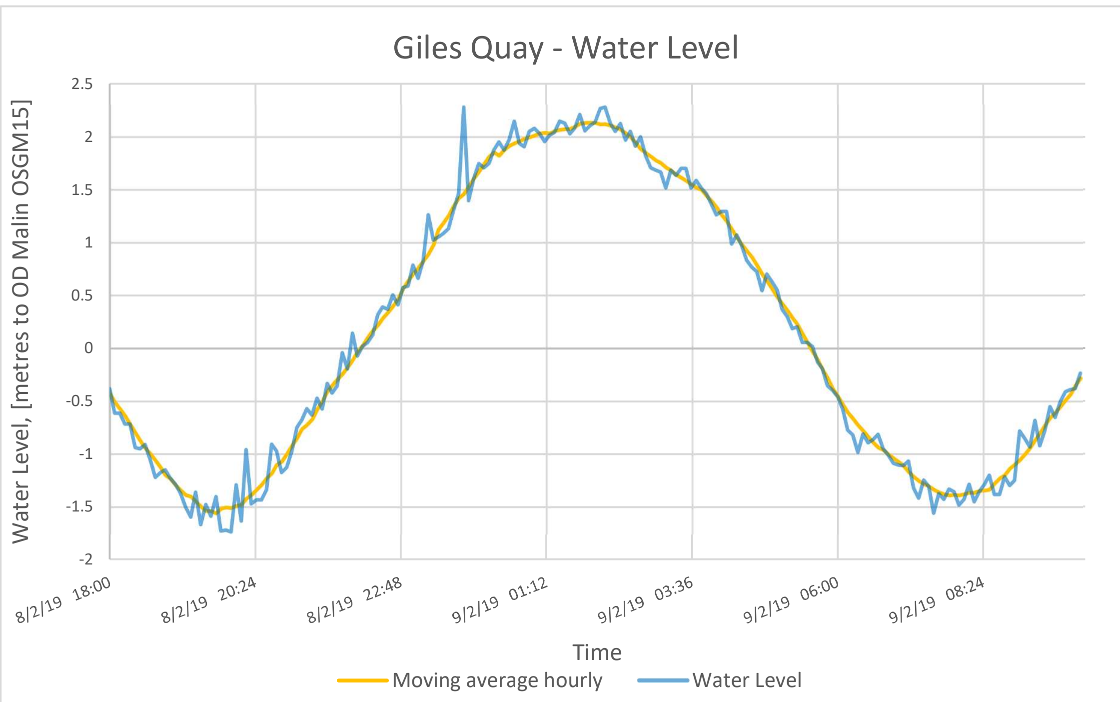


Figure 5: Example of Giles Quay water level data

4.2 Extreme Value Assessment

Due to the limited ability to separate the noise form the underlying record with confidence it was decided that any extreme value estimates from this record would not be of sufficient quality to inform any comparison to the ICWWS 2018 estimated extreme water levels. Since the Extreme Value Analysis (July 2021) the gauge at Giles' Quay is no longer operational and has been removed.

5. Findings

The previous work undertaken as part of the "Irish Coastal Wave and Water Level Modelling Study 2018: Phase 1 – Extreme Water Levels" provides estimates for water levels using a regional model. The output points of this are shown in Figure 6. These are presented in Table 2 and Table 3.

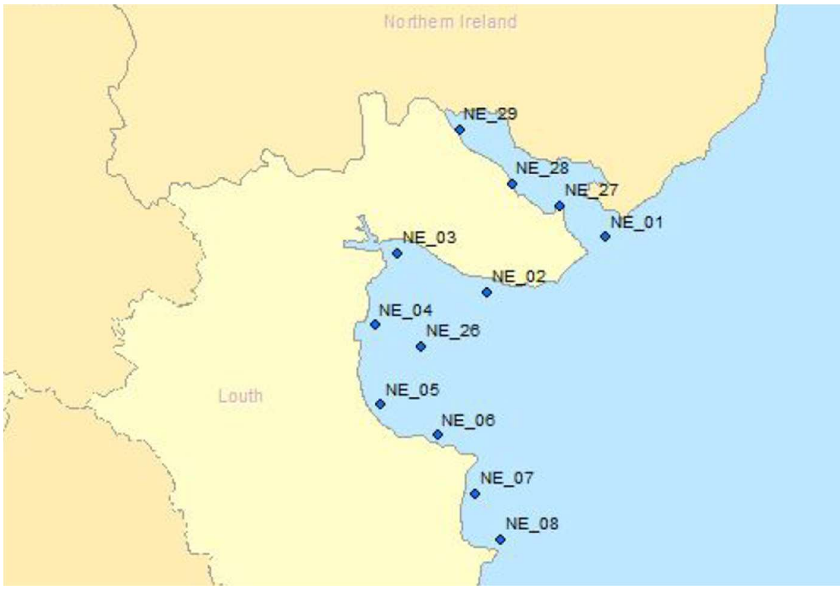


Figure 6: Location of North East (NE) coast extreme water level estimation points

Table 2: Estimated water levels for point NE_03, ICWWS Phase 1, 2018

	AEP	NE3
Water Level [metres to OD Malin (OSGM15) incl. seiche/setup	50%	3.28
	20%	3.36
	10%	3.43
	5%	3.49
	2%	3.57
	1%	3.64
	0.5% (target SoP)	3.70
	0.1%	3.85

Table 3 Estimated water levels for point NE_04, ICWWS Phase 1, 2018

	NE04 / AEP	NE4
Water Level [metres to OD Malin (OSGM15) incl. seiche/setup	50%	3.21
	20%	3.30
	10%	3.36
	5%	3.43
	2%	3.52
	1%	3.58
	0.5% (target SoP)	3.65
	0.1%	3.80

Of these two points (NE_03 and NE_04) the closest point to the tide gauge at Dundalk Port is NE_03. Comparing NE_03 to design levels estimated from our analysis of Dundalk Port gauge we found that the regional modelled water levels are higher, see Table 4. The tide gauge at Giles Quay was not deemed sufficiently reliable to compare extreme analysis levels with the regional model outputs.

Considering Dundalk Port gauge, the length of the record should provide reliable predictions up to twice the length of the record so up to 1 in 10-year return period. There is an average difference of ~0.16m between the extremes from the measured record and the ICWWS 2018, Phase 1 method.

Table 4: Comparison of estimated extreme water levels, metres to OD Malin (OSGM15)

AEP	NE3-ICWWS 2018	MLE Water level	Difference
50%	3.28	3.12	0.16
20%	3.36	3.22	0.14
10%	3.43	3.28	0.15
5%	3.49	3.34	0.15
2%	3.57	3.42	0.15
1%	3.64	3.48	0.16
0.5% (target SoP)	3.70	3.53	0.17
0.1%	3.85	3.65	0.20

Appendix H1 Dundalk Port - Identified independent peaks over threshold of 2.8m

Date/Time	Water level in mOD Malin OSGM15	OPW Quality rating
2016/02/11 12:50:00	2.843	!
2016/04/10 13:30:00	2.834	!
2016/05/08 12:05:00	2.803	*
2016/08/20 00:15:00	3.037	31
2016/10/15 22:20:00	2.941	31
2016/10/16 11:10:00	2.934	31
2016/10/16 23:05:00	3.056	31
2016/11/17 12:45:00	2.807	31
2016/12/13 22:55:00	2.814	31
2016/12/14 11:00:00	2.854	31
2016/12/15 11:30:00	2.904	31
2017/02/02 15:25:00	3.092	31
2017/03/31 13:25:00	2.866	31
2017/10/21 11:50:00	2.856	31
2017/11/07 00:25:00	2.806	31
2018/01/02 23:35:00	2.951	31
2018/01/04 12:55:00	2.867	31
2018/03/03 12:45:00	2.901	31
2018/03/04 13:10:00	2.933	31
2018/04/17 12:10:00	2.935	31
2018/09/11 00:00:00	2.856	31
2018/10/10 23:45:00	2.841	31
2018/10/12 00:45:00	2.98	31
2018/10/13 01:15:00	2.866	31
2018/11/06 22:30:00	2.848	31
2018/11/09 12:00:00	2.809	31
2018/11/10 00:45:00	2.863	31
2018/11/28 14:55:00	2.912	31
2019/02/08 13:50:00	2.841	31
2019/02/20 12:00:00	2.932	31
2019/02/21 12:15:00	2.861	31
2019/02/22 13:15:00	2.813	31
2019/09/28 23:00:00	2.842	31
2019/10/01 00:25:00	2.967	31
2019/11/26 11:10:00	2.983	31
2019/11/26 23:05:00	2.806	31
2020/01/13 13:20:00	3.133	31
2020/01/14 01:15:00	2.926	31
2020/02/09 11:25:00	3.124	31
2020/02/13 01:55:00	2.924	31
2020/02/15 16:55:00	2.827	31

2020/03/11 12:25:00	2.954	31
2020/03/12 01:20:00	2.846	31
2020/08/20 00:05:00	3.341	31
2020/08/21 01:45:00	3.201	31
2020/08/21 12:20:00	2.835	31
2020/10/20 01:35:00	3.075	31
2020/10/20 14:05:00	2.861	31
2020/11/01 23:20:00	2.87	31
2020/11/14 22:55:00	3.073	31
2020/12/13 21:50:00	2.868	*
2021/02/14 13:10:00	2.98	*
2021/04/28 11:45:00	2.803	*

The quality flag 31 indicates good data, the other flags highlight unchecked or suspect data. These have been visually checked in comparison to adjacent data.

Appendix H2 Return Period Calculation

Return periods calculation

```
> gpd.qq(PortPOT_EVA)
> gpd.pp(PortPOT_EVA)
> ReturnPeriods <- gpd.rtn.level(PortPOT_EVA,N=c(1, 2, 5, 10, 20, 50, 100, 200, 300, 1000),9)
> ReturnPeriods
$point.est
 [1] 3.058926 3.132665 3.224796 3.290658 3.353394 3.431778 3.487813 3.541188 3.571228 3.655550

$se
 [1] 0.03299071 0.04519855 0.07061228 0.09690592 0.12856757 0.17749615 0.21909450 0.26407334
0.29176971 0.37913537

> ReturnPeriods <- gpd.rtn.level(PortPOT_EVA,N=c(1, 2, 5, 10, 20, 50, 100, 200, 300, 1000),10)
> ReturnPeriods
$point.est
 [1] 3.070367 3.143562 3.235015 3.300392 3.362666 3.440472 3.496095 3.549076 3.578895 3.662596

$se
 [1] 0.03451915 0.04755727 0.07423428 0.10139052 0.13380575 0.18358194 0.22572529 0.27117733
0.29912040 0.38710198

> ReturnPeriods <- gpd.rtn.level(PortPOT_EVA,N=c(1, 2, 5, 10, 20, 50, 100, 200, 300, 1000),7)
> ReturnPeriods
$point.est
 [1] 3.031292 3.106343 3.200113 3.267148 3.331000 3.410779 3.467811 3.522135 3.552709 3.638533

$se
 [1] 0.02968984 0.04014158 0.06254370 0.08671420 0.11651291 0.16334559 0.20359627 0.24740419
0.27448953 0.36032645

> ReturnPeriods <- gpd.rtn.level(PortPOT_EVA,N=c(1, 2, 5, 10, 20, 50, 100, 200, 300, 1000),6)
> ReturnPeriods
$point.est
 [1] 3.014100 3.089966 3.184757 3.252521 3.317067 3.397714 3.455366 3.510281 3.541188 3.627945

$se
 [1] 0.02784201 0.03741438 0.05800134 0.08082693 0.10943629 0.15492988 0.19431957 0.23737898
0.26407334 0.34892998
```