

South West CFRAM Study

Final Hydrology Report
Unit of Management 21
June 2016

The Office of Public Works

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Executive Summary

The Office of Public Works is undertaking six catchment-based flood risk assessment and management (CFRAM) studies to identify and map areas with existing and potential future risk of flooding across Ireland. Mott MacDonald Ireland Ltd. has been appointed by the OPW to assess flood risk and develop flood risk management options in the South Western River Basin District. This hydrology report is one of a series of reports being produced as part of the South West Catchment Flood Risk Assessment and Management Study (SW CFRAM Study). This report details the assessment of the hydrological conditions across Unit of Management 21 (the Kenmare, Bantry and Dunmanus Bay catchments) which will form the inflows for the subsequent hydraulic modelling and mapping of the areas of flood risk.

A review and analysis of historical flood events, hydrometric data and hydrogeomorphological processes has highlighted flooding issues to urban areas in Kenmare and Bantry. Castletown Bearhaven and Durrus were also deemed to be at risk following the Flood Risk Review. The Flood Studies Update methodologies have been used to determine the existing design peak flows. Rainfall runoff methodologies have been used to derive characteristic flood hydrographs for eight specified flood probabilities across the sub-catchments. Corresponding coastal conditions have been developed for those areas at coastal flood risk. Calibration events were identified at Kenmare and Bantry where there was sufficient historical flood data.

Potential future catchment changes relevant to the Kenmare, Bantry and Dunmanus Bay catchments have been assessed including changes in urban development, land use and hydrology related to global climate change. Two future scenarios have been developed from this analysis, a Mid Range Future Scenario and High End Future Scenario, which have been used to develop potential future flows and extreme sea levels.

The resultant design flood hydrographs and coastal conditions will form the inflows for the hydraulic models. The knowledge of the hydrological processes and the historical flooding issues in the Kenmare, Bantry and Dunmanus Bay catchments established in this report will support the development of sustainable and appropriate flood risk management options in those areas at greatest flood risk.

1 Introduction

1.1 Context of the CFRAM Study

Flooding is a natural process that occurs throughout Ireland as a result of extreme rainfall, river flows, storm surges, waves, and high groundwater. Flooding can become an issue where the flood waters interact with people, property, farmland and protected habitats.

Flood risk in Ireland has historically been addressed through the use of structural or engineered solutions (arterial drainage schemes and / or flood relief schemes). In line with internationally changing perspectives, the Government adopted a new policy in 2004 that shifted the emphasis in addressing flood risk towards:

- A catchment-based context for managing risk;
- More pro-active flood hazard and risk assessment and management, with a view to avoiding or minimising future increases in risk, such as that which might arise from development in floodplains;
- Increased use of non-structural and flood impact mitigation measures.

A further influence on the management of flood risk in Ireland is the 'Floods' Directive [2007/60/EC]. The aim of this Directive is to reduce the adverse consequences of flooding on human health, the environment, cultural heritage and economic activity.

The Office of Public Works (OPW) is the lead agency in implementing flood management policy in Ireland. The OPW have commissioned a number of Catchment Flood Risk Assessment and Management Studies in order to assess and develop Flood Risk Management Plans (FRMP) to manage the existing flood risk and also the potential for significant increases in this risk due to climate change, ongoing development and other pressures that may arise in the future.

Mott MacDonald Ireland Ltd. has been appointed by the OPW to undertake the Catchment Flood Risk Assessment and Management Study (CFRAM Study) for the South Western River Basin District, henceforth referred to as the SW CFRAM Study. Under the project, Mott MacDonald will produce FRMPs which will set out recommendations for the management of existing flood risk in the Study Area, and also assess the potential for significant increases in this risk due to climate change, ongoing development and other pressures that may arise in the future.

1.2 SW CFRAM Study Process

The overarching aims of the SW CFRAM Study are as follows:

- Identify and map the existing and potential future flood hazard;
- Assess and map the existing and potential future flood risk; and,
- Identify viable structural and non-structural options and measures for the effective and sustainable management of flood risk in the South Western River Basin District.

In order to achieve the overarching aims, the study is being undertaken in the following stages:

- Data collection;
- Hydrological analysis;
- Hydraulic analysis;
- Development of flood maps;
- Strategic Environmental Assessment and a Habitats Directive Appropriate Assessment;
- Flood risk assessment of people, economy and environment;
- Development and assessment of flood risk mitigation options; and,
- Development of the Flood Risk Management Plan (FRMP).

The resultant FRMP will set out recommendations for the management of existing flood risk and the potential for significant increases in this risk due to climate change, ongoing development and other pressures that may arise in the future.

The South Western River Basin District is split into five Units of Management (UoM). These Units follow watershed catchment boundaries and do not relate to political boundaries. The Units are as follows;

- The Blackwater catchment (UoM18)
- The Lee / Cork Harbour Catchment (UoM19)
- The Bandon / Skibbereen Catchment (UoM20)
- The Dunmanus / Bantry / Kenmare Bay Catchment (UoM21)
- The Laune / Maine / Dingle Bay Catchment (UoM22)

1.3 Report Structure

This report aims to assess the hydrological conditions across the Dunmanus, Bantry and Kenmare Bay catchments and derive design peak flows, levels and hydrographs to be used in subsequent hydraulic modelling and mapping of key areas at risk.

Table 1.1 outlines the report structure and scope of work with a description of the key contents.

Table 1.1: Report Structure

Chapter	Key Contents of Chapter
1. Introduction	<ul style="list-style-type: none"> Context of the Study The SW CFRAM process and aims Scope of Work Flood Probabilities
2. Description of Study Area	<ul style="list-style-type: none"> Description of study area Description of hydrological characteristics of study area
3. Data Collection and Review	<ul style="list-style-type: none"> Overview of data used in the hydrological analysis Review and quality assessment of river level and flow data Review and quality assessment of rainfall data Review and quality assessment of coastal data
4. Review and Analysis of Historical Floods	<ul style="list-style-type: none"> Review of historical flood events Review of significant sources, pathways and receptors of flooding Estimation of flood probability for key historical events
5. Derivation of Design Flows and Levels	<ul style="list-style-type: none"> Definition of sub-catchments Derivation of the index flood, design peak flows and flow hydrographs Derivation of extreme sea levels and tidal curves
6. Hydrological Calibration, Sensitivity and Uncertainty	<ul style="list-style-type: none"> Review of historical data and selection of calibration events Derivation of calibration conditions Hydrological sensitivity and uncertainty in design hydrology
7. Summary of Design Flows	<ul style="list-style-type: none"> Principal outputs and findings of design hydrology Preliminary design flows and hydrographs for hydraulic modelling
8. Consideration for Hydrological and Hydraulic Model Integration	<ul style="list-style-type: none"> Full methodological approach to integrate hydrological outputs and hydraulic models
9. Hydrogeomorphology	<ul style="list-style-type: none"> Assessment of existing hydrogeomorphological processes Consideration of flood risk impacts
10. Joint Probability Analysis	<ul style="list-style-type: none"> Joint probability of fluvial events Joint probability of coastal events
11. Future Scenarios	<ul style="list-style-type: none"> Potential impacts of climate change to rainfall, river flows, sea level and land movement Potential catchment changes to land use and urbanisation Derivation of hydrology under future scenarios
12. Conclusions, Key Findings and Recommendations	<ul style="list-style-type: none"> Conclusions and key findings from the hydrological analysis and assessment Summary of Design Existing and Future Hydrology Recommendations for hydraulic modelling and the FRMP Recommendations for future improvements in the hydrological analysis

1.4 Flood Probabilities

The SW CFRAM Study refers to flood probabilities in terms of annual exceedance probability in preference to the use of “return periods” as used in previous reports. The probability or chance of a flood event occurring in any given year can be a useful tool to better understand the rarity of specific magnitude events for flood risk management. Due to popular descriptors of floods involving terms like the “1 in 100 year flood” there can be a public misunderstanding that a location will be safe from a repeat event of the same magnitude, extent and volume for the duration of the term (100 years in the above example). In reality, flood events of a similar or greater magnitude can occur again at any time.

Annual Exceedance Probability, henceforth referred to as AEP, is a term used throughout this report and the wider CFRAM studies to refer to the rarity of a flood event. The probability of a flood relates to the likelihood of an event of that size or larger occurring within any one year period. For example, a one in hundred year flood has a one chance in a hundred of occurring in any given year; 1:100 odds of occurring in any given year; or a 1% likelihood of occurring. This is described as a 1% annual exceedance probability (AEP) flood event.

Table 1.2 converts the ‘return periods’ to %AEP for key flood events as a reference to previous studies.

Table 1.2: Flood Probabilities

% Annual Exceedance Probability (%AEP)	Odds of a Flood Event in Any Given Year	Chance of a Flood Event in Any Given Year or Previous ‘Return Period’
50%	1:2	1 in 2
20%	1:5	1 in 5
10%	1:10	1 in 10
5%	1:20	1 in 20
2%	1:50	1 in 50
1%	1:100	1 in 100
0.5%	1:200	1 in 200
0.1%	1:1000	1 in 1000

The hydrological analysis uses a number of other acronyms and technical terminology which are defined in the glossary of this report.

2 Description of Study Area

2.1 Extent

The South Western River Basin District covers an area of approximately 11,160 km². The Study Area includes most of County Cork, large parts of Counties Kerry and Waterford along with small parts of the counties of Tipperary and Limerick. The Study Area contains over 1,800 km of coastline along the Atlantic Ocean and the Celtic Sea. There are five Units of Management within the South Western River Basin District, which are listed below:

- The Blackwater catchment (UoM18)
- The Lee / Cork Harbour Catchment (UoM19)
- The Bandon / Skibbereen Catchment (UoM20)
- The Dunmanus / Bantry / Kenmare Bay Catchment (UoM21)
- The Laune / Maine / Dingle Bay Catchment (UoM22)

This report covers the Dunmanus, Bantry and Kenmare Bay catchments in Unit of Management 21. It includes Four Mile Water, the River Mealagh, River Finnihy and a number of smaller tributaries and coastal catchments (Map 2.1). Unit of Management 21 contains four Areas for Further Assessment (AFAs) as listed in Table 2.1. There are no medium priority watercourses located downstream of the AFAs in UoM21.

Table 2.1: Areas for Further Assessment

Name	Unique ID	Fluvial Flood Risk	Coastal Flood Risk	County	Easting	Northing	Total Contributing Area Draining to AFA (km ²)
Bantry	210307	Yes	Yes	Cork	099750	048500	62.2
Castletown Bearhaven/ Castletownbere	210308	No	Yes	Cork	068000	046000	N/A (coastal)
Durrus	210309	Yes	No	Cork	095000	042000	38.9
Kenmare	210312	Yes	Yes	Kerry	090750	070500	37.2

Please note that the local name “Castletownbere” is henceforth referred to as “Castletown Bearhaven”.

2.2 River Features

The Study considers 26km of High Priority Watercourse (HPW) in Bantry, Durrus and Kenmare. There are no HPW river features in Castletown Bearhaven as the town is not considered to be at fluvial flood risk.

Bantry AFA

There are three distinct hydrological catchments in the Bantry AFA. The Mealagh catchment to the north of Bantry Town is a reasonably large catchment covering 56km². The River Mealagh rises in the uplands of the Maughanaclea Hills (113240, 053930) and flows approximately 10km to the west before skirting around Drombrow Lough and entering the Bantry AFA. The Mealagh flows through the town of Dunmark before passing through Dunmark Bridge and down a steep section into the tidally affected harbour. There is a small ridge to the west of Drombrow Lough that forms a low barrier between the Lough and the

Mealagh. The water in the Lough flows into the Mealagh by a small channel that has its confluence to the northeast, away from the AFA. In the area near to the AFA, where there is a risk of flooding from tributaries to the Mealagh, there are the Raheen Beg, Doneelagh, Milleencolla East and Milleencolla West streams. Flooding from the Ardnageehy tributaries in the upper reaches of the Doneelagh Stream has been shown during the course of this study to flow to the west, into the River Bantry catchment and not, as expected to the northeast into Doneelagh Stream.

Bantry Town itself resides in the River Bantry catchment, the middle hydrologically distinct catchment in the Bantry AFA. The River Bantry is 2.2km long, rises near Ardnageehy More (101050, 048450) and flows along a fairly steep channel (a gradient of up to 1 in 30) before passing into a tidally influenced culvert under Chapel Street in Bantry. The culvert passes under Bantry town centre and terminates in an outfall into Bantry Harbour. The River Bantry is joined by five tributaries: the Knocknaveagh, Sheskin East, Carrignagat, Dromleigh and Reenrour tributaries. The four tributaries to the south of Bantry River, the Knocknaveagh, Sheskin East, Carrignagat and Dromleigh, are all narrow and steep channels with many engineered sections, including culverts, weirs, bridges and aqueducts. The Reenrour Stream is the largest tributary to Bantry River and it has a shallower gradient of approximately 1 in 50. The lowest reach of the Reenrour is culverted and has a junction with Bantry River in the long culvert beneath Bantry Town.

The third hydrological catchment in the Bantry AFA contains the Kilnaruane and Dromacoosane Rivers which flow through a predominantly rural area on the coast to the south of Bantry.

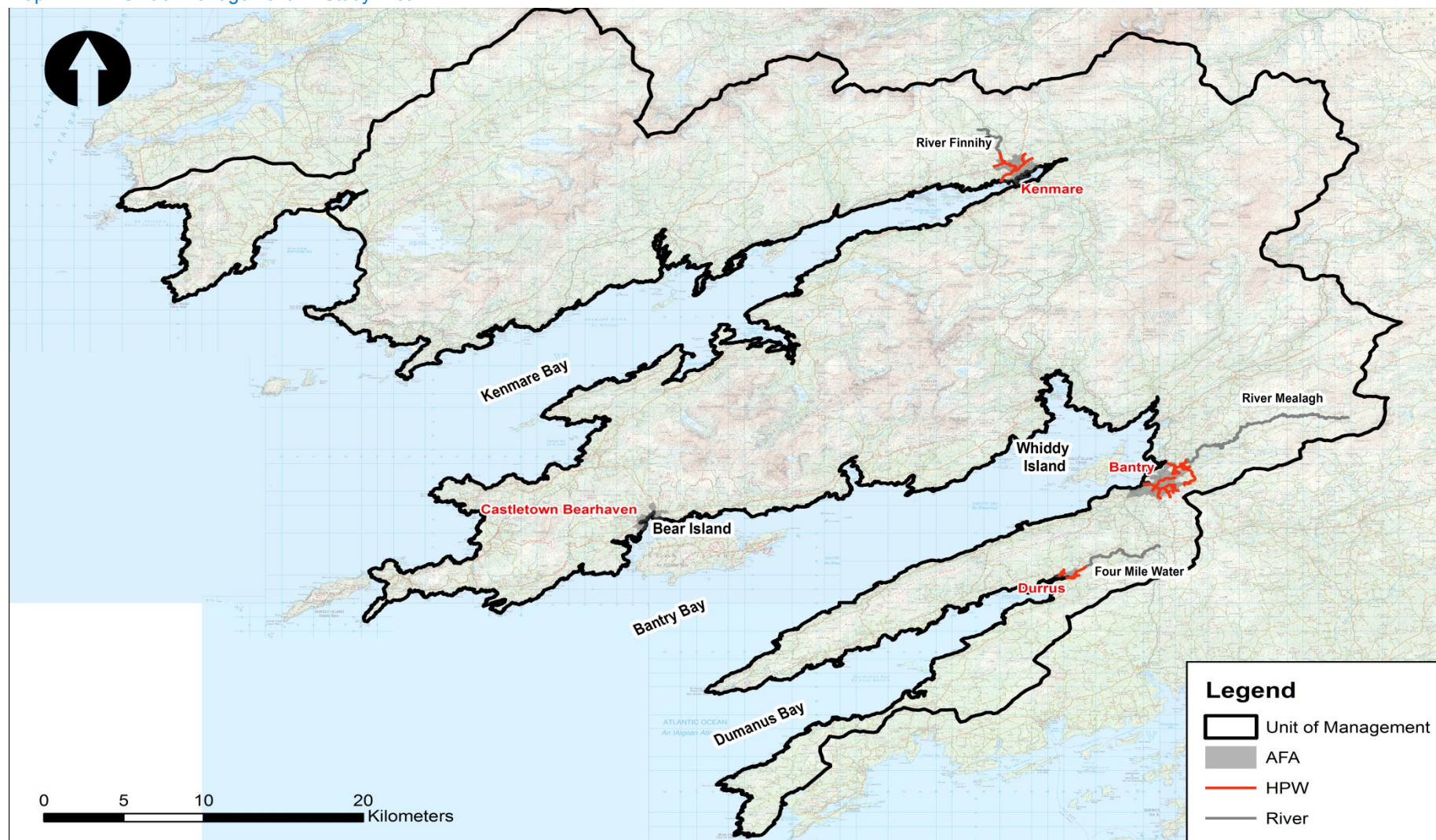
Durrus AFA

The Durrus River runs approximately 10km from its source in the Coomnagoragh Mountain range (0102200, 044770). At Ballycommene it is renamed Four Mile Water and continues as an open channel to Dunmanus Bay. The Four Mile Water River is tidally influenced as far upstream as the waterfall at (094730, 042040), 500m upstream of Carrigboy Bridge. The only tributary to Four Mile Water is the Ahanegavanagh Stream which flows southwards from the Coomkeen area (094480, 044850) to Dunmanus Bay, joining the Four Mile Water River in the tidally influenced reach downstream of Durrus town.

Kenmare AFA

The River Finnihy flows from Barfinnihy Lough at 084950,076590 down a very steep channel before being joined by a number of small tributaries, and flowing south-eastwards towards Kenmare. Within the town, the River Finnihy flows over a waterfall 300m upstream of Finnihy Banks estate, and is joined by the Lissaniska tributary immediately upstream of Finnihy Bridge. The river channel then meanders to the west, under Cromwell's Bridge and continues to outfall into Kenmare Bay/River at 090030,070190. The River Finnihy is tidally influenced as far as Cromwell's Bridge under typical tidal conditions but the tidal influence can extend beyond Finnihy Bridge under extreme high tides. The only other tributary considered in Kenmare is Gortamullen Stream which drains the bog land to the north of the N70. The Gortamullen Stream rises at 089802,071366 and then splits flow between the Claddanure catchment to the west and the Finnihy catchment to the east. The eastern branch flows down a stream reach (a gradient of 1 in 55) before entering a long culvert at the N70 (090208,071500) to join the River Finnihy immediately downstream of the waterfall.

Map 2.1: Unit of Management 21 Study Area



2.3 Coastal Features

The Kenmare, Bantry and Dunmanus Bays are orientated to the prevailing south-westerly storms. The shallow bathymetry in the bays funnels any incoming storm surges, increasing coastal risk and tide-locking of rivers entering the bays.

Kenmare AFA

Kenmare Bay known as Kenmare “River” is protected under the Natura 2000 act as a Special Area of Conservation for its shallow inlets and varying shoreline cliffs and dune areas. It narrows towards Kenmare into “The Sound” inland of the N71 crossing. The Sound is characterised by more estuarine features including a series of in-channel bars and tidal channel loops. The low tide channel width and shape is highly variable in this dynamic fluvial-tidal environment and varies from channel widths of 50m to 195m. There are also low lying areas at Reennagross which are covered by high spring tides.

Bantry Bay including Castletown Bearhaven and Bantry

Bantry Bay is a narrow tidal bay which extends from Dursey Island inland to Ballylicky and the Owvane River outfall. Bantry Bay has a number of islands which modify the tidal current and provide some protection to the mainland from incoming storm waves. These islands include Bear Island at Castletown Bearhaven and Whiddy Island at Bantry. Castletown Bearhaven Harbour is further protected from extreme waves by Dinish Island which is a low lying extension of the Castletown Bearhaven port with low sea walls protecting the quayside.

Dunmanus Bay including Durrus

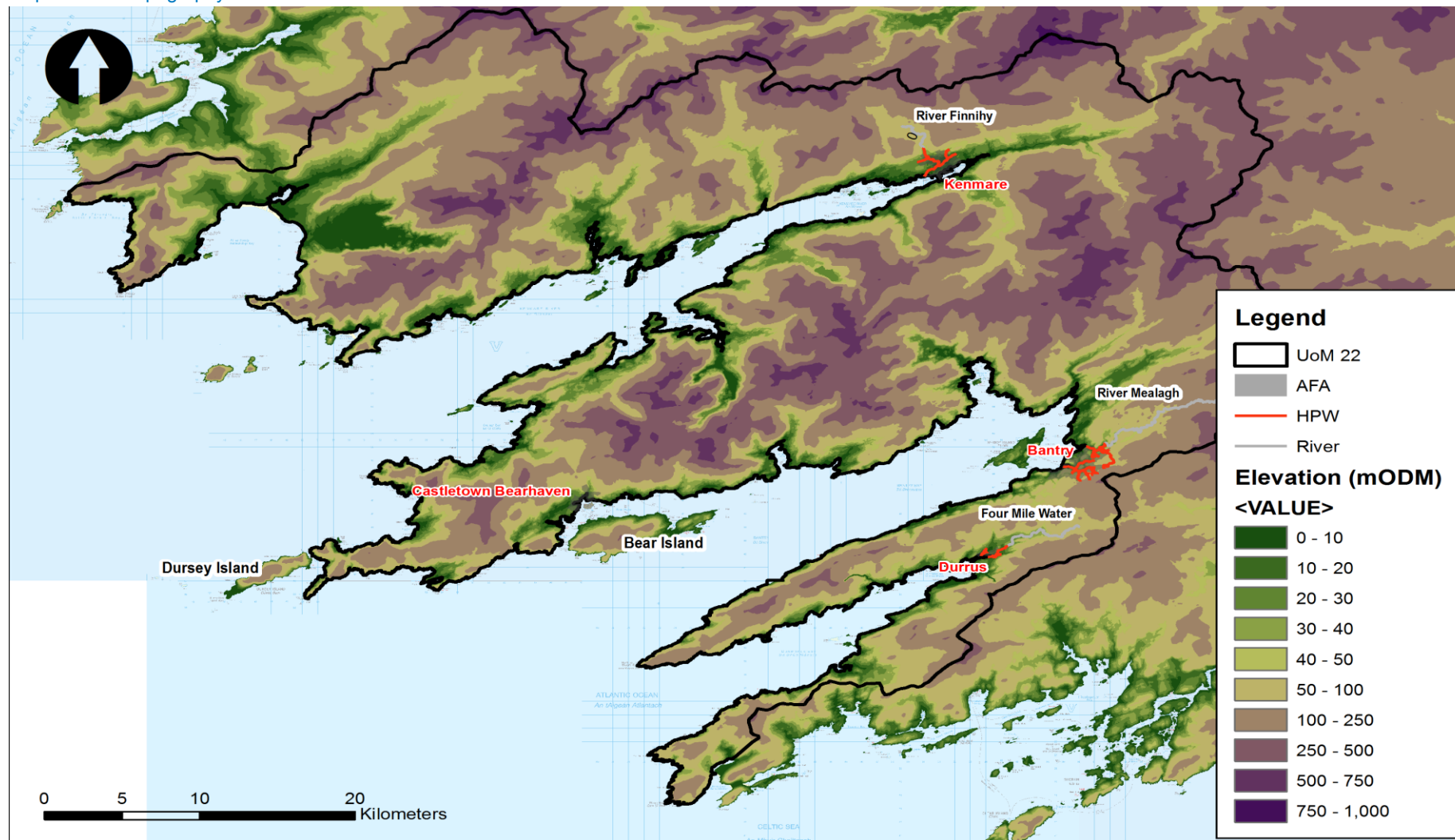
Dunmanus Bay is the smallest and narrowest of the three bays considered in UoM21. It extends from Mizen Head to Four Mile Water at Durrus. The Bay is characterised by steep cliffs along the headlands but develops more estuarine tidal bars at Four Mile Water outfall. Durrus AFA is actually located some distance from the tidal outfall of Four Mile Water, and well above the extreme coastal conditions. Therefore, flooding from coastal sources has not been assessed at Durrus for the CFRAM study.

2.4 Topography

Map 2.2 displays the variation in elevation and topography of UoM21. The AFAs considered are all located in small coastal catchments. The River Finnihy catchment ranges from <5mODM downstream of Bridge Street in Kenmare, up to 555mODM on Peakeen Mountain in its headwaters. The River Finnihy has a typical gradient of approximately 1 in 47 upstream of Kenmare, reducing to 1 in 160 through Kenmare. The floodplain is limited until the River Finnihy outfalls into Kenmare downstream of Bridge Street. However, the main town centre is located immediately adjacent to the river channel and at the bottom of a number of steep slopes.

Elevations in Castletown Bearhaven vary from 2mODM at the quayside up to 8m at West End (the watershed into Creevoige Stream catchment), and up to 30mODM at the outskirts of the town. The majority of the town is located on the hillside around the haven, or along the Aghakista River to the east. However, there is approximately 170,000m² below 5mODM along Main Street and the quayside which is vulnerable to coastal flooding.

Map 2.2: Topography



The Mealagh catchment ranges from < 5mODM at its tidal outfall, up to 500mODM at Nowen Hill in its headwaters. The floodplain is approximately 500m wide in the upper reaches until Inchiclogh where the gradient steepens and floodplain narrows towards Bantry. At the tidal outfall to the east of Bantry, the residential areas are located on ground above 5mODM, and significantly above the channel at Dunmark Bridge. In Bantry itself, elevations increase from 2mODM at the harbour to over 280mODM in the headwaters of Bantry Stream. The urban areas are located immediately adjacent to the steep Bantry Stream with 140,000m² around Wolfetone Square located below 5mODM. There are also low-lying areas vulnerable to coastal flooding around the Bantry House Estate in the Dromacoosane catchment where the stream outfalls under the N71 and sea wall.

The Four Mile Water/Durrus River catchment ranges from 0mODM at Dunmanus Bay up to 290mODM near Derryvahlla. In Durrus itself, the majority of the town lies within 2mODM to 10mODM with the lowest areas located at Sruth Mhuilleann estate.

2.5 Rainfall

The River Maine Standard Average Annual Rainfall (SAAR) typically increases with elevation. The highest values are associated with the highest relief near Kenmare (Map 2.3). Bantry and Durrus have slightly lower SAAR values below 2000mm due to the lower relief in this area.

Prolonged frontal Atlantic storm events dominate the rainfall events in UoM21, tracking from west to east. These heavy rainfall events combined with the relatively small steep catchments can cause overland flow and flooding issues. This is particularly acute in Bantry where it has overwhelmed the urban drainage network and caused landslides in the past.

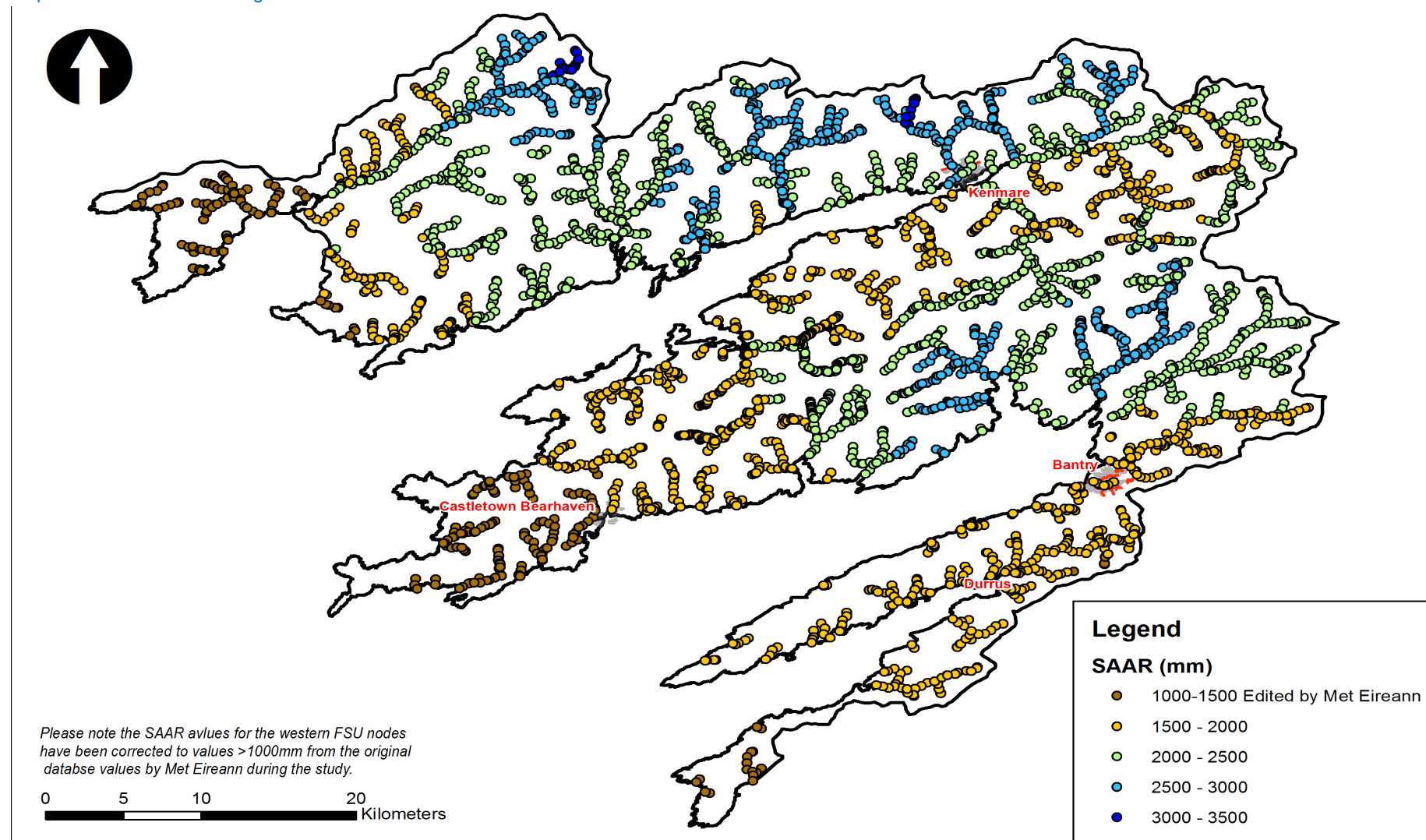
2.6 Geology

Map 2.4 provides the underlying geology of UoM21.

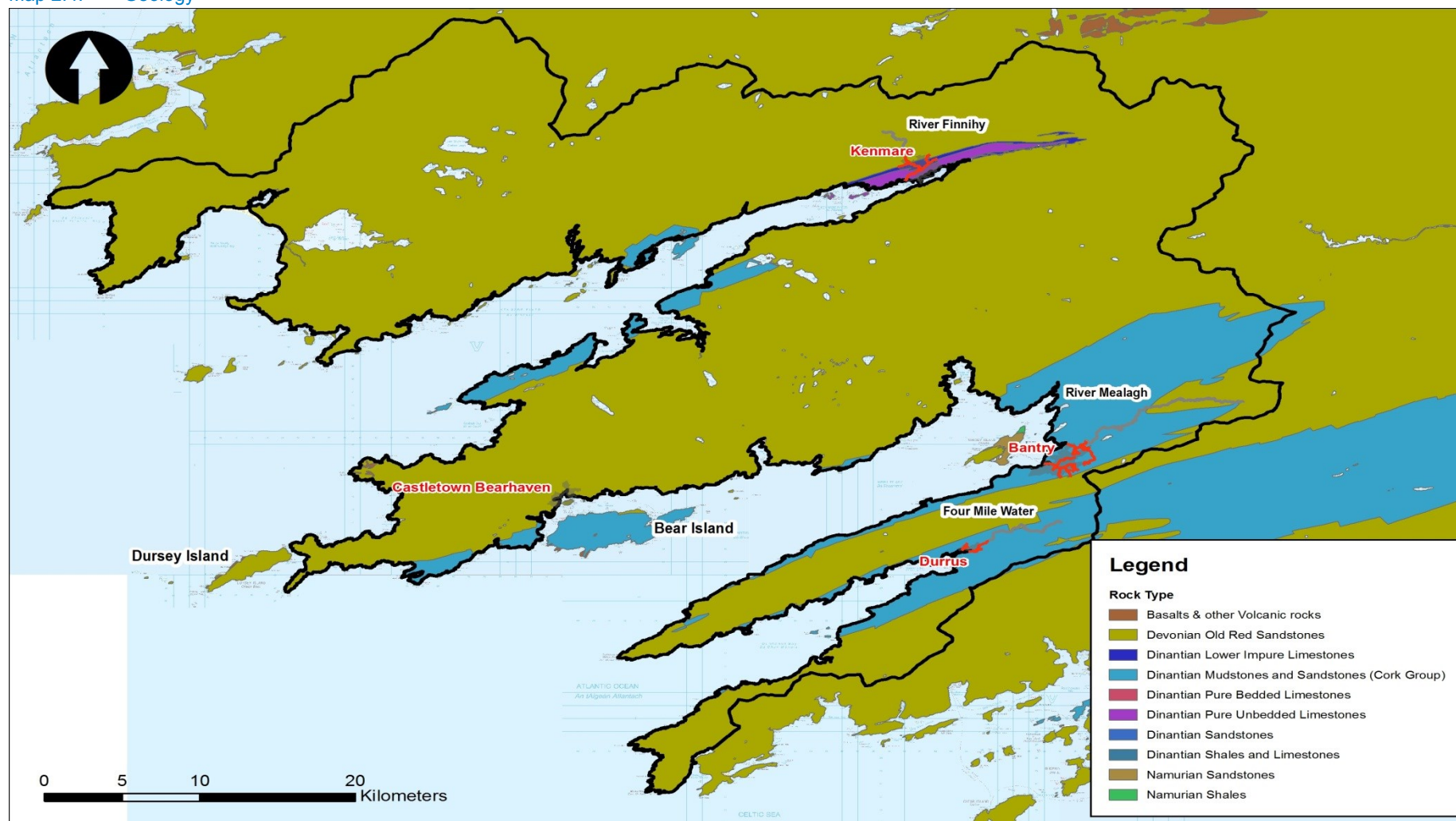
The promontories of UoM21 are formed of relatively resistant Devonian Old Red Sandstone, creating the steep relief of the coastal catchments along the headlands. Conversely, the bays are underlain by less resistant Dinatian limestones and mudstones, creating the shallower and larger catchments of the Roughty River, Owvane River, Mealagh River and Four Mile Water/Durrus River.

The majority of catchments in UoM21 are underlain by relatively impermeable geology of sandstone or mudstone. However, the Roughty River is underlain by relatively permeable limestone which can increase infiltration and therefore reduce peak flow when the ground is not saturated. When saturated, the permeable nature can prolong and exacerbate flooding issues by providing subterranean flow routes and/or groundwater flooding in addition to the river flooding. However, there were no records of such groundwater flooding issues in Kenmare. This is considered to be principally due to the steep topography.

Map 2.3: Standard Average Annual Rainfall



Map 2.4: Geology



2.7 Land Use

Land use in UoM21 is dominated by a mix of pastoral agriculture and peat land interspersed with forestry in the upper catchments. There is less than 10% forest cover in the majority of UoM21 catchments which is typically broad leaved and coniferous forest. The presence of peat and bog land in the upper catchment can provide additional storage when unsaturated or promote runoff when saturated. However, the hydrological response of these small coastal catchments is dominated by rapid runoff from the steep, sparsely-vegetated slopes. Additionally, localised surface water flooding can be exacerbated in the urban areas where roads and hard standing form flow routes down the steep slopes. However, the impact of urban land cover is relatively small on the wider routing of catchment flows.

The Killarney and Macgillicuddy Reeks Special Area of Conservation extends along the north of UoM21 and promotes tourism and recreational business land use in the region. The Kenmare River (Bay) Special Area of Conservation and Special Protection Areas offshore at Dursey Island also contribute to wildlife tourism land use, although these do not cover large expanses of land.

The major urban areas are located on the coast and/or adjacent to small rivers at Castletown Bearhaven (<1000 population), Kenmare (2200 population) and Bantry (3300 population). The smaller settlements such as Durrus, tend to be located in small coastal bays or at the tidal outfalls of rivers. Urban growth has been relatively low given the remote location and topography of UoM21, and the area is not identified as a focus for growth in any regional development plans.

3 Data Collection and Review

3.1 Data Register

A range of different data sources have been used to undertake the hydrological data analysis for Unit of Management 21. The use of local hydrometric data can greatly improve and validate flood flows for historic events and design flood events. The following sources of data have been reviewed in Unit of Management 21 (Table 3.1).

Table 3.1: Summary of Available Data

Type	Details	Owner	Period of Available Date
River Flows	15 minute interval data series with flow converted from water level EPA (operated by Kerry County Council)	The OPW	Various up to 2012
River Levels	15 minute interval data series EPA (operated by Kerry County Council)	The OPW	Various up to 2012
Rainfall Gauges	Daily rainfall values at gauges Hourly rainfall series at Valentia Observatory	Met Eireann	Various up to 2012
Extreme Sea Level	Irish Coastal Protection Strategy Study Total tide +surge design levels at 23 points	The OPW	Calculated for 2012
Wave Conditions	Water levels, wave heights and wave periods at Castletown Bearhaven and Kenmare Harbour.	The OPW	Calculated for 2013
Tidal Levels	15 minute tidal level at Castletown Bearhaven www.ioc-sealevelmonitoring.org	The Marine Institute Available via	Online records 2008 to 2013

A full data register can be found in Appendix A.

3.2 River Gauge Data

The locations of river gauges in the catchment with available water level and flow data are shown in Map 3.1. The existing hydrometric data has been assessed for the following common issues:

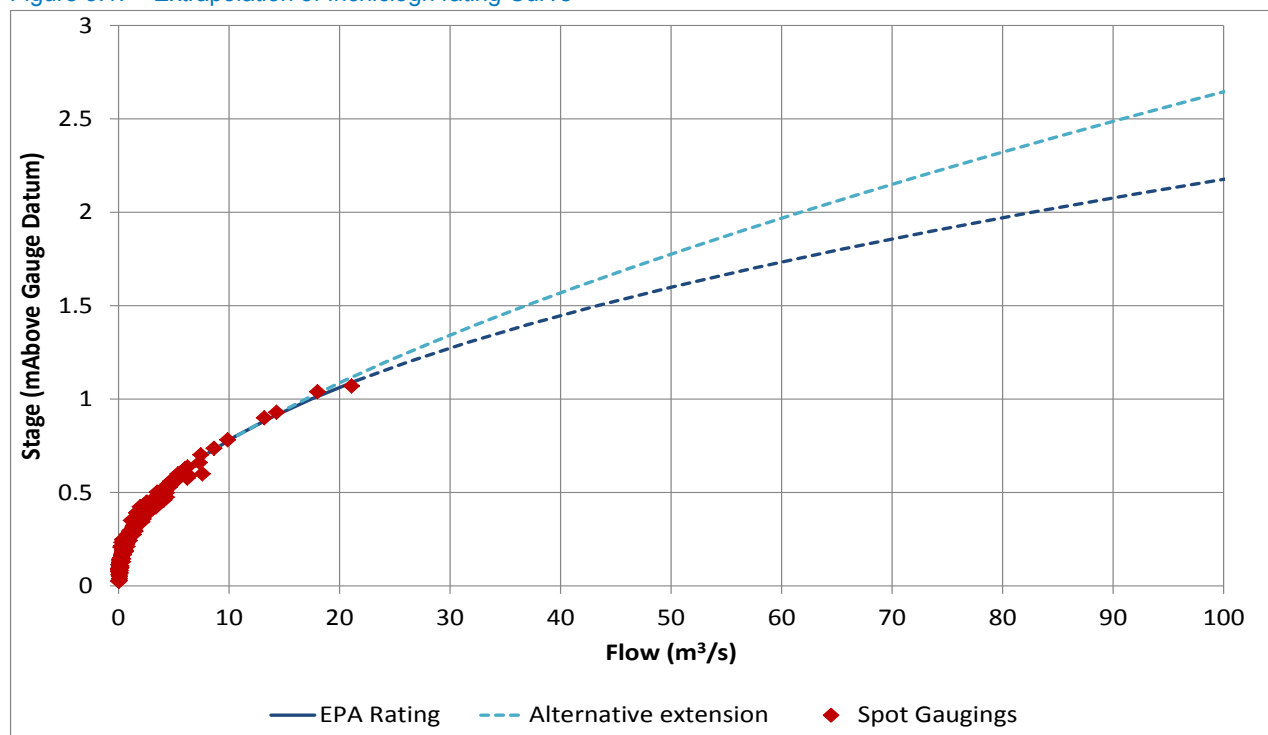
- Anomalous spikes or dips in water level and/or flow from the continuous data records;
- Capping of water level and/or flow, particularly for extreme events at fluvial gauges where extreme flows may be out-of-range;
- Trends in water level or flow over time that might be caused by systematic error of gauging equipment or erosion/sedimentation;
- Sudden shifts in level of the gauging datum;
- Comparison of AMAX flows and levels from digital gauged data with manually extracted AMAX series;
- Length of data record to enable hydrological analysis; and,
- Any significant data gaps.

Station 21004: There are over 35 years of flow and level records available at Inchiclogh gauge on the River Mealagh which flows into Bantry AFA. All but the highest flows were assessed to be in bank given that the gauge is located within a narrow valley with no floodplain and channel is 2-3 m below the road level. Analysis of the spot gaugings and rating curve indicated that the extrapolation of the rating curve is likely to be applicable up to the road level (bankfull) where the rating equation fits the spot gaugings well up to 1m stage (the limit of measure level). However, the extrapolation of the EPA rating (the dark blue line in Figure 3.1) leads to unusually high flow estimates above this level, compared with the catchment area of 45 km².

An alternative extrapolation was considered as part of the CFRAM study, the light blue line in Figure 3.1. This was derived from the existing spot gaugings but excluded the highest spot gaugings because these all came from a single event over 10 years ago which could be considered anomalous. The QMED flow would be reduced by 25% applying the alternative rating.

High flow gaugings were not available for this study to validate the extrapolation, but the low flow gaugings were deemed to be reliable. Therefore, the existing rating curve was used to inform QMED for the design scenarios as a conservative estimate. Given the uncertainty in high flows at this gauge, the pooled analysis was used to derive the flood growth curve. The alternative rating curve (the light blue line in Figure 3.1) was used to inform the sensitivity analysis on peak flow for the Mealagh catchment (see Chapter 6 of this report).

Figure 3.1: Extrapolation of Inchiclogh rating Curve



Stations 21002 and 21003: The Coomhola and Ballylickey gauges both provide longer term flow and level records, with reliable rating curves for out of bank flows. The AMAX series was checked against the extreme flows at Inchiclogh and found to be consistent. These gauges would be suitable for calibration, however it is not required as Inchiclogh is available.

The remaining gauges in UoM 21 are staff gauges with spot gaugings for low flows only, such as in Kenmare. These low flow spot gaugings are not suitable for the assessment of extreme flood events, but can be used to inform the calibration and undertake a reality check of the hydraulic model where flows are known. There are no hydrometric gauges in the Castletown Bearhaven and Durrus catchments. Appendix A contains a full list of the selected gauges and plots data quality for the hydrological analysis.

3.3 Rainfall Data

Available meteorological data from rain gauges and synoptic stations in and near to the catchments are shown in Map 3.2. The existing meteorological data has been assessed for the following common issues:

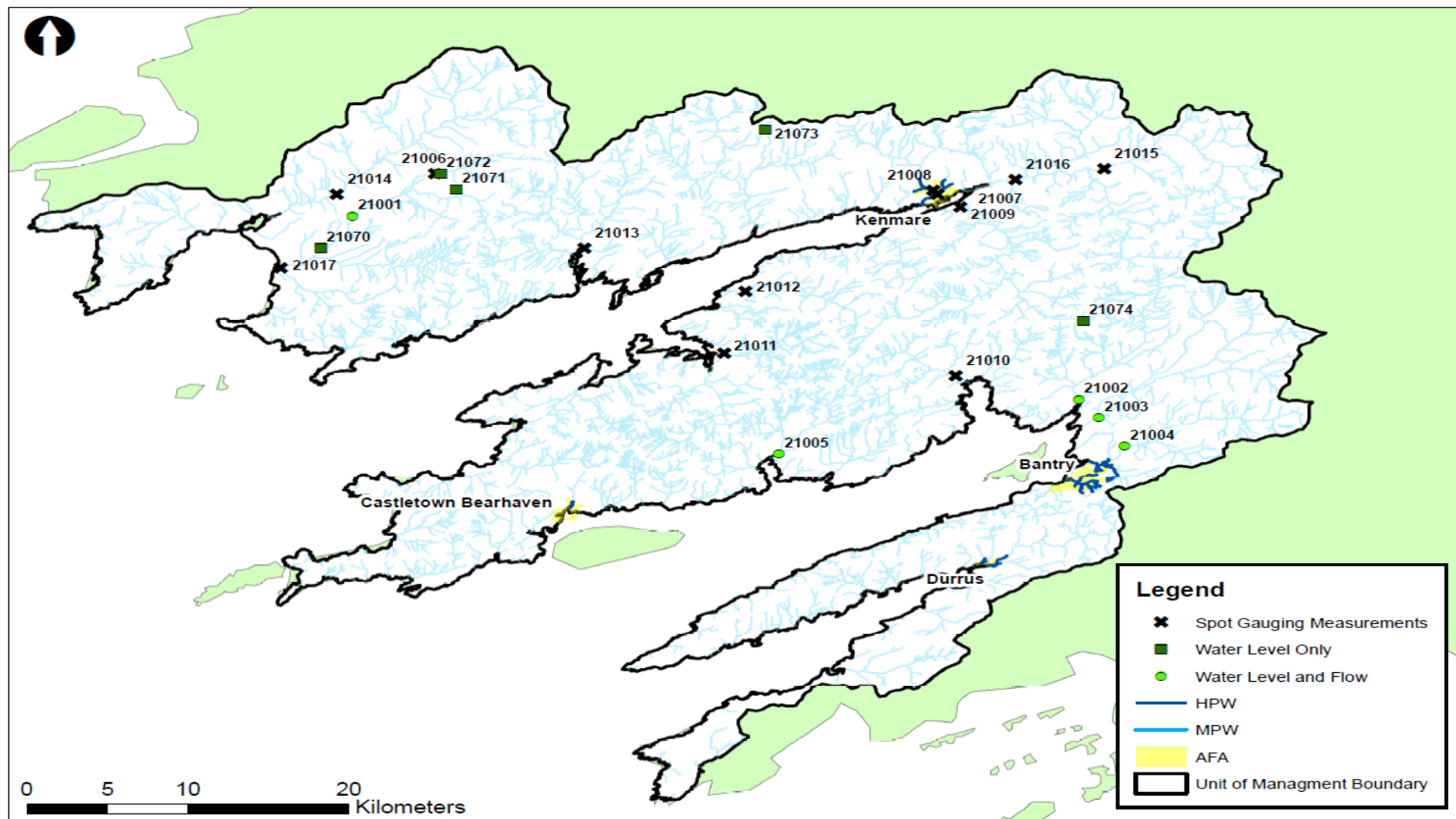
- Spatial distribution of intensity loggers and respective storage gauges (event based);
- Identification of gaps or erroneous data which have been cross-referenced with the Met Eireann climate stations to assess if significant events have been omitted;
- Identification of shifts in rainfall records using temporal and cumulative plots; and,
- Analysis of cumulative rainfall for key historic events.

Appendix A contains a list of the selected gauges for the preliminary hydrological analysis.

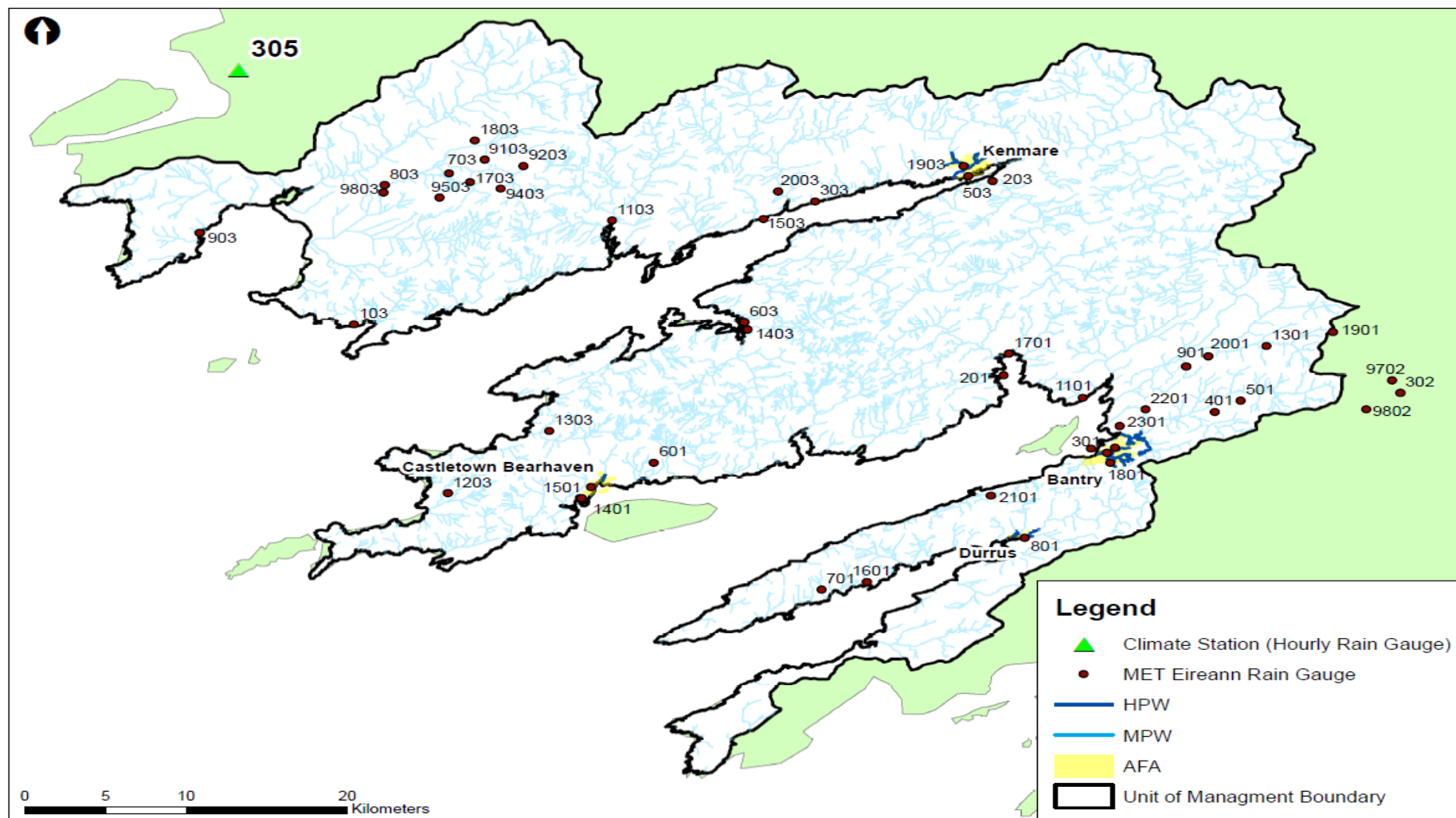
Detailed hourly rainfall is limited to the Valentia synoptic station (305), which is located outside the Unit of Management. However, this detailed hourly gauge can inform the rainfall profile in UoM21 where the storm event is deemed to be of similar magnitude and pattern. The long term rainfall record at Valentia was plotted against Bantry, Kenmare and Durrus daily rain gauges. The plots are provided in Appendix A. There is generally a weak positive trend with high rainfall events at Valentia correlating to more extreme events in the AFAs. However there is significant scatter, so the transfer of any rainfall profile from the Valentia Observatory has been considered on an event by event basis at the calibration stage.

The average annual rainfall in the west of the area is amongst the highest in Ireland. This limits the number of gauged catchments suitable for transfer of hydrometric parameters. Therefore, the rain gauges near Durrus, Bantry and Kenmare will be used to derive representative rainfall information for these AFAs. However, there is no rainfall data available after 1990 at Durrus (801), limiting the calibration of the rainfall-runoff models for more recent events. There was insufficient data available for the historic events to derive isohyets across UoM21. Chapter 4 discusses the available rainfall data and variation in recorded rainfall for key historic flood events. However, the majority of catchments assessed are less than 30 km² in area and hydrologically discrete. As such, the daily storage gauges are deemed to be representative, since it is unlikely the rainfall amount would significantly vary in these small coastal catchments.

Map 3.1: Available Hydrometric Data



Map 3.2: Available Meteorological Data



Radar analysis for these small mountainous and coastal catchments is not necessarily appropriate because the accuracy of radar will be limited by the rain-shadow effect in mountainous areas and the distance from the Shannon radar station. It was agreed with OPW that the daily storage gauges within the catchments would be representative of conditions on the ground. Therefore, radar data has not been considered further in the hydrological analysis.

3.4 Coastal Data

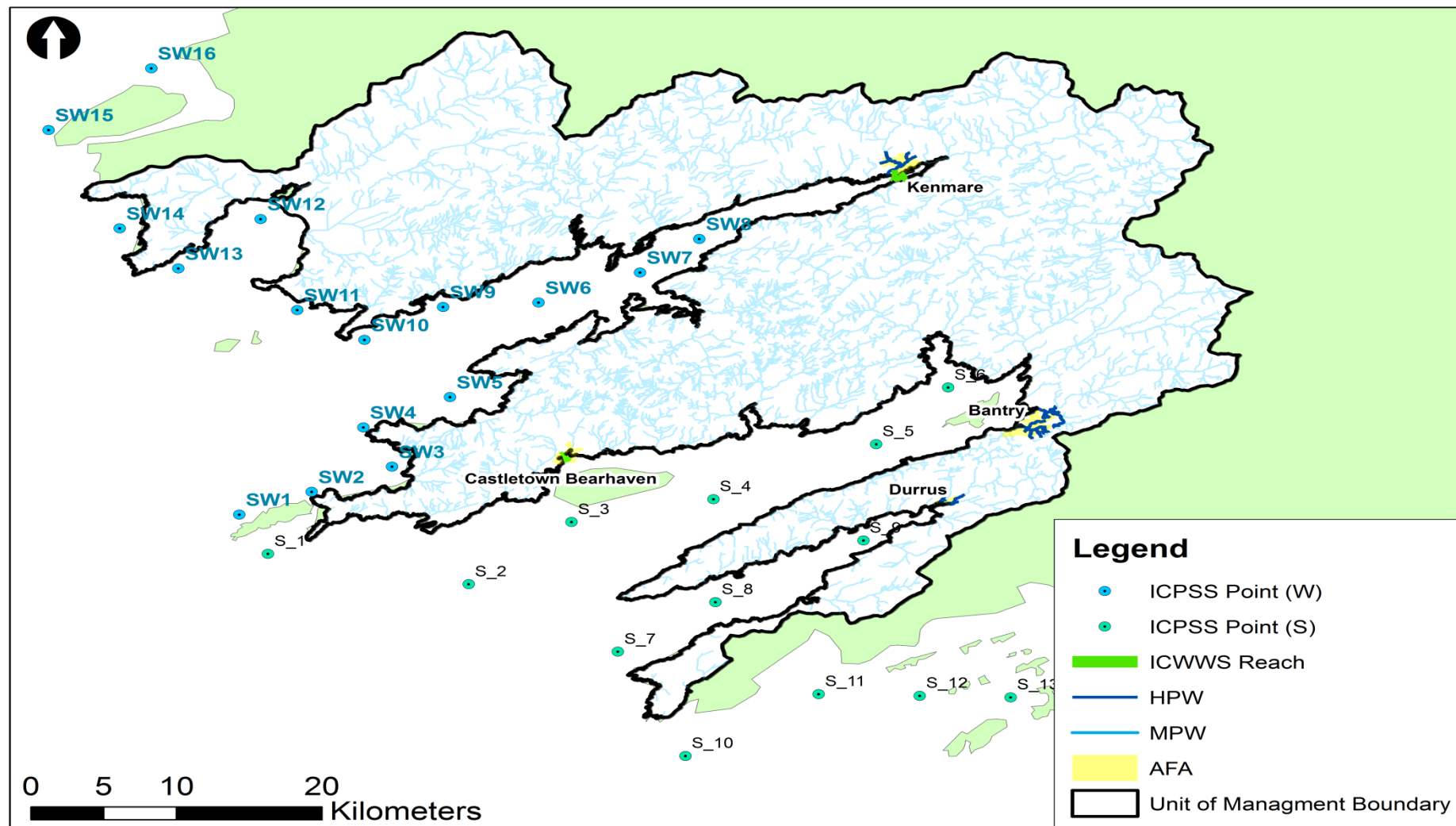
Map 3.3 shows the extreme coastal water level points and locations of other available coastal data.

The Irish Coastal Protection Strategy Study (ICPSS) data has been approved by OPW for use directly as the coastal boundaries for the South Western CFRAM models. The extreme sea levels will be used to define the magnitude of the tidal events along the coast for all AFAs. The extreme sea levels are calculated for near shore points, but do not necessarily consider the variation in water level all the way up the Bays.

The Irish Coastal Water Level and Wave Study (ICWWS) data provides more detailed information on extreme water levels and wave conditions at Castletown Bearhaven and Kenmare harbour. The ICWWS data provides extreme wave heights, wave periods and mean wave direction, with associated total tide plus surge levels at nearshore locations. Durrus and Bantry were not assessed to be vulnerable from extreme waves by the ICWWS study.

In addition to the calculated total tide plus surge levels from the above studies, recorded sea level data is also available online at the Marine Institute buoy at Castletown Bearhaven since 2008 (www.ioc-sealevelmonitoring.org). This tidal data has been used to inform recorded sea level for historic flood events, and compared with the predicted tide to derive storm surge elements for recent coastal events (see Chapter 6). The recorded sea levels were extracted for the specified events and found to be consistent with land elevations extracted from the LiDAR DTM. Data gaps of 2 to 3 days were found within the online dataset during 2008 and 2009, however these gaps did not affect the calibration events selected.

Map 3.3: Available Coastal Data



4 Historical Flood Review

4.1 Historical Flood Events

Table 4.1 summarises the source, extent and impact of flooding for the historic events identified where sufficient evidence was available. Historic flood events in UoM21 were identified from the floods database (www.floods.ie), previous reports, and drawing on interviews with Local Authority personnel and residents during the Flood Risk Review. There were limited details available for historic flood events, as detailed records of impacts for events more than 20 years ago were scarce.

Flood Event of 17th October 2012

A large storm surge of approximately 0.8m above the predicted tide resulted in flooding of Wolfetone Square in Bantry. The coastal walls have a number of openings where the rising tides flowed through to flood a number of properties along The Quay and Bridge Street. In other parts of Bantry, the low level walls were overtopped by waves. The low-lying topography of the town square led to the flooding of a number of properties on the south side of the square. No properties on the north side of the square were flooded but a private airfield located on the coast to the west of the town was affected by the coastal flooding.

Flood Event of 23rd October 2008

On the afternoon of the 23rd of October 2008 Kenmare Main Street was flooded to depths of over 0.5m. The event resulted in water coming out-of-bank along the Finnihy River and the Lissaniska Stream, affecting 37 and 11 commercial properties respectively. Market Square and a section of the N71 were also flooded. Tidal conditions, which are often a factor in flood related problems in Kenmare, were not a factor in this flood event as they were shown to be low upon inspection of the tide tables according to the post flood event report. The nearby Castletown Bearhaven gauge confirms the maximum recorded sea level was 0.73 mODM on 23rd October 2008 which is less than MHWS level (1.65mODM). Comparison with the Admiralty predicted tide indicates that the surge element was less than 0.2m.

Flood Event of 28th October 2004

Prolonged heavy rainfall over the month of October led to pluvial flooding along Kilgarvan Road, Bantry and subsequently caused mudslides from the saturated steep slopes around the town. No further evidence was available on precise locations, extents or photos of the event.

Flood Event of 5th November 2000

Flooding on the 5th of November was due to rainfall of around 131mm causing inundation in Bantry. Barrack Street flooded during the morning, causing problems with the Warner Centre. This combined with tidal flooding in Wolfetone Square, but no detailed information of the properties affected was available.

Flood Event of 5th August 1986

The largest gauged flows were recorded on this date at Inchiclogh gauge. Over 120mm of rain fell over 19 hours in the upper Mealagh, Owvane and Lee river catchments. This rainfall event would be between a 1%AEP and 0.67%AEP according to the DDF estimates. This heavy rain resulted in a 1.6%AEP river flow at Inchiclogh based on the statistical analysis. However, there were no records of property flooding in this event, or flood references in newspaper articles, although areas in the Lee catchment and Cork City flooded on the same day.

Flood Event of 31st January 1983

A combination of high tides and storm conditions caused wave overtopping which led to flooding of about 20 properties around Wolfetone Square and New Street in Bantry. The extreme tide levels prevented discharge from the urban sewers, which when combined with the heavy rainfall caused sewer flooding of these properties. A full review was carried out and triggered improvements to the urban drainage network and the construction of a wave wall to protect coastal properties.

Flood Events of 13th and 25th December 1981

The December 1981 flood events were very similar in source of flooding and extent to the aforementioned January 1983 flood. The severity of this flood event was estimated at 1 in 25 year or 4% AEP at the time.

Other Recurring Events

There are a number of anecdotal reports of flooding in UoM21. These provide useful insight into locations of flooding issues and relative flood frequency in addition to the formally reported events above. These include:

- Bantry
 - Lahadane experiences recurring flooding near the industrial park from the River Mealagh as reported on floodmaps.ie.
- Kenmare
 - 10 to 20 properties experience recurring flooding from the Finnihy River during periods of heavy rainfall and high tides causing the urban drainage system to back up around the square. This is typically around the N71 Bridge and Finnihy Banks estate. This was last observed in 1995/1996 but no date was given. Kerry County Council estimates this event as having a 10%AEP.
 - The bridge to the post-primary school (Riverside Villas) experienced recurring flooding from the River Finnihy as reported by staff during the Flood Risk Review.
 - Recurring flooding of the convent grounds from the River Finnihy was reported but the building was not affected as it is raised above the garden, as reported during the Flood Risk Review.
 - Recurring flooding at Scarteen Park from the Caol na Gabhair (Lissaniska) stream as reported on floodmaps.ie, although the frequency of this event is not given.

Table 4.1: Key Historical Flood Events

Date	Flooding Mechanisms	Areas Affected	Properties Flooded	Reported Duration of Flooding (Hours)
13/12/1981	Tidal flooding, groundwater flooding, exacerbated by heavy rainfall. Sewerage system of limited capacity causing surcharging of drains at Bantry.	Bantry: Wolfetone Square, New Street	Over 20 properties flooded at Bantry	Estimated to be ~24 hours
31/01/1983	Tidal and pluvial flooding. Sewerage system of limited capacity causing surcharging of drains.	Bantry: Woleftone Square, New Street	Over 20 properties flooded	Estimated to be ~12 hours
05/08/1986	Fluvial/pluvial flooding, intense rainfall recorded at gauges in the upper Mealagh but no flooding reported in Bantry.	Bantry: no areas reported	Number not reported	Estimated to be ~12 hours
05/11/2000	Fluvial/pluvial flooding, heavy rainfall event recorded at rain gauges.	Bantry: Wolfetone Square, New Street, Barrack Street. Gortloughra Bridge also affected.	Number not reported	Estimated to be ~19 hours
28/10/2004	Fluvial/pluvial flooding causing mudslides. Due to heavy rainfall over a sustained period previous to flood.	Bantry: Wolfetone Square	Number not reported	Estimated to be ~12 hours
23/10/2008	Fluvial event due to intense, heavy rainfall in the upper Finnihy catchment. The Heritage Trail footbridge was blocked by a large amount of debris.	Kenmare: Henry Street, Main Street, Shelbourne Street, Cromwell Courts, Gortamullen Heights and Scarteen Park.	36 residential properties, 11 commercial	Estimated to be 24 hours
17/10/2012	Tidal flooding from storm surge overtopped quay walls at a number of low openings.	Bantry: Wolfetone Square	2 residential properties and 8 commercial properties	4 hours

4.2 Historical Flood Mechanisms

The total rainfall at the daily storage gauges has been mapped for historic events, both spatially and temporally. Map 4.1 displays the total rainfall plot for the recent 2008 event across UoM21. There was very limited data available, and the scatter in the rainfall records made it inappropriate to infill gaps from nearby gauges as there was no single relationship. The maps for the other historic events have been provided in Appendix A. Following the review of the historic reports and interviews with Local Authority personnel during the Flood Risk Review, the key flood mechanisms were identified in UoM 21. These include:

Fluvial or river flooding

Fluvial flooding can occur when the capacity of the river channel is exceeded due to excess flow from heavy rainfall or releases from reservoirs upstream. Flood waters typically overtop river banks at low sections or where water is constricted by bridges or culverts forcing water levels to rise upstream and flood surrounding areas.

Fluvial flooding affects the upper catchments of Bantry, Kenmare and Durrus, particularly at structures where the capacity is less than the incoming flow.

Pluvial or surface water flooding

Pluvial flooding can occur when overland flow from intense rainfall or prolonged heavy rainfall is unable to enter the urban drainage network because the capacity of the system is exceeded and/or outfall is “tide-locked” preventing discharge. Pluvial flooding is exacerbated by the increase of impermeable areas (such as concrete or tarmac) associated with urbanisation, which increases the amount of overland flow. It should be noted that the study of pluvial flooding is not included in the scope of the CFRAM Study.

Bantry has suffered from pluvial flash flooding in the past due to the steep topography around the town and exposed location to Atlantic Storms. Durrus and Kenmare are also expected to be affected by pluvial flooding along roads given the steep topography of these AFAs

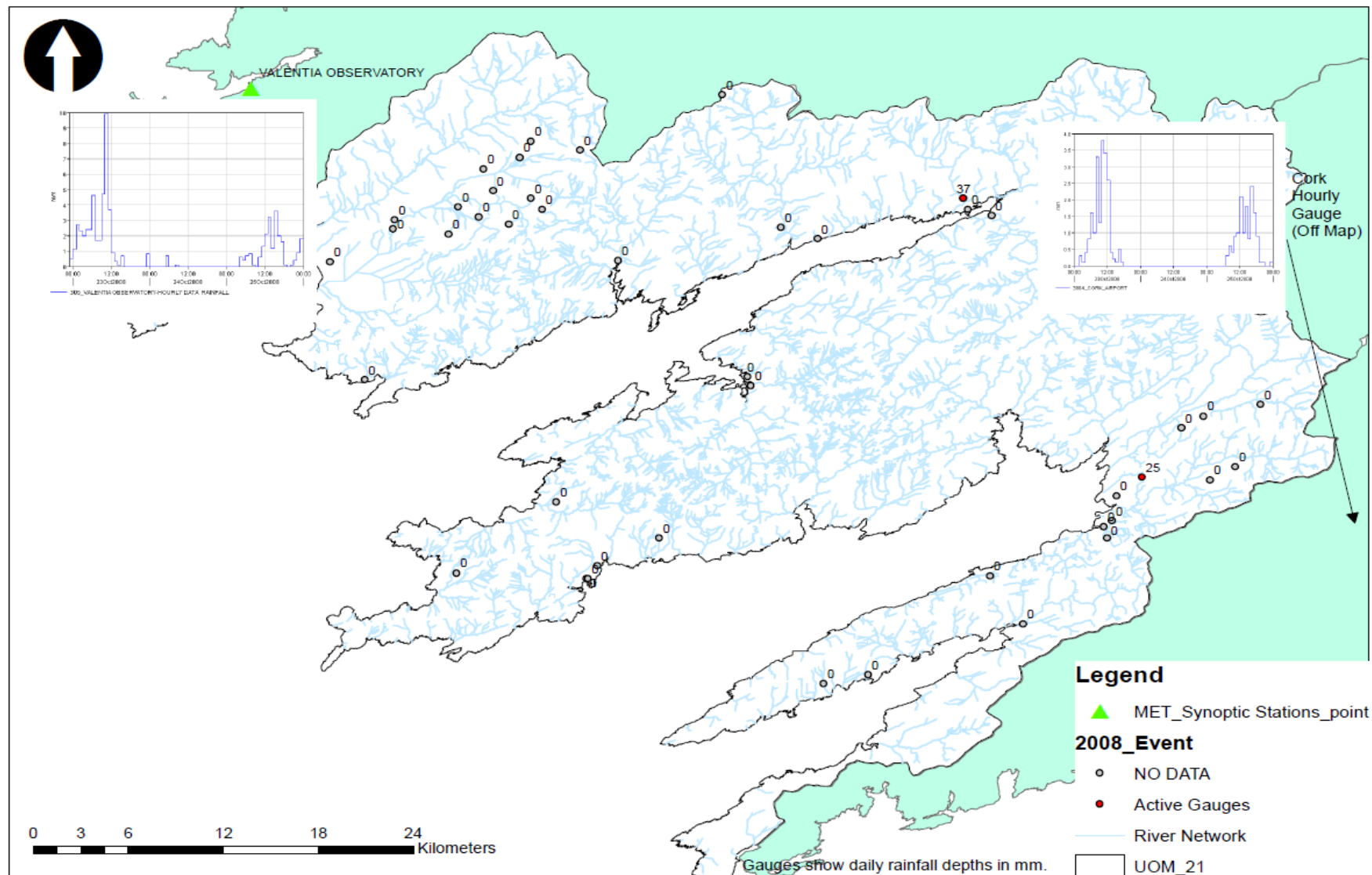
Coastal or tidal flooding

Extreme sea levels, waves and storm surges overtop coastal defences and river banks in tidally influenced reaches, particularly when combined with high river flows for tidal rivers. The risk to people can be very high from this form of flooding as the flood waters can be fast-flowing.

Bantry has been historically at risk from tidal flooding and wave overtopping from severe Atlantic Storms, particularly when combined with heavy rainfall. Kenmare is also reported to be at risk from coastal flooding particularly when extreme sea levels create “tide-lock” of the River Finnihy.

In addition to the mechanisms listed above, flooding can also occur from the following groundwater. This type of flooding can occur when water levels rise above the ground to flood low-lying fields and property basements, typically when the catchment is saturated. The onset of flooding is very slow and therefore hazard to people is limited. However, there are no records of groundwater flooding in UoM 21; hence groundwater flooding has been discounted from further analysis. It should be noted that the study of groundwater flooding is not included in the scope of the CFRAM Study.

Map 4.1: Variation in Total Rainfall for 23rd October 2008 Event



Based on the historical flood evidence, the key mechanisms for each of the AFAs are as follows:

Durrus

No historical flood evidence was available from the OPW database or from extensive searching of newspaper archives and websites. Site visits observations and interviews with local authority personnel suggest the new development along the river is vulnerable to flooding as water spills over the banks of Four Mile Water.

Bantry

Flooding is primarily caused by high tides entering the local drainage network and causing sewer flooding as well as river flooding from the Bantry Stream and tributaries. Bantry is prone to flash flooding from the numerous small steep rivers that flow through the town.

Kenmare

Flooding occurs from the River Finnihy, typically at the bridges (Riverside Villas, N71 and Creamery Road Car Park). Flooding also occurs along the Lissaniska Stream spilling out of bank in the golf course and at Park Lane Bridge, causing further problems at Scarteen Park. Interviews with the Local Authority personnel indicated that extreme tidal flooding causes backwater up to Finnihy Bridge, which when combined with high river flows can cause flooding to areas around Rose Cottages.

Castletown Bearhaven

Local websites report regular flooding from high tides combined with waves and heavy rainfall along the coastal front. Photographs indicate that this causes shallow flooding of the vulnerable properties along the quayside and lifeboat slipway.

4.3 Historical Flood Frequency

An estimate has been made of the frequency for the historical flood events where there was recorded rainfall and river flows for the AFAs in UoM21.

For all fluvial events, rainfall records were assessed across the region in order to establish whether each reported historic flood event was part of a region-wide storm event or a localised event. All the recorded events were found to be caused by large Atlantic depressions causing heavy rainfall across the small catchments, in combination with storm surges in the case of Castletown Bearhaven, Bantry and Kenmare.

The recorded peak flow at the nearby gauges was compared to their annual maximum series and the relative frequency of each event was derived using the Gringorten formula:

$$Fi = \frac{i - 0.44}{n + 0.12}$$

Where i is the relative rank in the annual maximum flow series (AMAX) and n is the number of values in the AMAX series. The resultant %AEP and rank estimates are presented in Table 4.2.

Table 4.2: Estimation of Flood Frequency for Historical Flood Events with Records of Flooding

AFA/Watercourse	Nearest Gauging Station		Historical Flood Event				
	Station No.	Location	Date	Peak Flow (m ³ /s)	Rank	AEP (%)	Catchment Wide/ Localised Rainfall
Bantry/Bantry Stream	21004	Inchiclogh	13/12/1981	202	2	4.3	Catchment wide rainfall event
			31/01/1983	N/A Coastally dominated	-	-	Catchment wide rainfall event but less than 50%AEP magnitude.
			05/08/1986	270	1	1.6	Catchment wide rainfall event with highest amounts (in excess of 120-160mm) falling in Kenmare and Bantry
			05/11/2000	No Data in Bantry*	-	-	Catchment wide rainfall event
			28/10/2004	98	14	37.5	Majority of rain fell on west of catchment. Rainfall period of 37 hours recorded at Valentia
Kenmare/Finniuhy	21008	Kenmare	23/10/2008	No Gauged Data* 43 Rainfall runoff estimate	1	20 to 10	Catchment wide rainfall event with 19 hours of continuous rainfall recorded at Valentia. The DDF estimate for this event is smaller than the 50%AEP. However, the rainfall runoff estimate and documented extent corresponds to an event between 20% and 10% according to the flood history and design flood growth curve.
Bantry/Coastal	N/A	Castletown Bearhaven Recorded Water Level Transferred to Bantry	17/10/2012	N/A Coastal Event	1	10	N/A Coastal Event

*Data unavailable due to lack of reliable gauged data or data gap.

5 Design Flows

5.1 Overview

The hydrological approach draws on the data review described in Chapters 3, 4 and 5 of this report and the latest Flood Studies Update (FSU) guidance. The hydrological analysis to derive design fluvial hydrographs for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP has been undertaken as follows:

- Define the sub-catchments and locations at which to calculate design flows (Section 5.2);
- Estimate the index flood flow for the 50% AEP flood (Section 5.3);
- Estimate the flood growth curve to derive more extreme flood events (Section 5.3);
- Estimate the typical flood hydrograph shape (Section 5.4).

The hydrological analysis to derive design coastal conditions for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP has been undertaken as follows:

- Transformation of total tide plus surge levels along the coast to the model outfalls into the open sea (Section 5.5.1);
- Estimate the typical tide plus surge profile (Section 5.6.1);
- Estimate wave overtopping discharges at vulnerable locations (Section 5.6.2).

5.2 Definition of Sub-Catchments

5.2.1 Hydrological Estimation Points

Hydrological estimation points (HEPs) have been chosen at key locations in the Kenmare, Bantry and Durrus catchments to form the hydraulic model inflows, intermediate target flows for the model to achieve, and downstream conditions for the model.

The HEPs were identified through a GIS analysis based on the following principles from Section 6.5.3 of the Generic CFRAM Specification:

- A central location within the AFA;
- Flow gauging stations used in the hydrological analysis;
- Upstream and downstream limits of each hydraulic model reach;
- Major confluences which contribute significant flow to the modelled reach; and,
- Locations where the physical catchment descriptors (PCD) significantly change from the upstream catchment, i.e. catchment centroid more than 25km away, ± 0.15 change in BFI and ± 0.07 change in FARL.

Table 5.1 summarises the selected HEPs prior to hydraulic modelling. Individual maps and catchment descriptors for each AFA and MPW reach are given in Appendix B.

There are no HEPs identified in Castletown Bearhaven as the AFA was not assessed to be at fluvial flood risk.

Table 5.1: Selected HEPs

HEP Type	Number in UoM21
Gauged	1
Model Inflow	23
Target	31
Downstream	5
TOTAL	60

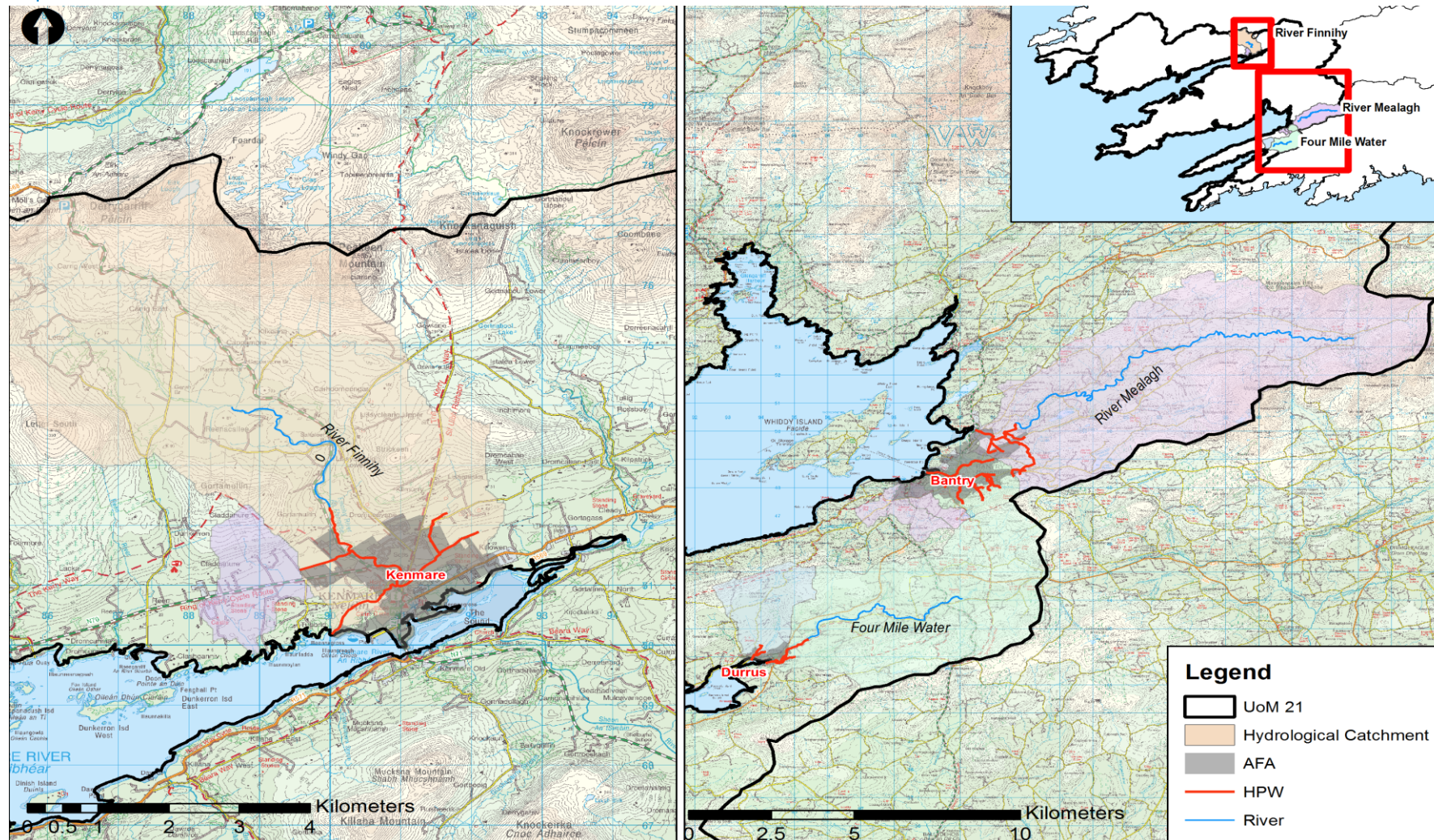
5.2.2 Sub-Catchment Boundary Delineation

Kenmare, Bantry and Durrus AFAs were conceptualised into sub-catchments based on the latest Flood Studies Update (FSU) database (supplied 2011). Map 5.1 displays the key sub-catchments for these AFAs.

GIS spatial analysis was undertaken on the national digital elevation model to determine slope aspect and subsequently identify the watersheds for each catchment. The output from this GIS analysis was compared with the automated FSU catchment boundaries and verified against manual interpretation from Ordnance Survey mapping at 1:50,000 scale, previous hydrological reports, and observations from site visits. The other physical catchment descriptors were also reviewed including; average slope (S1085); average rainfall (SAAR); runoff indicators (SPR); permeability indicators (BFI); and attenuation (FARL). Information from the Geological Survey of Ireland (GSI) was also used to assess the impact of underlying geology and aquifers on permeability and groundwater dominance, as well as to inform those catchments influenced by karstic systems.

No significant modifications were made to the original FSU database physical catchment descriptors which are provided in Appendix B. Cork County Council has provided details of a proposed water supply reservoir in the upper reaches of a tributary of the Mealagh catchment. The proposed size of this reservoir relative to the Mealagh catchment is unlikely to have a significant impact on the flood attenuation from the Reservoirs and Lakes (FARL) catchment descriptor at Bantry. The reservoir has not been constructed yet and cannot be considered as a future change to the physical catchment descriptors.

Map 5.1: Fluvial Sub-Catchments



5.3 Flood Frequency Analysis for Fluvial Flows

5.3.1 Approach

Flood frequency analysis was undertaken at gauged and ungauged sites to derive the design fluvial hydrographs for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events as boundary conditions for the hydraulic modelling.

Gauged Sites

The index flood flow was derived from the median value of the Annual Maximum Flood Series (AMAX) at gauged sites within or linked to the AFAs, and compared with the FSU 7-variable QMED rural estimate (FSU WP2.3). Previous research by the FSR indicated that the index flood is proportional to $AREA^{0.77}$. This relationship was applied as a check to identify atypical QMED flows for catchment size.

The Extreme Values (EV1), logistic (LO), generalised logistic (GLO) and generalised extreme value (GEV) distributions were then fitted to the AMAX series to establish the most appropriate flood growth curve for %AEP up to twice the record length at the gauged location (FSU WP2.2). For rarer, more extreme events, hydrologically similar gauge sites were selected to form a pooling group based on the Euclidian distance measure (d_{ij}) between catchment characteristics at the gauged site. Descriptors considered include AREA, SAAR, BFISOILS, the ratio of the highest gauged flow to QMED, the presence of underlying karstic features and any issues highlighted by the OPW hydrometric team.

There were a limited number of appropriate gauged sites available to form the pooling sites given the small, wet nature of the UoM21 catchments and few gauged small catchments across Ireland. Therefore, it was not always possible to find sufficient pooling sites of a similar size, BFI and SAAR, and the selection criteria had to be relaxed in order to achieve the target record length of 500 years (5 times the target 1%AEP). The selection of the pooling group was a balance between selecting hydraulically similar sites, maintaining homogeneity across the group and achieving the required record length. The pooled L-Moment average for each pooling group was then compared with the various distributions to guide the selection of the most appropriate flood growth curve.

Ungauged Sites

At ungauged locations, the $QMED_{rural}$ values were estimated using the 7 variable equation (FSU WP 2.3) based on gauged data from 190 sites across Ireland:

$$QMED_{rural} = 1.237 \times 10^{-5} AREA^{0.937} BFISOILS^{-0.922} SAAR^{1.306} FARL^{2.217} DRAIN^{0.341} S1085^{0.185} (1 + ARTDRAIN2)^{0.408}$$

Where:

- AREA is the total contributing area of the catchment
- BFISOILS is an index of permeability
- SAAR is the Standard Annual Average Rainfall between 1961 and 1990
- FARL is an index of floodplain attenuation
- S1085 is the typical slope between 10% and 85% along the river reach
- ARTDRAIN2 is a proportion of the catchment which is artificially drained.

Pivotal gauged sites were then used to adjust the $QMED_{rural}$ as recommended by FSU WP 2.3. The pivotal gauged sites were selected from hydrologically similar gauges across Ireland with a preference for geographically close locations to better represent rainfall characteristics in the South West area. Hydrological similarity was guided by the similarity of physical catchment descriptors based on FSU hydrological guidelines:

- Area of pivotal site within a factor of 5 of the target ungauged HEP;
- BFI soils index within 0.18 of the target ungauged HEP;
- SAAR within a factor of 1.25 of the target ungauged HEP;
- FARL within 0.05 of the target ungauged HEP.

Grade A gauges were assumed to be of reliable quality unless otherwise stated by the FSU report. Grade B gauges were further assessed for the presence of lakes/reservoirs, significant karstified features and FSU quality of the gauge, to ensure the gauge was suitable to inform the adjustment of $QMED$ at the ungauged target HEP.

It should be noted that the FSU 7 variable equation was not developed for catchments less than 5km^2 in size due to the lack of reliable gauge records for such small catchments in Ireland. Alternative methods, including the rational method, were found to better represent small catchments on average but tended over predict peak flows for small lowland catchments (Institute of Hydrology 1978). The modified rational method (1981) is also not suitable to estimate greenfield runoff as it was developed specifically for sewer design. The consensus from an exhaustive literature review was that it was not possible to verify the most appropriate methodology without gauged records. The FSU approach has been compared with the Rational method for catchments under 5km^2 in UoM21, taking into account the limitations with estimating reliable parameters and the routing of flows through the catchment.

The pooled analysis was used to derive appropriate flood growth curves for all ungauged sites. The selection and review of pooling groups was guided by the same approach as described in the gauged approach above. The pooling group AMAX data was collated to create a combined record length of 500 years, which is in accordance with the 5T rule of five times the record length of the target design event, i.e. the 1 in 100 year or 1% AEP event. The pooled L-Moment average for each pooling group was used to identify discordant sites and select the most appropriate statistical distribution.

5.3.2 Estimation of the Index Flood

The calculated QMED at Inchiclogh gauge on the River Mealagh is provided in Table 5.2 and compared with the FSU 7 QMED rural estimate. The gauged QMED is unusually large for the catchment area of 45 km² and more than double the QMEDrural estimate. However, detailed analysis of the spot gaugings and gauge location indicates that the extension of the rating should be reliable up to bankfull. Furthermore, the gauged QMED of 88m³/s is broadly equivalent to the anecdotal flood history and initial comparison with channel capacity of natural reaches downstream. Therefore, the gauged QMED of 88 m³/s was accepted for design hydrology.

Table 5.2: Gauged QMED Mealagh at Inchiclogh

Gauge ID	Name	Watercourse	QMED AMAX EPA Rating	QMED rural	Years Data
21004	Inchiclogh	Mealagh	88	38	31

For ungauged sites, the QMED was calculated using the FSU 7 variable approach and adjusted using pivotal sites. The pivotal sites were selected based on hydrological similarity as described in Section 5.3.1. Gauges 20005, 20006, 21001 and 22006 were typically used to adjust the QMEDrural estimate for the ungauged HEPs as they were hydrologically similar except in area as there were very limited small catchments which had similar SAAR values. The upper confidence limit of QMED (95th percentile) has been calculated for each HEP based on the factorial standard error of 1.37 (see WP 2.3). The confidence limits will guide sensitivity tests during the hydraulic modelling phase and the screening of preliminary flood risk management options in areas at significant flood risk.

Table 5.3 compares the FSU 7 variable QMEDrural estimates with the rational method estimate for the index flood for the ungauged catchments in Bantry, as an example.

Table 5.3: Ungauged QMED Estimates at Bantry

HEP ID	Locations	Watercourse	AREA (km ²)	FSU 7 var. QMED rural (m ³ /s)	FSU 7 var. QMED adjusted (m ³ /s)	Rational Method QMED (m ³ /s)
21_7225_2	Wolfetone Square outfall	Bantry River	4.24	4.4	6.4	7.1
21_7668_2	Bantry House outfall	Dromacoosane	2.38	2.3	2.7	2.9

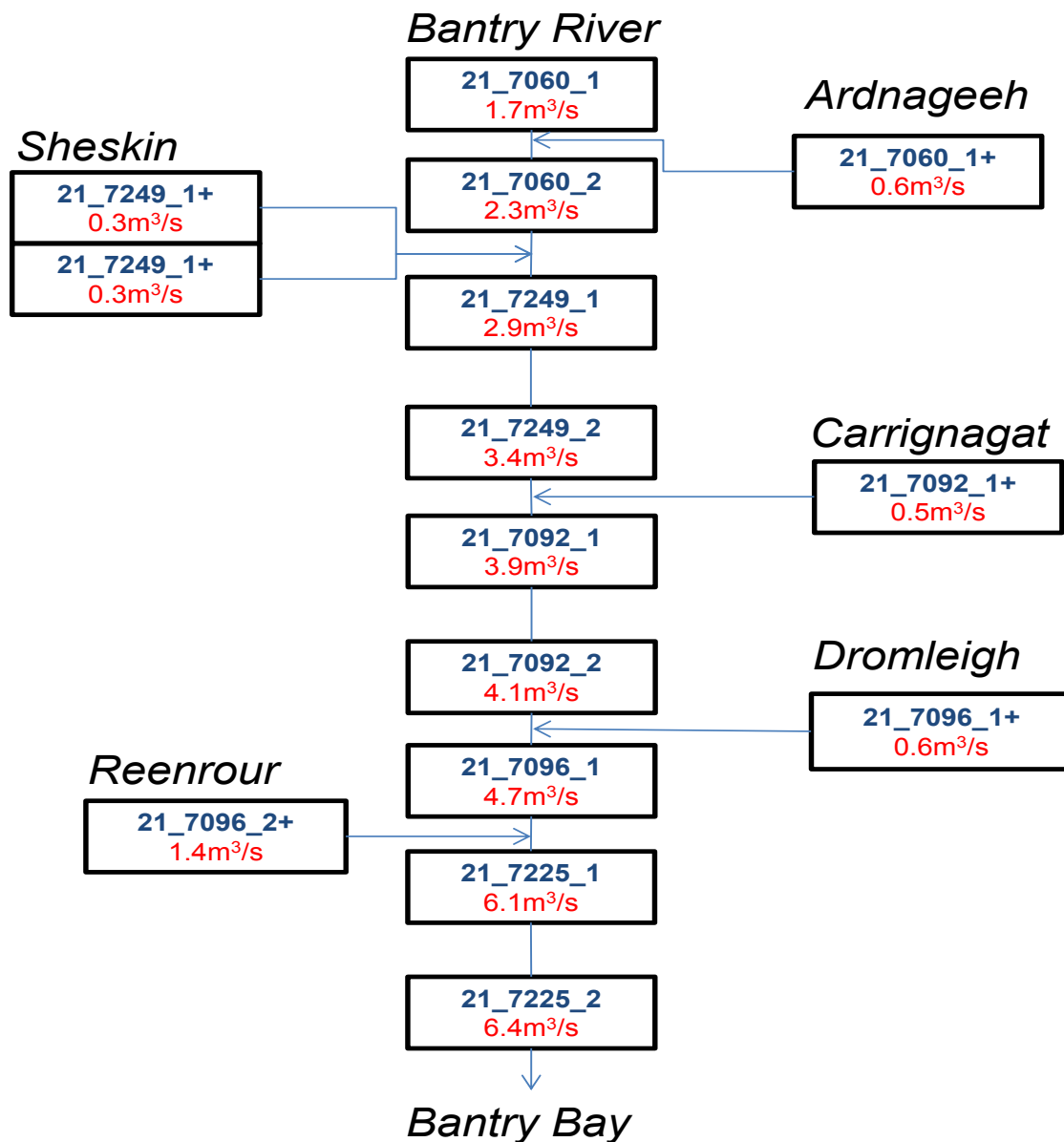
The rational method tends to estimate a slightly larger QMED due to the uncertainties deriving accurate SOIL and runoff coefficients from coarse hydrological maps and equations used. In UoM21 the difference between the two approaches was less than 10% and within the 95 percentile limit of the FSU 7 variable equation. The FSU 7 variable adjusted QMED was selected for the design QMED because it uses more accurate catchment descriptors and matched better with the routing of flows in gauged catchments. Sensitivity tests have been undertaken on design flows which incorporate the discrepancies between the FSU and Rational methods.

The recorded QMED values at gauges were indexed to $AREA^{0.77}/10$ and factors were typically found to be between 7 and 26 across UoM21. The smallest catchments tended to have lower factors due to the limitations of the ungauged methods to derive QMED discussed above. The Mealagh catchment was the exception with an unusually large factor for the catchment area. As discussed above, this may be attributed to the uncertainty in the high flows rating at Inchiclogh gauge. Additional high flow gaugings are required to verify the extrapolation of the rating curve.

QMED was also checked to ensure the flows increase downstream with contributing area. An example schematic of the final QMED values for the Bantry River catchment is provided in Figure 5.1. As discussed above, the estimation of QMED on small tributaries quite uncertain without observed data to provide validation. Therefore, the QMED values for the have smaller catchments been adjusted based on the available pivotal sites to ensure target flows downstream are met.

The details of the selected pivotal sites, QMED estimate and schematics for all HEPs are provided in Appendix C.

Figure 5.1: Example Schematic of QMED for Bantry River in Bantry AFA



5.3.3 Derivation of Flood Growth Curves

Pooling groups of hydrologically similar sites were developed for each HEP and the pooled record was used to in flood frequency analysis to develop the design flood growth curves as described in Section 5.3.1. The pooling group sites aimed to have AREA within a factor of 5; SAAR within a factor of 1.25 to 2 and BFI within ± 0.18 . The criteria were lowered for selection of pooling groups sites in the smallest sub-catchments of Bantry, Kenmare and Durrus. This more lenient approach was taken in order to achieve a balance between finding hydrologically similar sites and achieving the 500 years pooled record length from the target 1%AEP.

For each potential pooling group site, the presence of karstic geology was checked from the Geological Survey of Ireland data and compared with the BFIsoils parameter. The following sites were found to be influenced by karst across the majority of the catchment and rejected from pooling groups used for UoM21: 23012, 27070, 27003, 30020, 30021. It should be noted that gauges 19001, 19020, 21004 and 22009 were also been rejected from pooling analysis due to the OPW's hydrometric team's concerns with the estimation of high flows at these sites.

Figure 5.2 provides an example of the flood growth plot at each HEP using the Inchiclogh gauge as an example. Figure 5.3 provides the corresponding L Moment plot of the pooled average. The full pooling group details used to derive the flood growth curves are provided in Appendix C.

Figure 5.2: Example Flood Growth Curve Plot for Inchiclogh Gauge on the Mealagh River

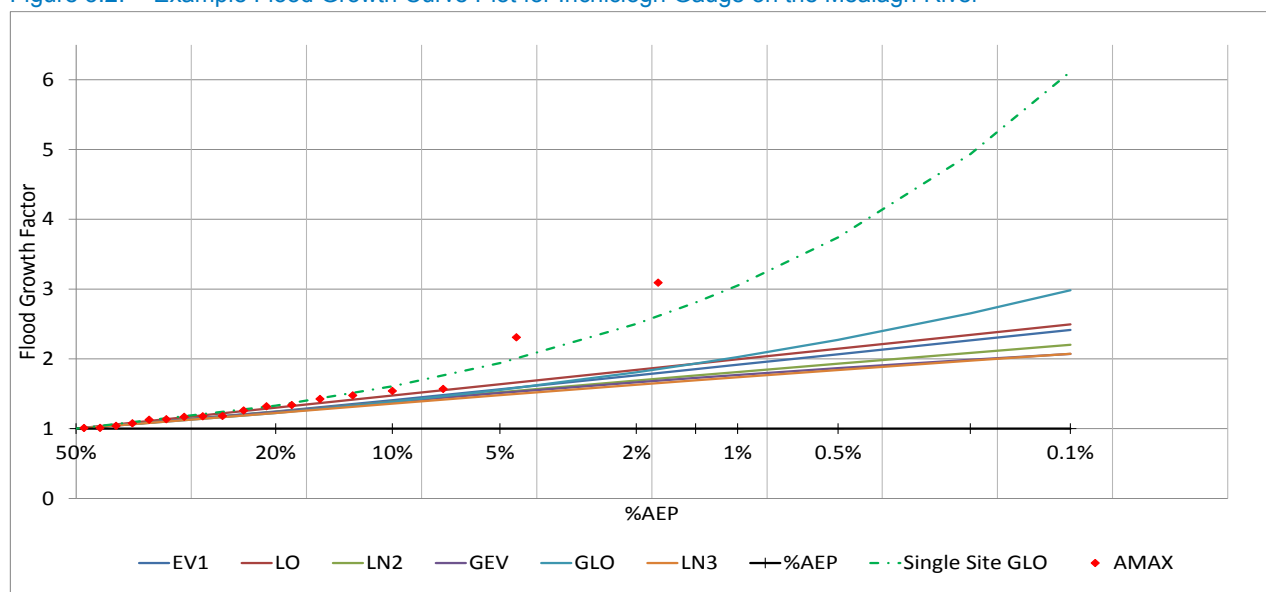
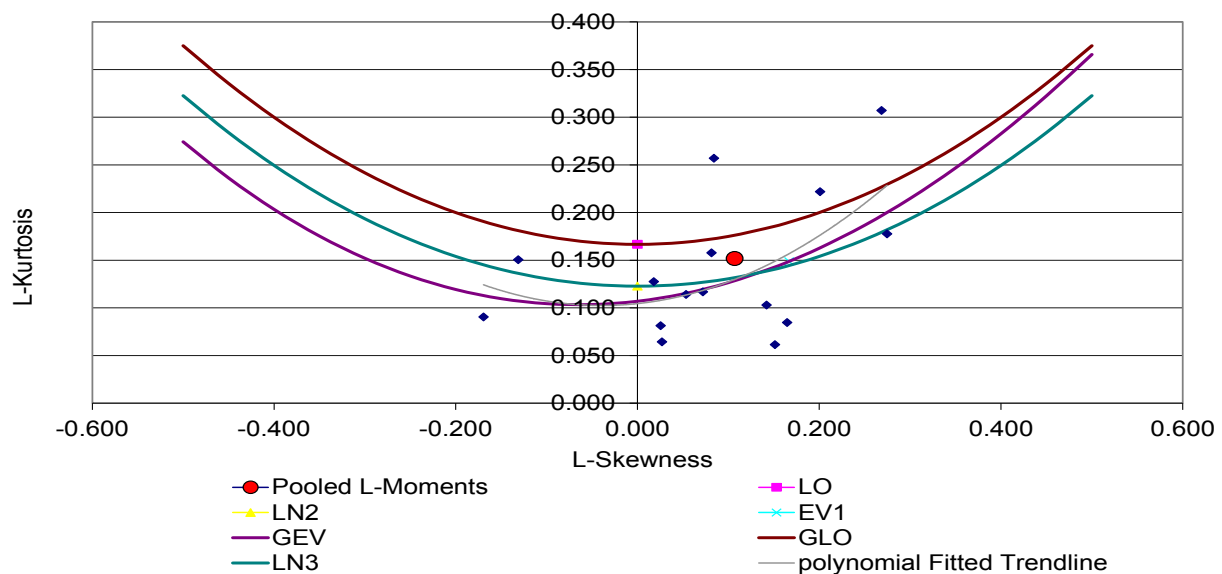


Figure 5.3: Example L-Moment Plot for Inchiclogh Gauge on the Mealagh River



The single site flood growths is skewed by the two largest AMAX events in 1977 and 1986, thus predicting larger significantly larger flood growth factors above the 5%AEP. However the flow estimates for the largest events are suspect due to the uncertainties in the high flows rating at this gauge. Once these two suspect years are omitted the AMAX data and pooled average more closely follows the EV1 and GLO distributions. In principle, the GLO curve was selected for the more extreme 0.5%AEP and 0.1%AEP as it was deemed to provide a more conservative estimate of peak flow which accounts for the uncertainty in the flood growth curve generation.

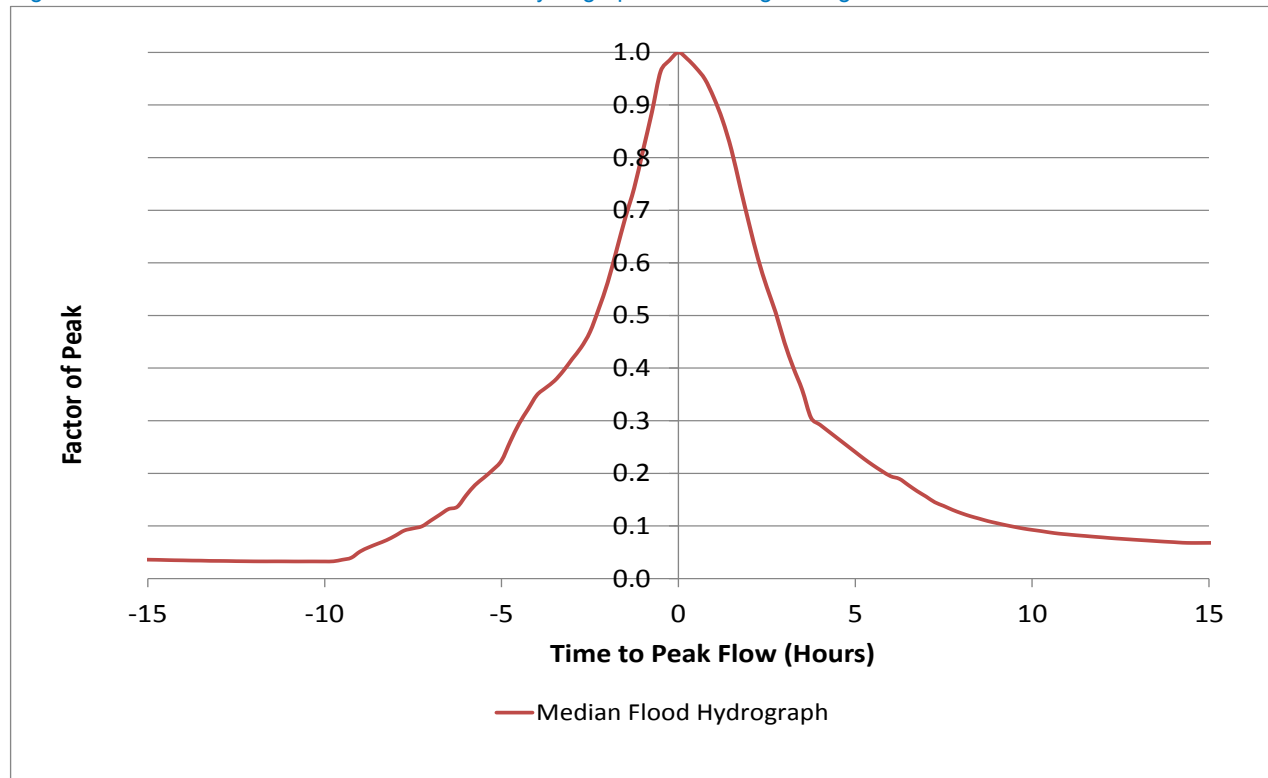
Appendix C summarises the detailed flood frequency analysis for the other reaches in UoM21.

5.4 Hydrograph Generation

Flood extent, depth, velocity and hazard are governed by the shape and duration of a flood flow hydrograph as well as the magnitude of the peak flow. Therefore, design inflow hydrographs were derived at each HEP as follows.

At gauged locations, the hydrograph width analysis approach was used to derive the median flood hydrograph as the characteristic flood hydrograph for subsequent use in the hydraulic modelling and development of flood risk management options. The 15 minute flow data was extracted for each of the AMAX events at each fluvial gauge, standardised by the peak flow, and the width exceedance for each event derived at specified percentiles of the peak flow. The median of the width exceedance was then used to compile the design flood hydrograph (Figure 5.4).

Figure 5.4: Median Width Exceedance Flood Hydrograph at Inchiclogh Gauge



Many of the ungauged catchments within UoM21 are steep and have a high base flow index dissimilar to gauges across Ireland used in the development of the FSU UPO-ERR gamma curve hydrograph. Hydrographs in UoM21 are therefore likely to vary significantly from those in other flatter and larger catchments in other RBDs. Figure 5.5 compares the gauged median width exceedance hydrograph at Inchiclogh gauge with the following hydrographs:

- FSU UPO-ERR Gamma curve derived from the catchment descriptors;
- FSU UPO-ERR Gamma curve adjusted by the most hydrologically similar site (23012);
- FSU UPO-ERR Gamma curve adjusted by site 36012 to better match the gauged hydrograph; and,
- FSSR16 rainfall runoff hydrograph.

The FSSR16 parameters for Inchiclogh gauge were updated using the latest Depth Duration Frequency (DDF) parameters from the Met Éireann Study (2007)¹, and Jenkinson's r value was calculated as per the FSSR16 equation:

$$r = \frac{M5 - 60MIN}{M5 - 2DAY}$$

¹ Met Éireann (2007) Technical Note 61: Estimation of Point Rainfall Frequencies.

The resulting FSSR16 parameters derived are presented in Table 5.4 below. The critical duration and time to peak (T_p) were derived based on S1085, URBAN, SAAR and MSL using the FSSR16 methodology. It should be noted that the FSSR16 approach does not represent the sub-surface stores and flow paths of karstic systems. However, none of the catchments within the AFAs are underlain by significant karstic geology. Hence the FSSR16 can be deemed appropriate in this respect.

Table 5.4: Updated FSSR16 Parameters

FSSR 16 Parameter	Inchiclogh gauge (21004)
M5 - 60 min (mm)	16.3
M5 - 2 day (mm)	76.7
M5 -25 day (mm)	251.1
Jenkinson's r	0.213
Catchment Wetness Index (CWI)	122
Critical Storm Duration, D (hours)	10.5
Time to Peak, T_p (hours)	4.6

The regression-based UPO-ERR Gamma curve was calculated from the physical catchment descriptors in accordance with FSU WP 3.1. The three components of the hydrograph are:

- Gamma Curve (Rising Limb) - n

$$y = \left(\frac{x + T_r}{T_r} \right)^{n-1} \left[\text{Exp} \left(-\frac{x(n-1)}{T_r} \right) \right]$$

- Inflection Point (Starting point of Recession Limb) - T_r

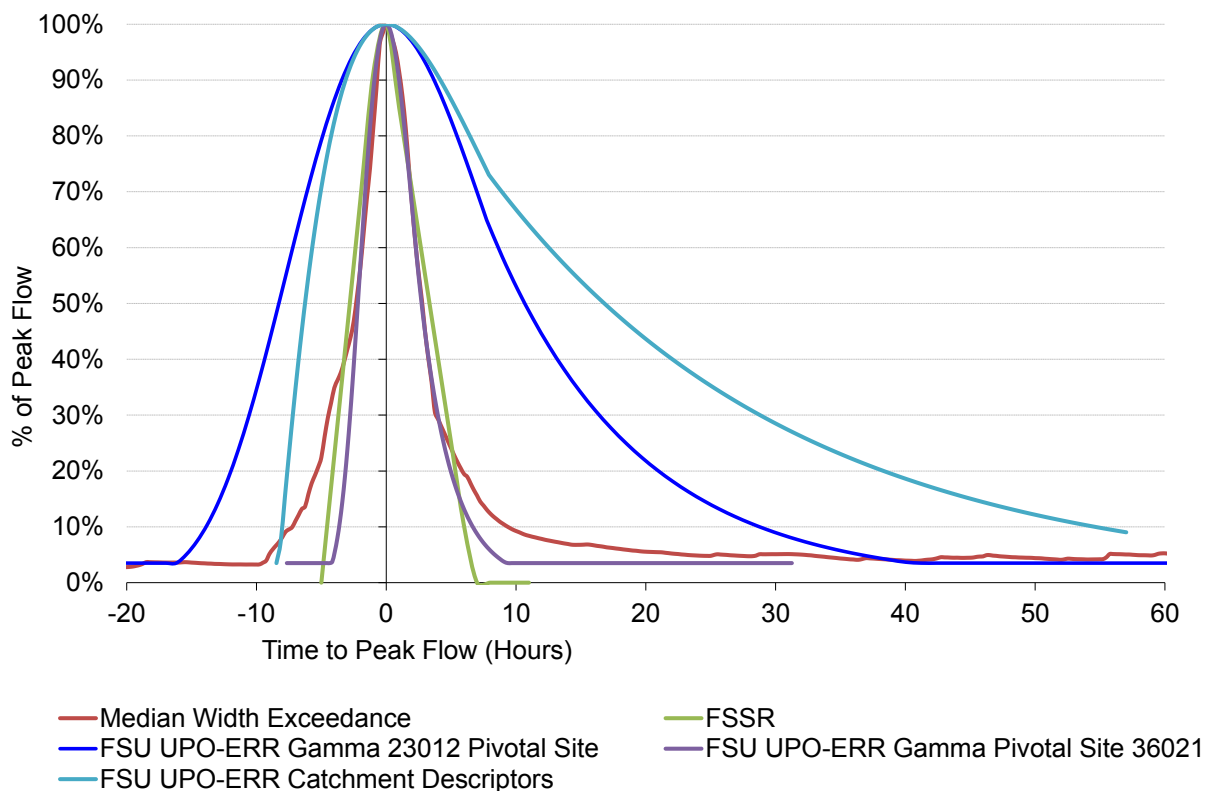
$$x_o = \frac{T_r}{\sqrt{n-1}} \quad y_o = \left(\frac{x_o + T_r}{T_r} \right)^{n-1} \text{Exp} \left(\frac{x_o(n-1)}{T_r} \right)$$

- Exponential Decay Curve (Recession Limb) - C

$$y = y_o \text{Exp} \left(-\frac{x - x_o}{C} \right)$$

The n , T_r and C parameters were estimated from the physical catchment descriptors for the study area and were used to derive an initial estimate of the flow hydrograph. The T_r and C values were subsequently adjusted based on hydrologically similar pivotal sites from the FSU database. Hydrologically similar sites were selected based on slope, attenuation and permeability and compared to the target sites catchment area and SAAR to ensure similar responses to rainfall.

Figure 5.5: Comparison of Flood Hydrographs at Inchiclogh Gauge



The catchment descriptors and most hydrologically similar pivotal site hydrographs both overestimate duration and flood volumes compared with the gauged median width exceedance hydrograph. The hydrograph shapes based on pivotal site 36021 and the FSSR16 rainfall-runoff hydrograph are both very similar to the gauged median width exceedance hydrograph. The FSSR16 rainfall-runoff hydrograph, which has been applied across Ireland successfully to date, appears to produce hydrograph shapes that are most suited to these wet rapid response catchments. This is because it takes slope (S1085) and catchment area into account within hydrograph shape calculations. Therefore, the FSSR16 rainfall runoff hydrograph has been applied to all ungauged HEPs outside the Mealagh catchment.

The details of the resultant design flood hydrographs for each reach are provided in Appendix C.

5.5 Coastal Conditions

5.5.1 Total Tide plus Surge Levels

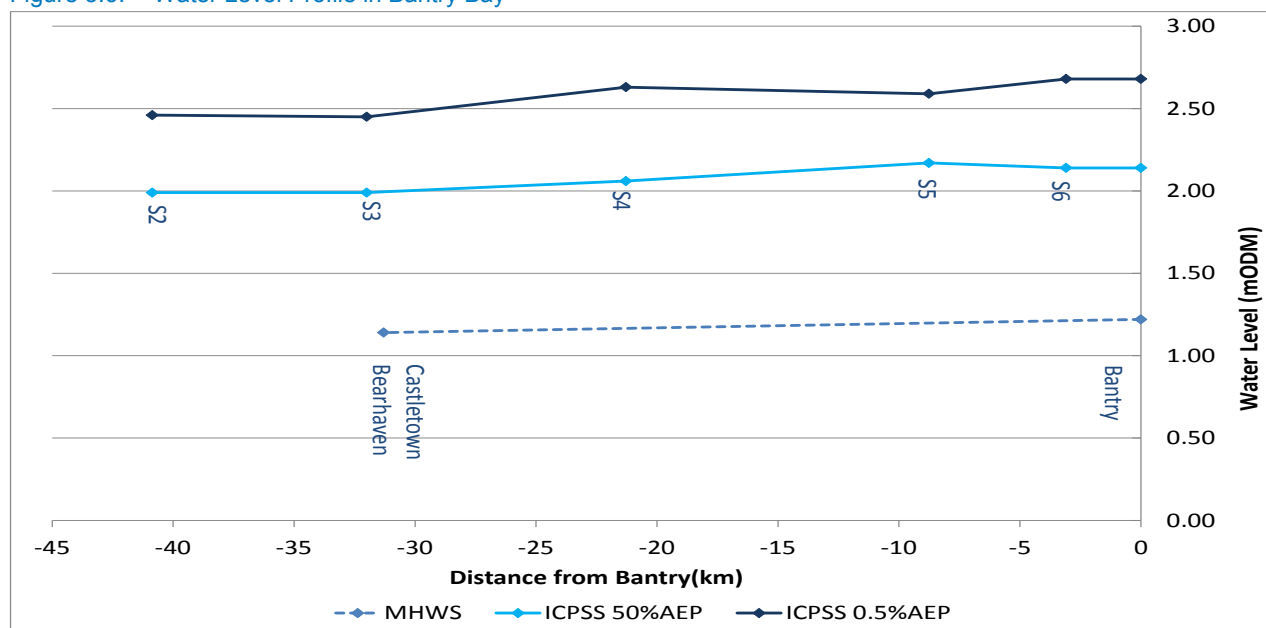
Extreme sea levels around the Irish coastline incorporate both the astronomic tide (caused by planetary forcing) and storm surge elements (caused by atmospheric pressure), henceforth referred to as “total tide plus surge levels”. The flood frequency analysis for extreme sea levels has already been undertaken as part of ICPSS (2012) for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events.

Bantry Bay (Bantry and Castletown Bearhaven AFAs)

The ICPSS has derived total tide plus surge levels along Bantry Bay (Figure 5.6). It is apparent that the water level does not increase consistently as the tide progresses up the bay for the 50%AEP event, as the level at point S5 is greater than at S6. This is likely to be due to the local variation in seiche along the bay assessed as part of the ICPSS. Additionally, the 50%AEP water level profile differs from the 0.5%AEP water level profile because the different ICPSS points have different extreme value analysis for the larger magnitude events.

As a reality check, the ICPSS profiles were compared to the MHWS water profile from the Admiralty Prediction points at Castletown Bearhaven and Bantry to verify the typical trend. Both the MHWS and 0.5%AEP ICPSS profile agree with each other, estimating a 0.2m increase in water level between Castletown Bearhaven and Bantry. Therefore, the ICPSS profiles were deemed to be acceptable and were used to inform the design total tide plus surge levels in Bantry Bay.

Figure 5.6: Water Level Profile in Bantry Bay



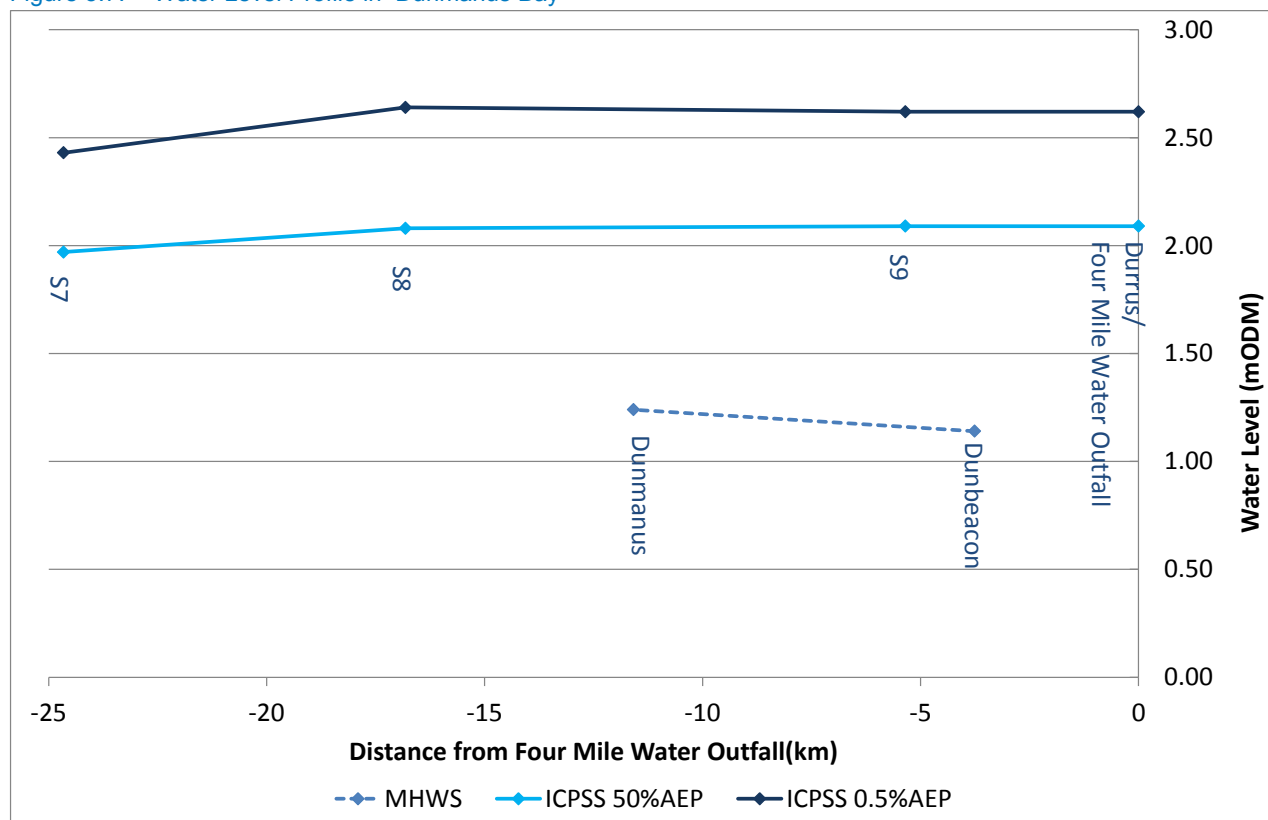
Bear Island and Whiddy Island are expected to modify the tidal currents from Bantry Bay to Castletown Bearhaven and Bantry AFAs respectively. However, the long term record at Castletown Bearhaven was used in the derivation of the ICPSS model. Therefore, ICPSS point S3 is considered to be broadly representative of water levels within the haven. There is no tidal gauge data at Bantry Harbour to confirm any variation in water level around Whiddy Island. However, it is not expected that water levels at Bantry Harbour would differ significantly from ICPSS point S6 because the tidal channel is relatively wide and would not provide excessive constriction to the tide. Therefore ICPSS point S6 is considered to be broadly representative of water levels at Bantry.

Dunmanus Bay (Durrus AFA)

No coastal flood risk was identified at Durrus AFA during the Flood Risk Review as the town is situated 1km upstream of the open sea on Four Mile Water and is largely protected from storm surges and waves by Rossmore Point and Murreagh. However, appropriate water levels have been derived as follows to define the coastal conditions for the fluvial dominant flood in Durrus.

The ICPSS has derived total tide plus surge levels along Dunmanus Bay and then have been compared with the MHWS profile derived from Admiralty prediction points in the bay (Figure 5.7).

Figure 5.7: Water Level Profile in Dunmanus Bay

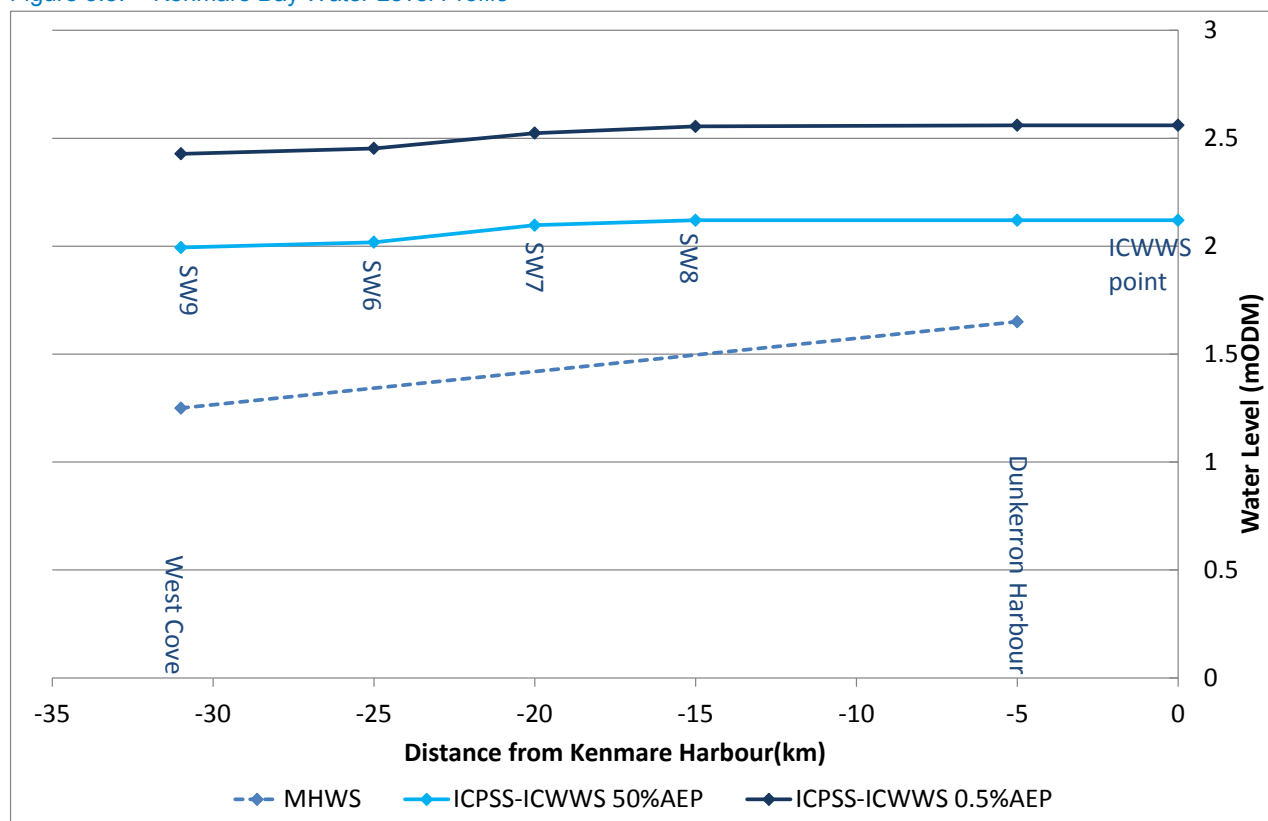


All the water level profiles indicate a flat to slightly negative trend in water level as the tide progresses up Dunmanus Bay. The ICPSS extreme water level profile was selected for the design scenario to be consistent with these national studies. Therefore, ICPSS point S9 has been used to inform coastal conditions at the outfall of Four Mile Water for Durrus AFA.

Kenmare AFA

In Kenmare, the RPS offshore model has been used to calculate extreme total tide plus surge levels up to Rossmore Island (SW8), which is some 14km offshore from Kenmare. There is no tidal gauge data at Kenmare. However, the recent ICWWS analysis, which is based on the RPS model for water levels, assumes the same water level as SW8 for scenario when wave heights are at a minimum. Therefore, the RPS offshore model would suggest a flat water level profile upstream of SW8. On the other hand, the analysis of the mean high water spring water level profile between admiralty prediction points in Dunkerron Harbour and West Cove indicates a 0.4m increase in water level as the tide progresses up Kenmare Bay. These two water level profiles are compared in Figure 5.8. The ICPSS-ICWWS extreme water level profile was selected for the design scenario to be consistent with these national studies.

Figure 5.8: Kenmare Bay Water Level Profile

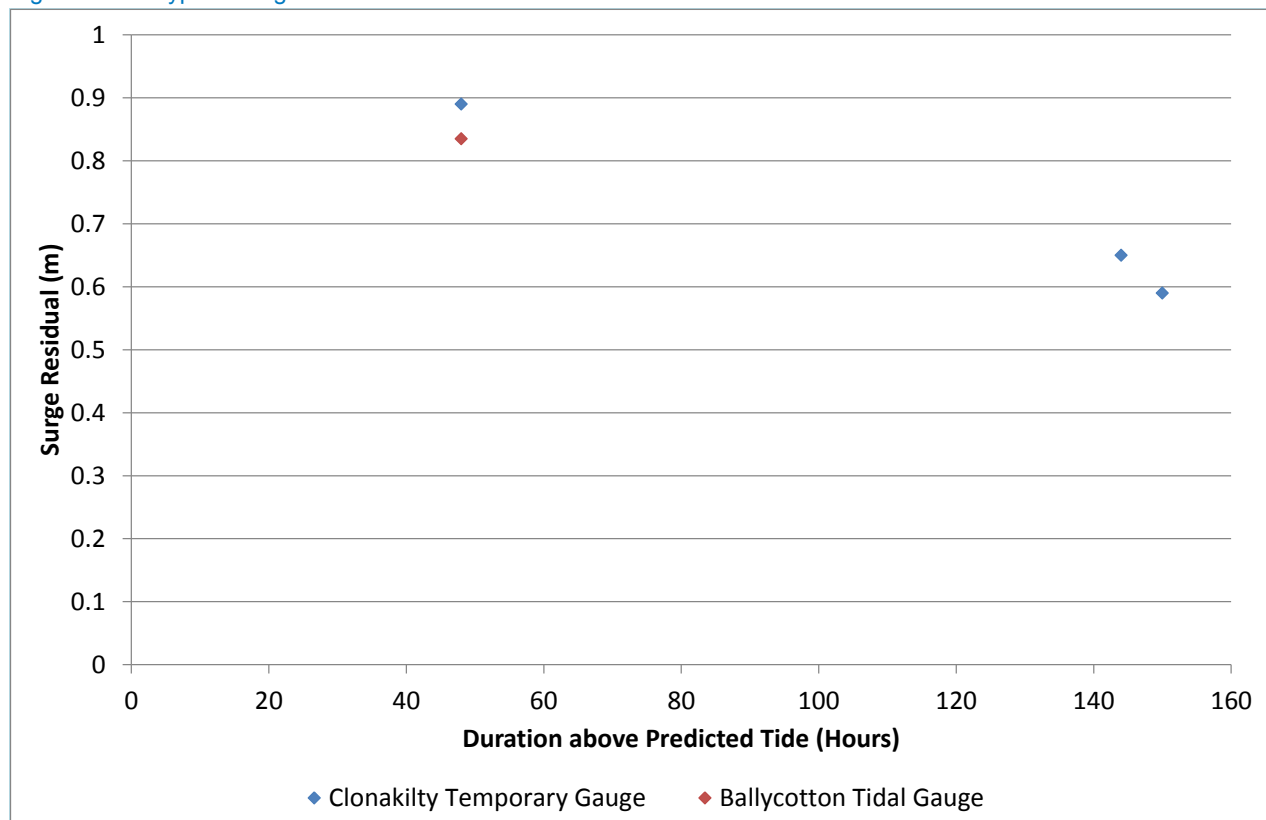


5.5.2 Design Tidal Curve

The shape of the astronomic curve defines the duration of the rising (flood) and falling (ebb) tide. In deep water the astronomic curve can be assumed to be largely symmetrical, depending on the relative phasing of the various harmonic components. However, the shoaling of the tide in shallow estuarine areas can modify the shape.

The admiralty tide tables² were used to inform time differences in mean high water and low water between the primary port (Cobh) and the local prediction points at Castletown Bearhaven, Bantry, Dunkerron Harbour and Dunmanus Harbour to modify the astronomic tidal curve. Storm surges caused by Atlantic storms can often cause elevated sea levels over several diurnal tidal cycles. Surge residuals were calculated from the tidal gauge data along the south west coast for the most extreme events (Figure 5.9). The larger surge residual has a total duration of approximately 48 hours or 4 tidal cycles. The 48 hour duration has been assumed as a credible duration for an extreme surge event and a symmetrical surge profile assumed in the absence of a detailed gauge with recorded surge residuals.

Figure 5.9: Typical Surge Duration in South West Ireland



² United Kingdom Hydrographic Office (2013) Admiralty Tidal Tables Volume 1, 2013.

The design surge profile was then standardised by the peak surge residual and scaled on top of the astronomic curve to achieve the design extreme sea levels (Figure 5.10). It was assumed that the peak of the surge and the peak of the spring astronomical high tide coincide. This provided a conservative estimate of the combined tidal curve. It is recognised that the peak of the astronomic tide does not necessarily correspond with the peak surge as they are governed by different mechanisms. However, without long term tidal and surge residual data along the South West coast it is not possible to assess the joint probability between these two elements

Figure 5.11 displays the combined tidal curves for the design 50%AEP event in UoM21.

Figure 5.10: Example Tide Plus Surge Curve Generation at Castletown Bearhaven

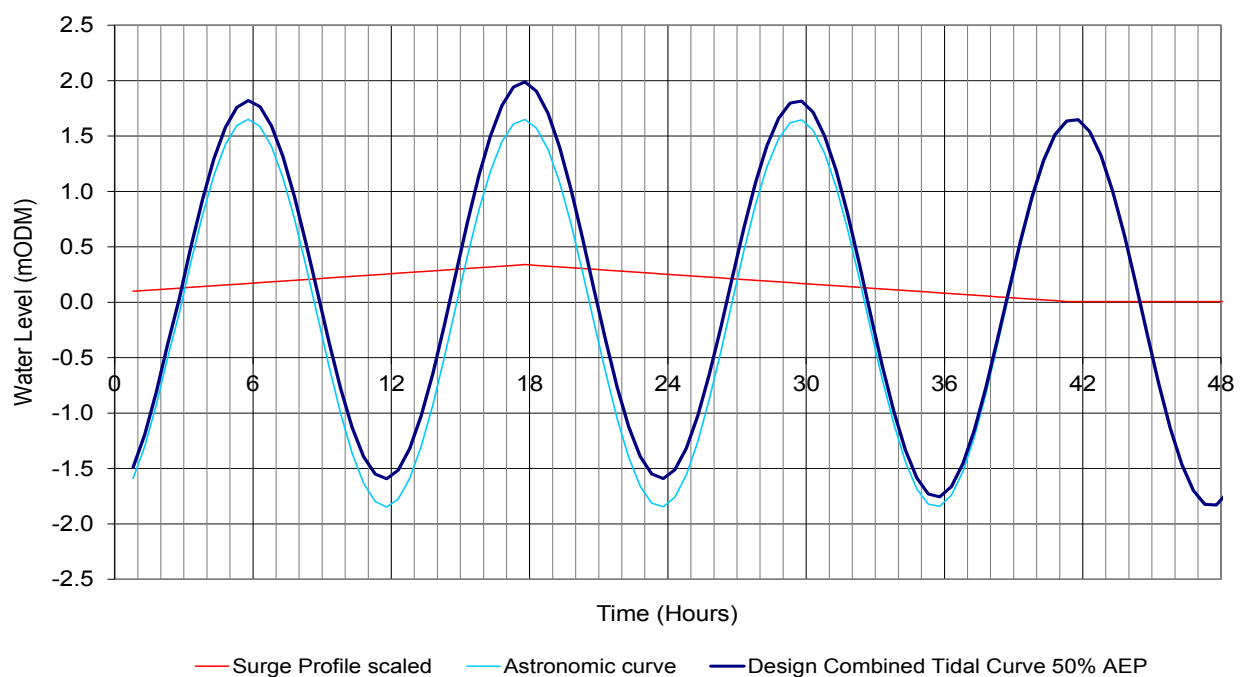
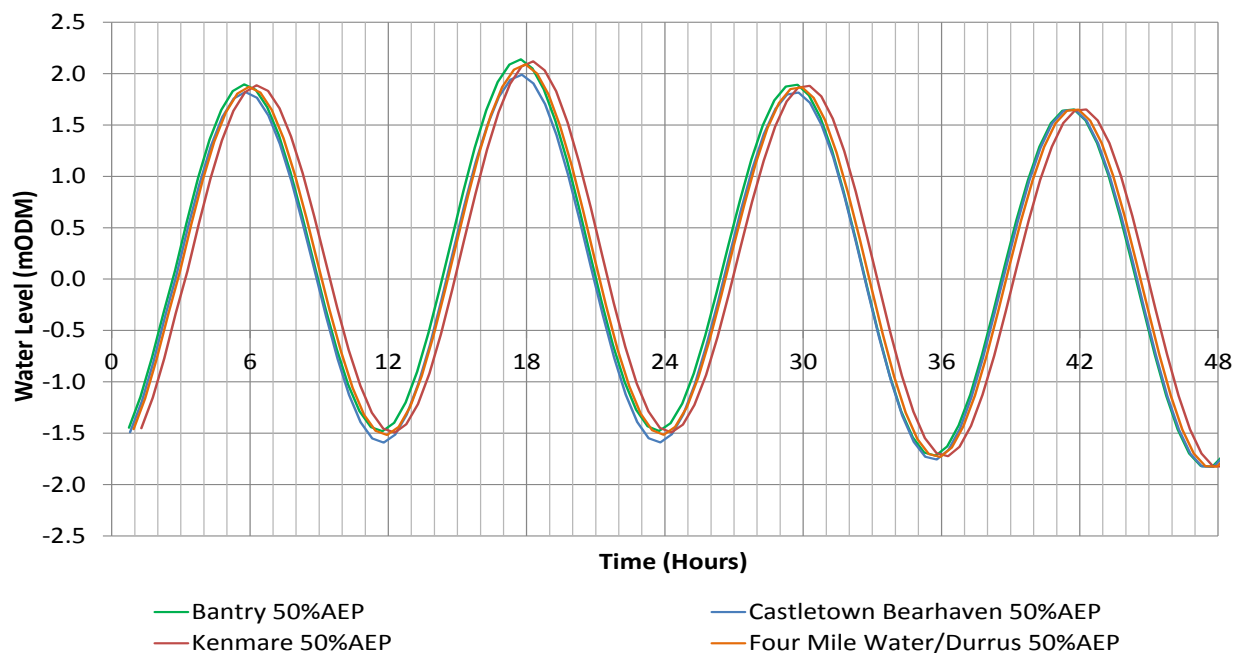


Figure 5.11: 50%AEP Design Total Tide Plus Surge Curves



5.5.3 Wave Overtopping

The ICWWS identified two AFAs that were potentially vulnerable to wave overtopping in UoM21, namely Castletown Bearhaven and Kenmare Harbour.

The source-pathway-receptor model can be readily applied to wave overtopping.

- Source – wave overtopping volumes based on wave run-up spilling over the coastal frontage
- Pathway – flow path of the wave overtopping discharge from the coastal defence to the receptors considering topography behind the defence.
- Receptors – roads, properties, environmental designations etc. affected by the wave overtopping and their relative location to the wave overtopping.

A screening process was undertaken for the vulnerable reaches and three approaches to assessing wave overtopping were developed for the CFRAM study:

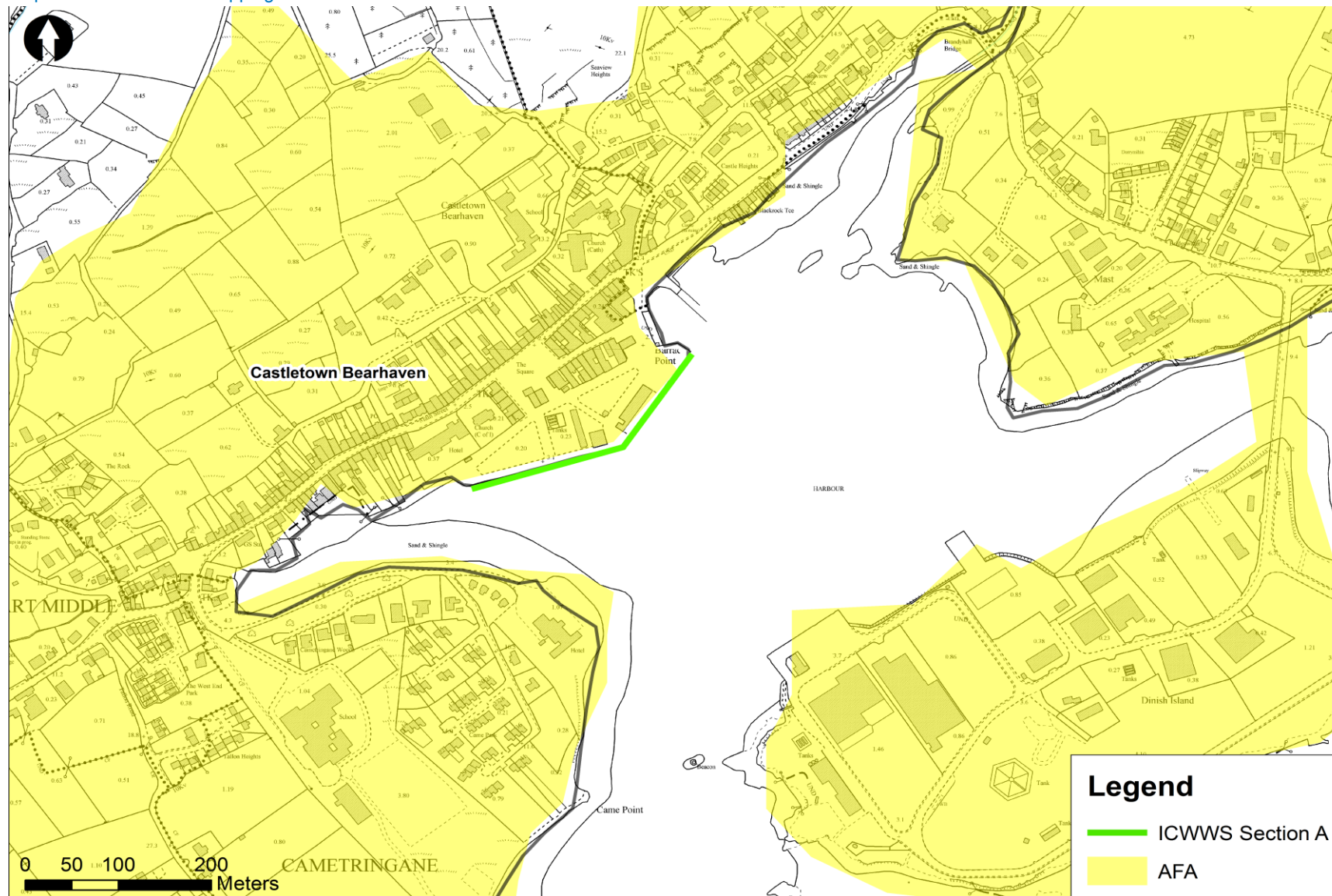
- Wave overtopping unit discharges – the calculation of unit discharge is sufficient to inform flood risk where wave overtopping volume is insufficient to flow down the backslope of coastal defences or the water would immediately drain back to the sea due to high relief inland.
- Mapping of wave overtopping volumes – the mapping of total wave overtopping volumes is required where wave overtopping discharges are able to flow down the backslope of coastal defences to affect receptors, often in locations where the defences are above the coastal floodplain.
- No consideration of wave overtopping – wave overtopping calculations are not required where still water overtopping (Mechanism 1) dominates as the additional volume from wave overtopping can be considered negligible in comparison with the limitless volume of the incoming tide.

The ICWWS split Castletown Bearhaven into one section and Kenmare into three sections of similar crest height and defence type (Map 5.2 and Map 5.3). Table 5.5 outlines the approach for each section based on the criteria above.

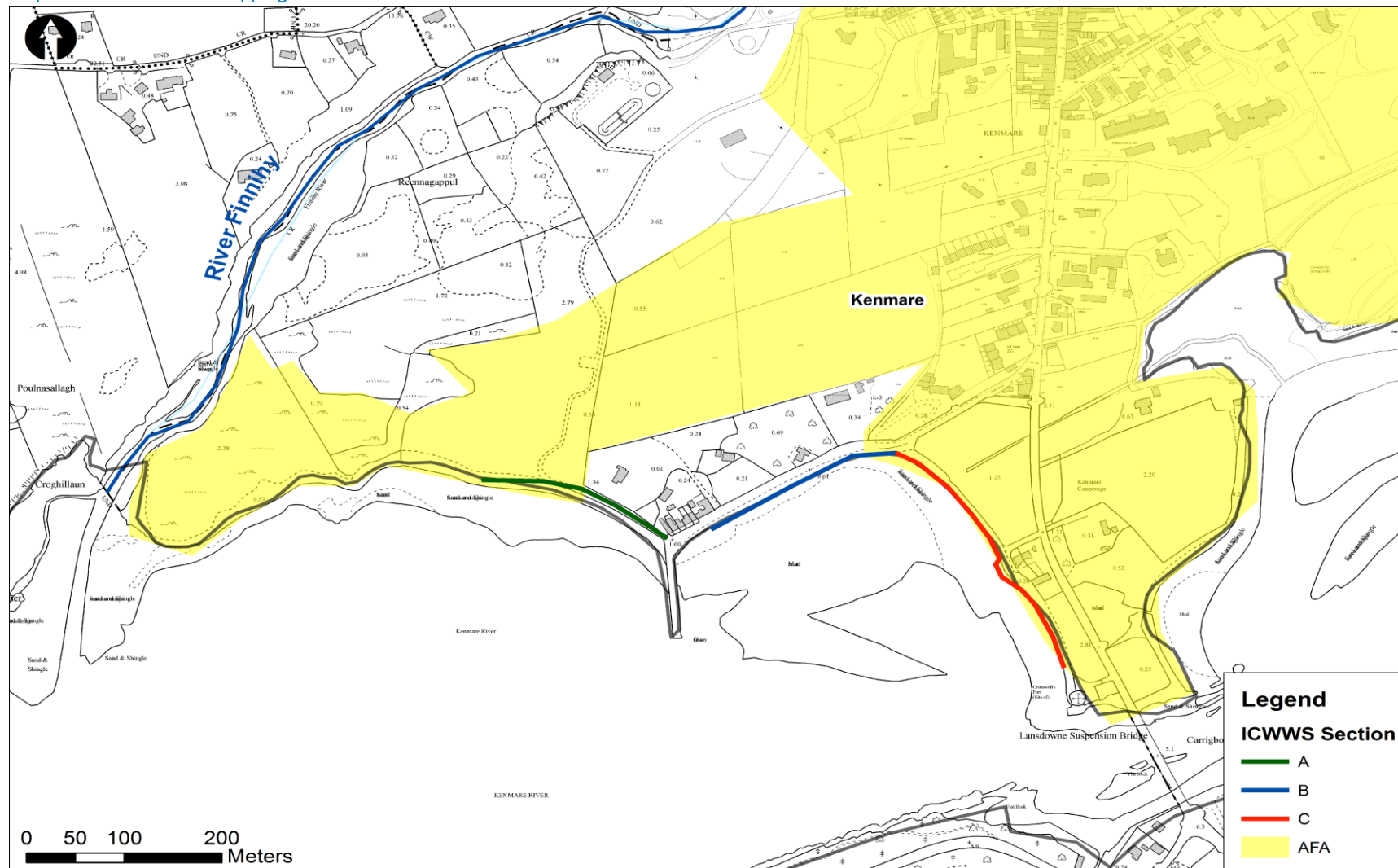
Table 5.5: Wave Overtopping Approach

Reach	Source	Pathway	Receptors	Approach
Castletown Bearhaven A	Wave overtopping of a vertical concrete wall	Flows across quay and down roads towards Main Street	Road adjacent. Properties located downslope.	Mapping of wave overtopping volume for relevant scenarios.
Kenmare A	Wave overtopping of a shingle slope leading to road/track with groynes	Flows along road/track and potentially across flat agricultural land inland.	Road and agricultural land adjacent.	Mapping of wave overtopping volume for relevant scenarios.
Kenmare B	Wave overtopping of a vertical concrete wall	Flows along the road drains immediately back to the sea	Road and a few properties adjacent. Majority of properties located upslope.	Mapping of wave overtopping volume for relevant scenarios
Kenmare C	Wave overtopping of a shingle slope leading to grassed bank	Flows away from grass embankment to low-lying agricultural land inland.	Agricultural land and a few properties adjacent.	Mapping of wave overtopping volume for relevant scenarios.

Map 5.2: Wave Overtopping Sections at Castletown Bearhaven AFA



Map 5.3: Wave Overtopping Sections at Kenmare AFA



The wave overtopping discharges were calculated for the sections using empirical equations of wave run up for vertical walls, and general hydraulic principles to fully account for the transition from the valid limit of the empirical equations (Mechanism 2) to full still water overtopping (Mechanism 1). The six different combinations of total tide plus surge levels and wave heights from the ICWWS were assessed to find the critical scenario for wave overtopping for each AEP. Table 5.5 summarises the critical discharges for the target %AEP events. Full details of the analysis for all scenarios can be found in Appendix C.

Table 5.6: Critical Wave Overtopping Unit Discharges for Key %AEP

Reach	Section	Defence Type	Effective Crest Level (mODM)	Unit Discharge (l/s/m)		
				10%AEP	0.5%AEP	0.1%AEP
Castletown Bearhaven	A	Concrete vertical wall	3.03	<0.01	0.03	0.18
Kenmare	A	Shingle slope leading to road/track with groynes	2.34	19.96	Still water overtopping	Still water overtopping
Kenmare	B	Concrete vertical wall	2.43	0.20	Still water overtopping	Still water overtopping
Kenmare	C	Shingle slope leading to grassed bank	2.45	3.29	Still water overtopping	Still water overtopping

Castletown Bearhaven was found to be at limited flood risk from wave overtopping with only 0.18l/s/m overtopping the quay in the extreme 0.1%AEP event. Such small volumes of overtopping would produce less the 0.1m depth of flooding which is likely to drain immediately back to sea or be drained by the local surface water system. The rate of overtopping for the current scenario should be considered in the health and safety requirements of the quayside operation. The rate of overtopping increases to significant volumes for the mid-range scenario therefore; the mid-range future scenario will be mapped.

Up to 20 l/s/m overtops the shingle beaches and quayside at Kenmare Harbour in the smaller events such as the 10%AEP event. The wave overtopping volumes will be mapped in the subsequent hydraulic modelling and mapping report for the 10% to 5%AEP events where there are significant volumes of overtopping but not still water overtopping. The Kenmare sections were dominated by still water overtopping from the extreme total tide plus surge level in the 2%AEP and larger magnitude events. Therefore, further analysis of wave overtopping for the future scenarios is not required.

6 Hydrological Calibration, Sensitivity Testing and Uncertainty

6.1 Calibration Events

6.1.1 Selection of Events

Historical flood evidence was collated for those events listed in Chapter 4 from post-flood surveys and anecdotal evidence was collated from local residents during the Flood Risk Review. Table 6.1 scores each of these events based on a number of criteria related to the location, hydrology and data availability on a scale of 0 to 3 where:

- 0 is not available
- 1 is poor or unlikely
- 2 is fair or possible
- 3 is good or likely

These scores are then combined to create an indicative calibration score for the available historical flood evidence in accordance with Guidance Note 23³. The following events have been considered for the calibration based on the indicative calibration score:

- 23rd October 2008 – extreme fluvial event in Kenmare.
- 17th October 2012 – extreme tidal event and surface water/fluvial event in Bantry.

There is a long record of flow data at Inchiclogh gauge (35 years) which covers a number of events. However, the severe 1981 and 1983 events were largely caused by pluvial flooding and tidal backwater, affecting the urban drainage systems. Modelling of the urban drainage network is beyond the current scope of the CFRAM Studies. The Inchiclogh gauge itself forms the inflow to the hydraulic model therefore hydrological calibration is not necessary. Despite the long record of flow at Inchiclogh, there were no date-specific wrack marks, extents, photos or reports of areas flooded, nor any information from interviewees that could be used to support full model calibration for any of the other historic fluvial events in the Mealagh catchment. However, floodmaps.ie reports of recurring flooding at Lahadane will be used to check the relative frequency of flood extents in the Mealagh catchment.

The calibration in Bantry, Kenmare, Durrus and Castletown Bearhaven will be supplemented by verifying the modelled outline such that there is “reasonable” representation of the historical flood frequency and sensitivity analysis on the key hydraulic parameters used in accordance with GN23.

³Jacobs, (January 2013) Guidance Note 23 Model Calibration. Version 1.

Table 6.1: Selection of Calibration Events

Event	Location/ Watercourse	Likely Accuracy of Flow Estimate ¹	Likely Accuracy of Gauged Level Estimate	Known Hydraulic Conditions ²	Likely Accuracy of Spot Levels ³	Reliable Flood History ⁴	Indicative Calibration Score	Calibration Approach
13/12/1981	Bantry/Bantry Stream and Coastal Castletown Bearhaven/Coastal	1	0	1	1	2	5	Catchment changes since 1981 particularly with the urban drainage network. Modelled outline to reflect reasonable historic flood frequency, otherwise use sensitivity tests to assess hydraulic parameters.
31/01/1983	Bantry/Bantry Stream and Coastal	1	0	1	1	3	5	Catchment changes since 1983 particularly with the urban drainage network. Modelled outline to reflect reasonable historic flood frequency, otherwise use sensitivity tests to assess hydraulic parameters.
05/11/2000	Bantry/Bantry Stream and urban drainage	1	0	1	0	0	2	Insufficient evidence for this event to calibrate flood level and extent beyond channel. Use sensitivity tests to assess hydraulic parameters.
28/10/2004	Bantry/Bantry Stream and urban drainage	1	0	1	0	0	2	Insufficient evidence for this event to calibrate flood level and extent beyond channel. Use sensitivity tests to assess hydraulic parameters.
23/10/2008	Kenmare/ Finnihy River	1	0	3	3	3	10	Calibrate main channel and coastal flood risk to large event data. Smaller tributaries in Kenmare should take note of uncertainties due to blockage.
17/10/2012	Bantry/ Coastal and urban drainage	1	0	3	3	3	10	Calibrate main channel and coastal flood risk to large event data. Smaller tributaries within the Bantry catchment and the Mealagh catchment should take note of uncertainties due to blockage.

Note 1: 3 = gauged flows are available in the catchment, 2 = gauged flows used from pivotal gauges nearby, 1 = rainfall data used to estimate flows and 0= no flow estimate available

Note 2: Hydraulic conditions relate to controls on water levels during a flood e.g. level of blockage, wall collapse etc.

Note 3: Levels during a known flood event NOT at a gauged location that represents a true flood level rather than a localised issue.

Note 4: Any information that includes date/time, precise location and mechanism of flooding.

6.1.2 Calibration Hydrology Approach

The following steps were undertaken to derive the hydrographs for the selected calibration events at ungauged HEPs:

- Transfer the representative rainfall profile from the hourly data at Valentia Observatory to the AFA based on the ratio of the 24hour rainfall total at each AFA.
- Derive the FSSR16 catchment average rainfall parameters for the gauged catchment from DDF and adjust based on the recorded soil moisture deficit.
- Estimate the flow hydrograph at the gauge using the FSSR16 equations.
- Adjust the phasing of the ungauged HEPs to achieve the flood levels at reliable points.

23rd October 2008

For the October 2008 event, the total rainfall at daily rain gauge 1903 located in Kenmare was compared with the rainfall recorded over 19 hours at Valentia Observatory (Table 6.2).

Table 6.2: Transfer of Rainfall for October 2008 Event

Location	Total Recorded Rainfall 23 rd October 2008 (mm)	Ratio to Valentia Observatory	DDF %AEP Estimate for 19 Hour Duration Event
Valentia Observatory	44.8	N/A	> 50%AEP
Kenmare	50.1	1.12	> 50%AEP
Bantry	36.1	0.81	> 50%AEP

The amount of rainfall in both locations was very similar but was estimated to have a greater than 50%AEP according to the Depth Duration Frequency (DDF) estimate. The application of Theissen polygons was considered but rejected as there was insufficient gauge data to accurately model the variation of rainfall across UoM21 (Map 4.1).

However, the soil moisture deficit records at Valentia Observatory indicated that soils in Kenmare were fully saturated prior to this event. The rainfall profile from Valentia was transferred and applied to the Inchiclogh gauge and calibrated to the recorded flow (Figure 6.1). The percentage runoff was increased up to 75% as a feasible limit of overland flow given the saturated conditions. The time to peak (Tp) was reduced by 20% to 3.7 hours to achieve the gauged flow. All other rainfall runoff parameters were as the design parameters.

The calibrated percentage runoff of 75% was transferred to Kenmare along with the scaled rainfall profile based on Table 6.2. The Tp will differ catchment to catchment based on the time to concentration and therefore it was not applicable to adjust the Tp from Inchiclogh to the hydrologically separate and remote catchment at Kenmare. The resultant hydrograph for the River Finnihy is presented in Figure 6.2.

The corresponding parameters (Table 6.3) will be applied to each of the HEP inflows to the hydraulic models with the transferred event rainfall profile. Phasing of the hydrological inflows will be adjusted in combination with the hydraulic parameter calibration in order to achieve the reported flood levels, extents and mechanisms for this event.

Figure 6.1: Calibrated FSSR16 Hydrograph at Inchiclogh Gauge for 23rd October 2008

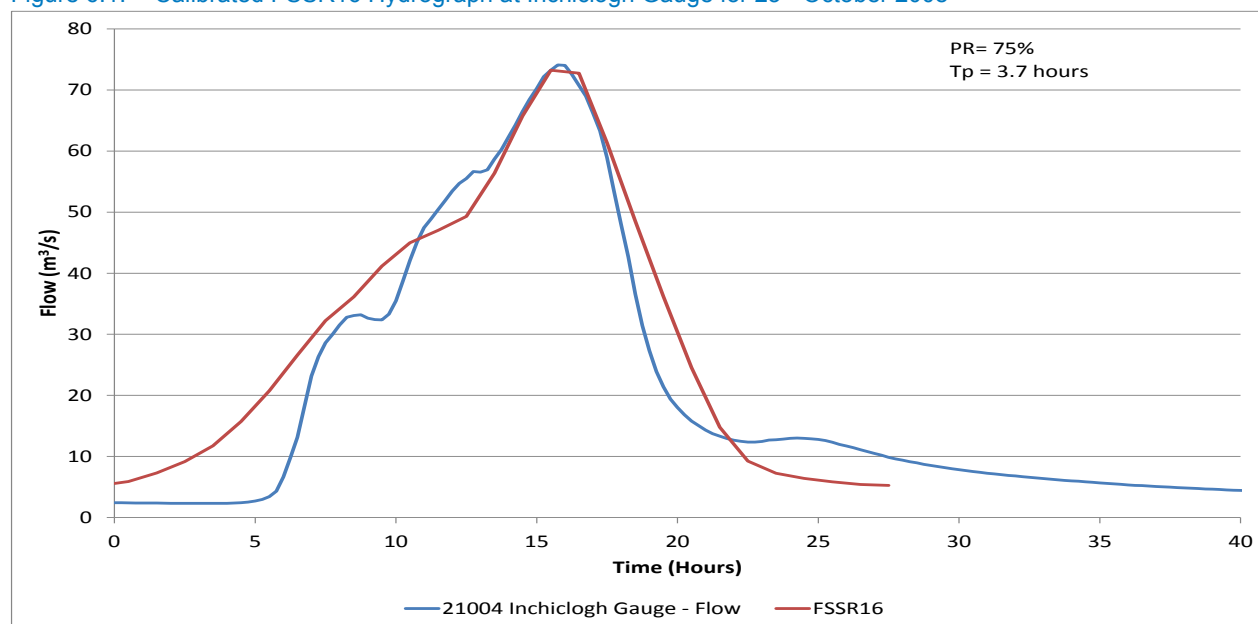


Figure 6.2: Estimated Hydrograph at Kenmare for 23rd October 2008

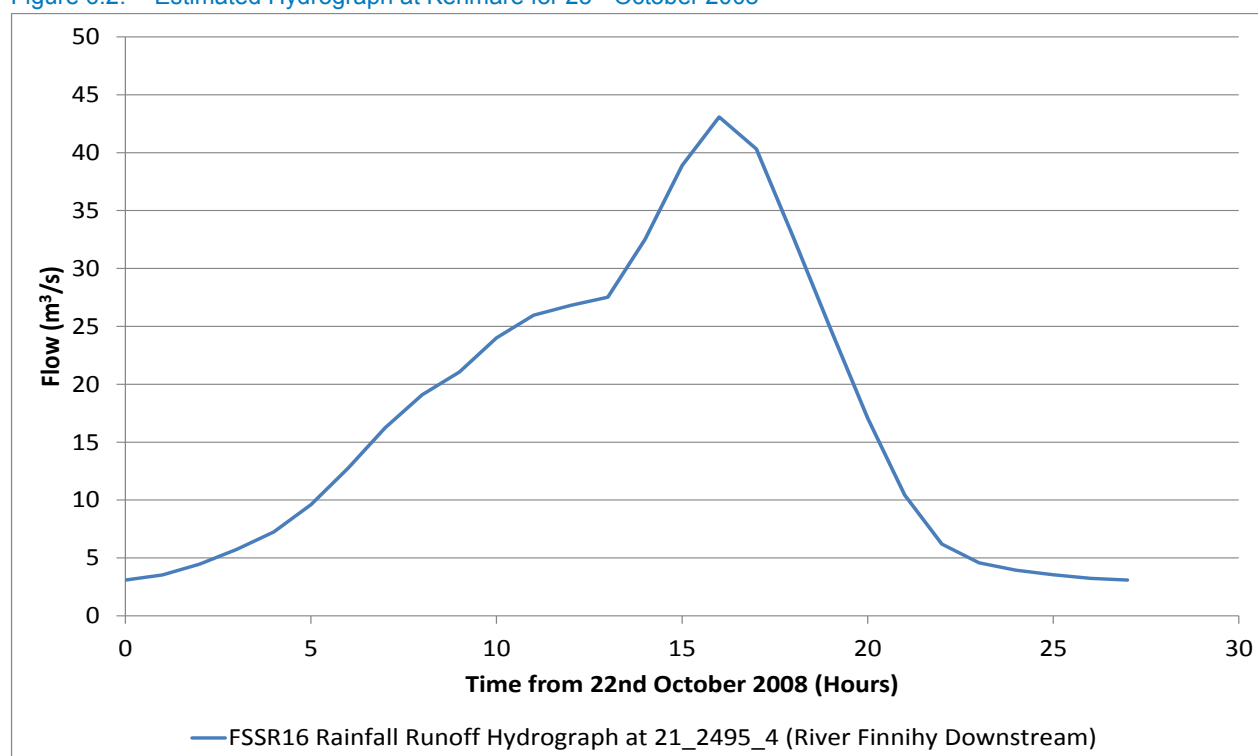


Table 6.3: Estimated FSSR16 Parameters for 23rd October 2008

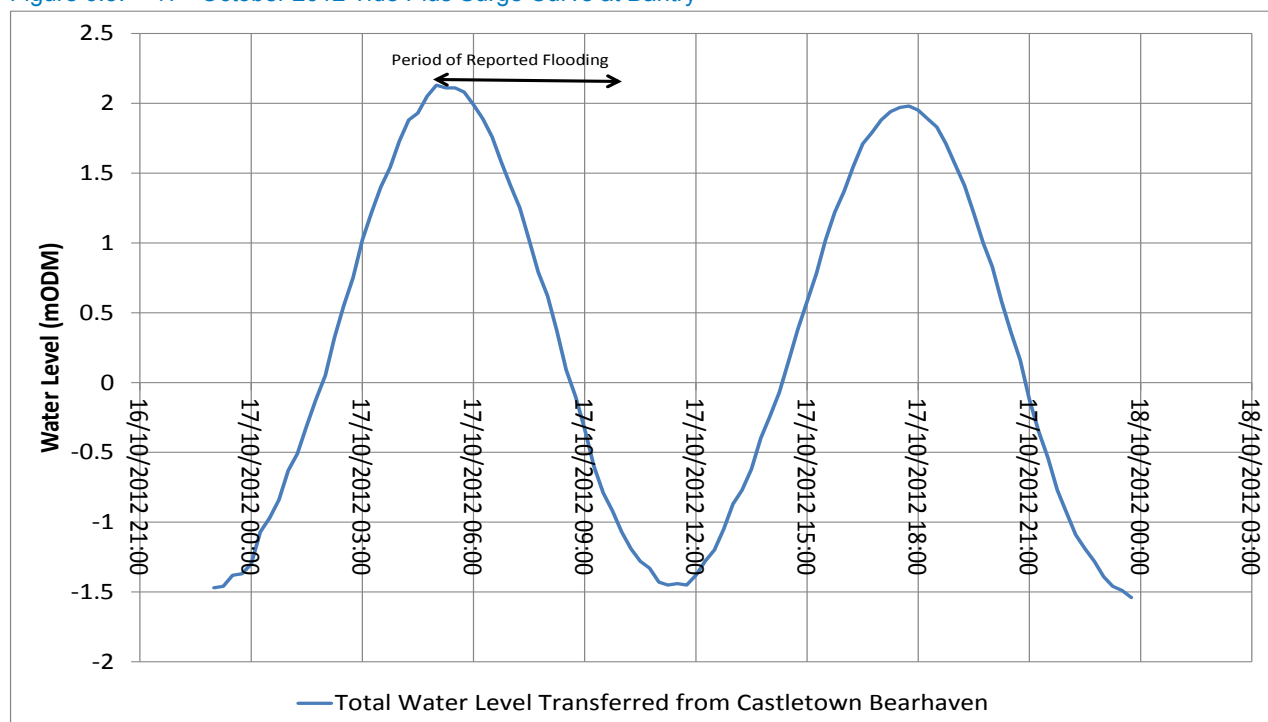
FSSR 16 Parameter	Kenmare HEPs
M5 - 2 day (mm)	122.3
M5 -25 day (mm)	428.8
Jenkinson's <i>r</i>	0.180
Catchment Wetness Index (CWI)	125
Standard Percentage Runoff	75%
Storm Duration, D (hours)	19

The lack of river flow data or local hourly rainfall data within the Finnihy catchment limits the confidence in the rainfall-runoff generated hydrograph. However, the calibration of rainfall parameters at the nearby Inchiclogh gauge provides a conceptual calibration for Kenmare. More detailed rainfall data and river flow/level data would be required to validate the rainfall runoff parameters.

17th October 2012

For the 17th October 2012 tidal event, the recorded water level at Castletown Bearhaven tidal gauge was transferred to Bantry based on the design water level profile (Figure 6.3). A peak water level of 2.3mODM was estimated which is just less than the design 10%AEP total tide plus surge level. The %AEP estimate is broadly equivalent to anecdotal flood reports of tidal flooding along the quay in Bantry. There were no reports of river flooding for this event. Therefore in-bank flows have been applied for the fluvial inputs.

Figure 6.3: 17th October 2012 Tide Plus Surge Curve at Bantry



6.2 Sensitivity and Uncertainty Testing

The SW CFRAM study requires an understanding of sensitivity in hydrological and hydraulic parameters in order to inform the uncertainty analysis in the flood mapping process. The key areas of uncertainty in the hydrological analysis of UoM21 are:

- Uncertainty in the extrapolation of the rating curve at Inchiclogh Gauge;
- Uncertainty in the QMED rural regression equation;
- Uncertainty in the pooling group and statistical distribution used to estimate the flood growth curve;
- Uncertainty in the transformation of water levels up the bays.

Sensitivity in Flows

There is some uncertainty in the extrapolation of the rating curve at Inchiclogh gauge as discussed in the data review in section 3.2 of this report. The original EPA rating was used for the design hydrology as a conservative estimate. However the alternative extrapolation was used to inform the sensitivity to peak flow. QMED and the design peaks could be reduced as much as 25% based on the alternative extrapolation shown in Figure 3.1. Therefore, sensitivity to a 25% reduction in the 1%AEP target flow should be considered in the subsequent hydraulic modelling of the Mealagh catchment in Bantry AFA.

The FSU WP 2.3 states a factorial standard error (FSE) of 1.37 in the QMED rural regression equation based on the 190 gauges across Ireland used to derive the equation coefficients. Approximate 68% and 95% upper confidence limits for QMED were then calculated as follows:

$$68\% \text{ confidence limit} = QMED * FSE$$

$$95\% \text{ confidence limit} = QMED * FSE^2$$

The uncertainty in the flood growth curves and pooling groups selected for a sample of 85 gauging stations across Ireland was investigated as part of the FSU WP 2.2. The percentage standard error in design peak flow varied from 4.0 to 9.0 at the target fluvial 1%AEP.

The upper confidence limits from each source of peak flow uncertainty were combined to estimate overall uncertainty in design peak flow at the target 1%AEP for ungauged HEPs. This resultant upper limit of the 1%AEP flow was typically within 10% to 30% of the design 1%AEP peak flow (see Appendix C). Therefore, it was deemed that a sensitivity test of a 30% increase in peak flow at the target 1%AEP should be considered in the subsequent hydraulic modelling of all HEPs in UoM21.

Sensitivity in Transformation of Total Tide Plus Surge Level

Section 5.5.1 highlighted the following uncertainties in the design water level profiles:

- The assumed impacts of seiche in Bantry Bay cause differing water level profiles along Bantry Bay where water level does not increase progressively up the bay, and this effect differs for each of the %AEP events. Total Tide plus surge levels vary by up to $\pm 0.13\text{m}$.
- The MHWS profile in Kenmare Bay indicates a greater increase in water level up the Bay than the more extreme ICPSS water level profile. The MHWS profile shows an increase of 0.4m as opposed to the ICPSS increase of less than 0.13m .

GN 22⁴ recommends a sensitivity test that considers a 0.5 m increase in water levels for the design events, which is broadly equivalent to the mid-range future scenario. An increase of 0.5m would form a conservative estimate of the uncertainties in water level listed above.

⁴JBA (2012) CFRAM Guidance Note 22. Sensitivity Analysis.

7 Summary of Design Flows

The design flows from this hydrology report inform the inflows to the hydraulic model to assess flood risk from the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1%AEP fluvial and tidal flood events. The key hydrological findings for design flow in UoM21 are as follows:

- Historic flood events
 - Major flood events were identified in UoM21 since 1980 from both extreme storm surges and extreme rainfall and river flows.
 - The largest gauged event was on 5th August 1986 at Inchiclogh gauge, near Bantry. It was estimated to have a 1.6%AEP but no flooding of properties was reported.
 - More recent flooding in Bantry and Kenmare was reported to affect up to 40 properties. These events were estimated to have up to a 10%AEP and were caused by storm surges and the River Finnihy respectively.
 - There was no flood history identified in Durrus or Castletown Bearhaven.
 - The calibration in Kenmare and Bantry will be based on the following events where there is sufficient information:
 - 23rd October 2008 – extreme fluvial event in Kenmare.
 - 17th October 2012 – extreme tidal event and surface water/fluvial event in Bantry.
- Design flood flows
 - Peak flood flows were derived in the Finnihy, Mealagh, Bantry and Durrus catchments for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1%AEP events using the recommended FSU methodology outlined in Work Package 2.2 and 2.3.
 - The design flood hydrograph for ungauged HEPs was based on the FSSR16 rainfall runoff methodology which was scaled to the design peak flows from the FSU approach. The time to peak of the FSU UPO-ERR Gamma curve was not deemed representative of these wet rapid response catchments along the far west coast.
 - The design flood hydrograph at Inchiclogh gauge and the Mealagh catchment was based on the median width exceedance flood hydrograph which was derived from gauged data.
- Design coastal conditions
 - The design extreme sea levels were extracted from the ICPSS for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1%AEP tidal events. These levels were then transformed to Kenmare, Bantry, Castletown Bearhaven and Durrus based on available ICPSS data, ICWWS data and admiralty prediction points.
 - The astronomic curve and surge profile were derived from the admiralty predicted astronomic tide and typical duration of surge events in the South West.
 - The final design tidal curve was derived from the combined astronomic tide and design surge profile scaled to meet the design extreme sea levels.
- Uncertainty and Sensitivity
 - Flows at Inchiclogh gauge could be reduced by 25%, dependent on the extrapolation of the rating curve used. This 25% reduction in peak flow will inform the sensitivity tests in the Mealagh catchment.
 - The uncertainty of the 1%AEP target peak flow was estimated to range up to +30% for UoM21 ungauged HEPs which will inform the sensitivity tests in the hydraulic modelling.
 - The water level profiles in Kenmare, Bantry and Dunmanus Bays have a reasonable level of uncertainty associated with them given the lack of gauge data to verify the progression of the tide up

these ria-like estuaries. Therefore, a 0.5m increase in water level was recommended in accordance with GN22.

Table 7.1 and 7.2 provide the design peak flows and total tide plus surge levels respectively. These flows and levels are subject to change following the subsequent integration into the hydraulic model and calibration processes.

Table 7.1: UoM21 Design Peak Flood Flows at Key Locations

HEP	Gauge	50%AEP (m³/s)	20%AEP	10%AEP	5%AEP	2%AEP	1%AEP	0.5%AEP	0.1%AEP
Bantry AFA									
21_5827_3	21004(Inchiclogh gauge)	87.5	106.8	120.6	135.3	157.1	176.0	197.3	258.5
21_6258_3	Mealagh downstream	96.8	118.1	133.3	149.6	173.7	194.5	218.1	285.7
21_7225_2	Bantry downstream	6.4	8.2	9.4	10.6	12.1	13.2	15.8	16.9
21_7668_2	Dromacoosane downstream	2.7	3.4	3.9	4.4	5.2	5.8	6.6	8.8
Castletown Bearhaven AFA –No fluvial flood risk was identified so design flows are not required.									
Durrus AFA									
21_8044_2	Four Mile Water Downstream	17.0	21.2	24.2	27.4	32.2	36.3	40.9	54.3
21_6225_2	Ahanegavanagh stream	6.2	7.7	8.7	9.8	11.5	12.9	14.5	19.1
Kenmare AFA									
21_2495_4	Finnihy downstream	37.2	46.1	52.5	59.3	69.4	78.1	88.0	116.4
21_6311_3	Lissaniska downstream	3.0	3.8	4.296	4.9	5.7	6.4	7.2	9.5

Table 7.2: UoM21 Design Total Tide Plus Surge Levels

Location	Location	50%AEP (mODM)	20%AEP	10%AEP	5%AEP	2%AEP	1%AEP	0.5%AEP	0.1%AEP
Kenmare	ICPSS Point SW8	2.12	2.22	2.28	2.35	2.43	2.49	2.56	2.70
Castletown Bearhaven	ICPSS point S3	1.99	2.09	2.16	2.22	2.31	2.38	2.45	2.60
Bantry	ICPSS point S6	2.14	2.25	2.33	2.42	2.52	2.60	2.68	2.86
Durrus	ICPSS point S9	2.09	2.20	2.28	2.36	2.46	2.54	2.62	2.79

8 Considerations for Hydrological and Hydraulic Model Integration

8.1 Integration of Inflows

Design hydrographs have been derived at HEPs to represent the hydrological processes across the Bantry, Durrus and Kenmare AFAs as discussed in Chapter 5 of this report. The HEPs will be integrated with the subsequent hydraulic models as follows:

- Point inflows at the upstream model extents;
- Point inflows at key tributary inflows;
- Lateral inflows representing the inflow from the intervening areas between target HEPs.

The point inflows representing the upstream model extents and tributary inflows will be integrated with the relevant cross-sections in the hydraulic model accounting for a significant displacement from the HEP calculated location. The lateral inflows will be integrated with the relevant cross-sections at locations which fit the following criteria:

- Natural inflows from minor watercourses which are not considered explicitly within the hydrology;
- Overland flow paths identified from surveyed low points in the river bank and site walkover.

The lateral inflows will be calculated from the difference between the design flow hydrographs from the upstream and downstream HEPs for a reach. The resultant hydrograph will be distributed evenly across those locations where the contributing area increases linearly downstream, or area-weighted where the contributing area increases disproportionally downstream.

Table 8.1 outlines the total number of inflows based on the criteria above for each model. These will be further refined and discussed in the hydraulics report.

Table 8.1: Model Inflows

Model	Number of Inflows
Bantry	22
Durrus	6
Kenmare	8
Castletown Bearhaven	N/A Coastal only

In order to enhance the modelling outputs and ensure hydrological continuity along the larger catchments, the hydraulic models will be calibrated to the design peak flows derived at the target HEPs. The hydrological inflows will be iteratively scaled and phased such that the hydraulic model maintains the design peak flows along the reach as part of the hydraulic modelling process. However, it should be noted that the design fluvial flows do not consider the following hydraulic processes:

- Backwater effect at confluences;
- Exchange of flows between tributaries at confluences; and,
- Significant modification to the hydrograph shape due to floodplain attenuation and /or hydraulic structures.

Therefore, it is not appropriate to calibrate the hydraulic model to HEPs upstream of confluences where there are significant out-of-bank flows.

In UoM21, the design storm duration has been derived from the time to peak and SAAR applying the FSSR16 approach. This was adjusted to produce the critical storm duration for each AFA assuming a single design storm event which is appropriate, as rainfall does not physically vary throughout these small coastal catchments (< 30 km²).

8.2 Integration of Downstream Conditions

The downstream conditions for each model will be as outlined in Table 8.2 to fully account for the relevant fluvial and tidal backwater effects as appropriate.

Table 8.2: Downstream Boundary Conditions

Model	Downstream Condition
Bantry	Full tidal boundary at the downstream of the Mealagh, Bantry and Dromacoosane catchments using the design tidal curves set out in Chapter 5.
Castletown Bearhaven	Full tidal boundary along the coast/haven using the design tidal curves set out in Chapter 5.
Durrus	Full tidal boundary at the downstream of Four Mile Water using the design tidal curves set out in Chapter 5.
Kenmare	Full tidal boundary along the coast and at the downstream of the River Finnihy using the design tidal curves set out in Chapter 5.

An iterative approach will be used to phase the design tidal curves so that the peak tide coincides with the peak flow in Bantry, Durrus and Kenmare as a conservative estimate of flood risk.

9 Hydrogeomorphology

9.1 Approach

The hydrogeomorphological processes ongoing in the river channels can have a significant impact on flood flows and the resultant flood risk. The assessment of hydrogeomorphological features focuses on whether the processes appear to be in equilibrium and whether there are any processes taking place at present which are likely to affect the flood risk indicators. This may include:

- Recent interventions to the channel/hydrology to control flood risk which have accelerated erosion or deposition;
- The use of inappropriate bank protection which may transfer erosion downstream; or
- Straightening or reprofiling the channel which may cause the watercourse to attempt to revert back to a more natural state.

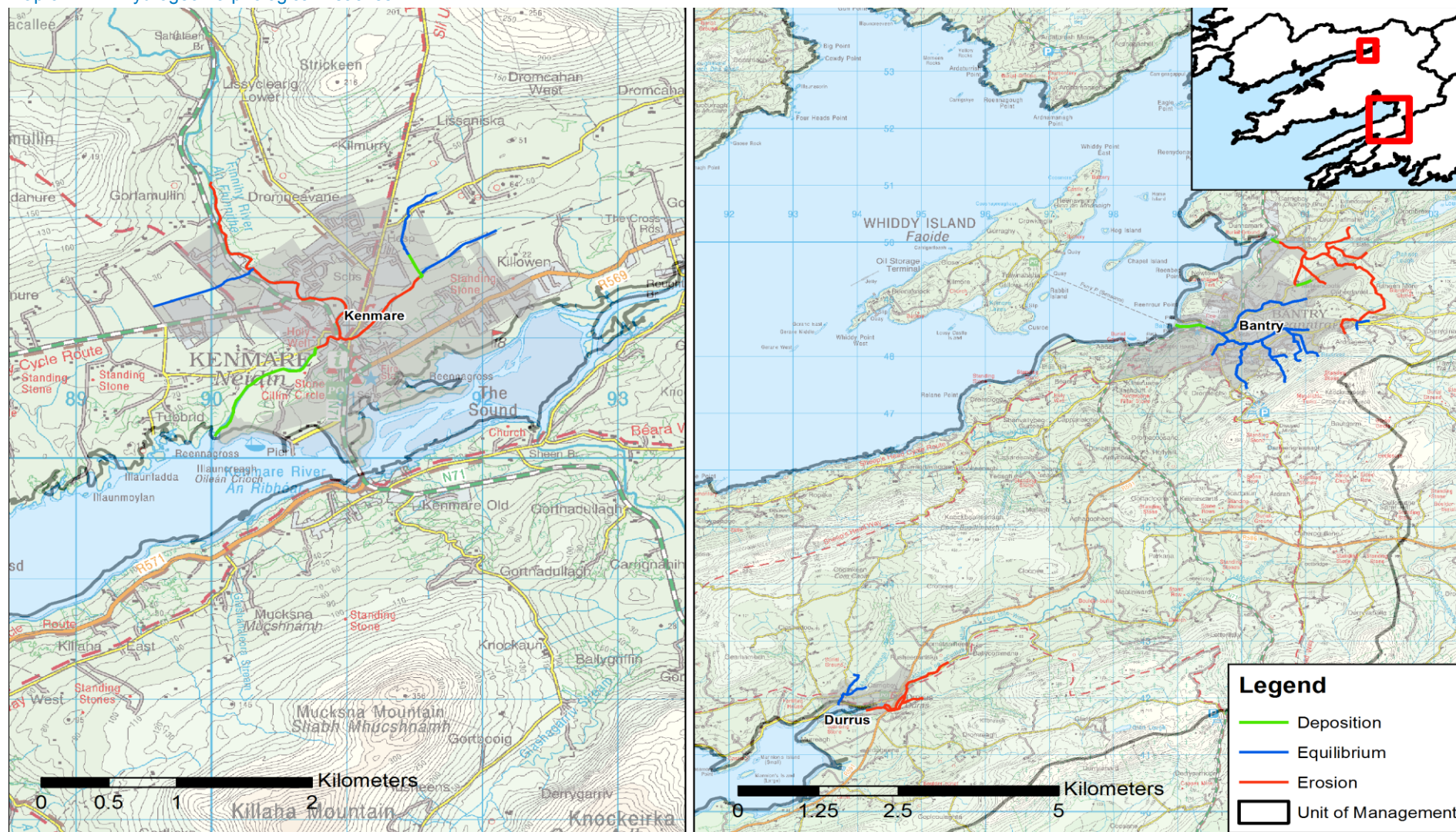
This has included an assessment of:

- Typical land use, soils and geology as provided in Chapter 2;
- Channel gradient based on the river channel survey;
- Bank and bed material and condition based on site visits, aerial photographs and survey photographs;
- Channel planform based on Ordnance Survey maps and aerial photography; and
- The presence of structures (bridges, weirs, culverts) /channel modifications (e.g. straightening, bank protection, bank reprofiling).
- The survey data and photographs are provided in the separate survey report.

9.2 Assessment

The HPWs were split into broad reaches of similar hydrogeomorphological characteristics based on the approach above, and an assessment made on the current erosion and deposition features (Map 9.1).

Map 9.1: Hydrogeomorphological Reaches



River Finnihy Catchment

Photo 9.1: Creamery Bridge, Kenmare



Captured: 07/03/2013

The River Finnihy and its tributaries the Lissaniska Stream and Gortamullin Stream are artificially constrained in their downstream reaches through Kenmare centre where the river channel has been walled and culverted under bridges and roads through the town centre. The rivers are very steep, flowing over large boulders and gravel-sized sediment upstream of Cromwell's Bridge. There is natural headward erosion and scour features at the waterfall on the River Finnihy, but this is at a slow rate given the resistant nature of the underlying geology. A number of in-channel gravel bar features were observed, particularly under the Creamery Bridge where the complex flows through the bridge and round the tortuous bends result in deposition in the areas of slack water. Downstream of Cromwell's Bridge, the gradient becomes

shallower and the river is tidally influenced resulting in the deposition of silts and fines between low and high tide. This deposition process forms sand bars at the outfall of the Finnihy into Kenmare Bay.

Gortamullin Stream drains an area of bog land and steep upland areas without much vegetation to prevent diffuse erosion. There were no excessive erosion or deposition processes observed at the time of this Study as the stream is very steep and has sufficient velocity to remove any sediment. The outfall of the downstream culvert is located above the Finnihy bed and no deposition issues were observed. However, there is the potential for an increased fine sediment load in this stream if the land use of the upper catchment were to change into the future.

The Lissaniska Stream drains an area of pastoral upland so there is a potential for diffuse erosion and introduction of fines although no active bank erosion was observed. The upper reaches are heavily vegetated and woody debris forms an important check on sediment and flows in channel. The debris also presents a blockage risk to small bridges downstream. The river is eroding its bed as it flows over steep boulders in the channel before depositing any fines in the online ponds of Scarteen Park, upstream of the town. However, it was not judged to be rapid based on the historic aerial photographs.

Bantry Catchments

The River Mealagh is largely natural and constrained by steep valley sides formed by the underlying resistant geology. Within the narrow floodplain, the river channel meanders across the low-lying floodplain although there were no signs of active bank erosion or meander migration at the time of this Study. However, there is an acute bend 200m downstream of the survey limit which increases velocities and erosion on the outside bend and flow inefficiencies on the inside bend. There were a number of in-channel deposition bars observed downstream of this point to Lahadane before the river flows over a natural waterfall at Dunmark Bridge. There is natural headward erosion and scour features at the waterfall but this was observed to be relatively minor given the resistant nature of the underlying geology.

Downstream of the waterfall, the river is tidally influenced and the fine sediment from the upland reaches and Bantry Bay are deposited in this reach with low velocities. On the tributaries, there was significant deposition observed on the Millenoola Stream at the undersized culverts alongside the road.

Photo 9.2: Urban Channel in Bantry



Captured: 02/10/2012

In contrast, the Bantry catchment is heavily modified where the steep small tributaries have been entrained into walled channels and long culverts through the town. The upper reaches are very steep and heavily vegetated and in-channel woody debris modifies flows. This woody debris combined with urban debris presents a potential blockage risk for the numerous structures downstream. The weir structure at the Library forms a mill pond reducing velocities and encouraging deposition in this reach. Downstream of the Library waterwheel, the river enters a long culvert before outfalling into the tidal harbour. The tide-locking and small inlet of this structure leaves it vulnerable to siltation and blockage thus reducing capacity.

Durrus Catchment

Photo 9.3: Waterfall, Durrus



Captured: 01/03/2013

The Durrus River/Four Mile Water drains an area of upland with little vegetation increasing the potential for diffuse erosion and an increased fine sediment load. The river itself flows over large gravel-sized sediment and waterfalls such as the natural weir feature upstream of School Road. Natural headward erosion was observed at this feature and similar waterfalls downstream, which are gradually lowering the effective weir crest and thus the water levels upstream. In the lower reaches, the river is tidally influenced and deposition of silts and fines dominates between low and high tide. Undermining of the river banks was observed in this reach suggesting the planform of the river is adjusting although it was not judged to be rapid based on the historic aerial photographs.

9.3 Impact on Flood Risk

The upper reaches of the Finnihy, Four Mile Water and Mealagh were observed to be eroding their beds although the rate of erosion was low given the resistant underlying geology. This is a natural process which will lower effective weir crests and thus the water levels over time but was not deemed to present any immediate flood risk to the AFAs.

The greatest deposition was observed in the tidal outfall of all rivers although over-widening of the River Finnihy at key bridges has led to the deposition of gravel bars as a hydrogeomorphological response. There is the potential for these bar features to become mobilised during extreme flood events and trapped against the bridge structures, thus reducing capacity after the flood. Smaller urban streams, such as the Bantry Stream, are prone to blockage at small culverts resulting from woody debris from the upstream reaches and urban detritus through the town itself.

Although siltation was observed at the outfall of Bantry River and Dromacoosane Stream, the current rate of depositions was not observed to be unsustainable or judged to require additional maintenance in the future. Overwidening of key bridges on the River Finnihy has led to the deposition of gravel bars as a hydrogeomorphological response. The reduction in capacity at these bridges over time could contribute to flood risk upstream without human intervention. There is a potential risk of blockage from woody debris in Bantry and Kenmare. However, the importance of these structures and the impact of any blockage on flood risk to the AFA will be identified during the subsequent hydraulic modelling and mapping.

10 Joint Probability

10.1 Overview

The design flows on each river reach and total tide plus surge levels provided in Chapter 7 have been derived independently of each other. In reality, there can be dependency between sources of flooding which can be described by the joint probability to achieve a target %AEP event. The CFRAM study considers the following joint probabilities:

- Fluvial-fluvial – Where a range of combinations of flow on a main river combines with flow on a tributary to generate a specific %AEP flood downstream.
- Fluvial-coastal – Where an approaching depression generates a storm surge which combines with a river flood to generate a specific %AEP event at the coast.

The joint probability between total tide plus surge levels and extreme waves has been considered separately under the ICWWS study. The resultant combinations have been assessed in Chapter 5 above to establish the critical scenario for wave overtopping for each target %AEP. Therefore, this will not be re-examined in the following sections.

10.2 Fluvial-Fluvial Dependence

The joint probability between fluvial flows on the main watercourse and its tributaries was guided by the methodology set out in Flood Studies Update Work Package 3.4. The FSU methodology assessed the dependence between fluvial inflows based on the distance between catchment centroids; the ratio of catchment areas; and, the difference in FARL, a measure of floodplain attenuation. Table 10.1 sets out the combinations in UoM21 for tributary inflows to achieve the target %AEP on the main watercourse.

In all cases, the tributaries in UoM21 were hydrologically similar to the main watercourse but significantly smaller. The joint probability %AEP on the smaller tributary inflows tended to be the more frequent smaller events in order to achieve the target flow on the main watercourse. The combination of flows on the main watercourse and each tributary is unlikely to affect flood risk at the confluence. This is because the tributaries are relatively steep compared with the main watercourse in UoM21.

Table 10.1: Fluvial-Fluvial Dependence

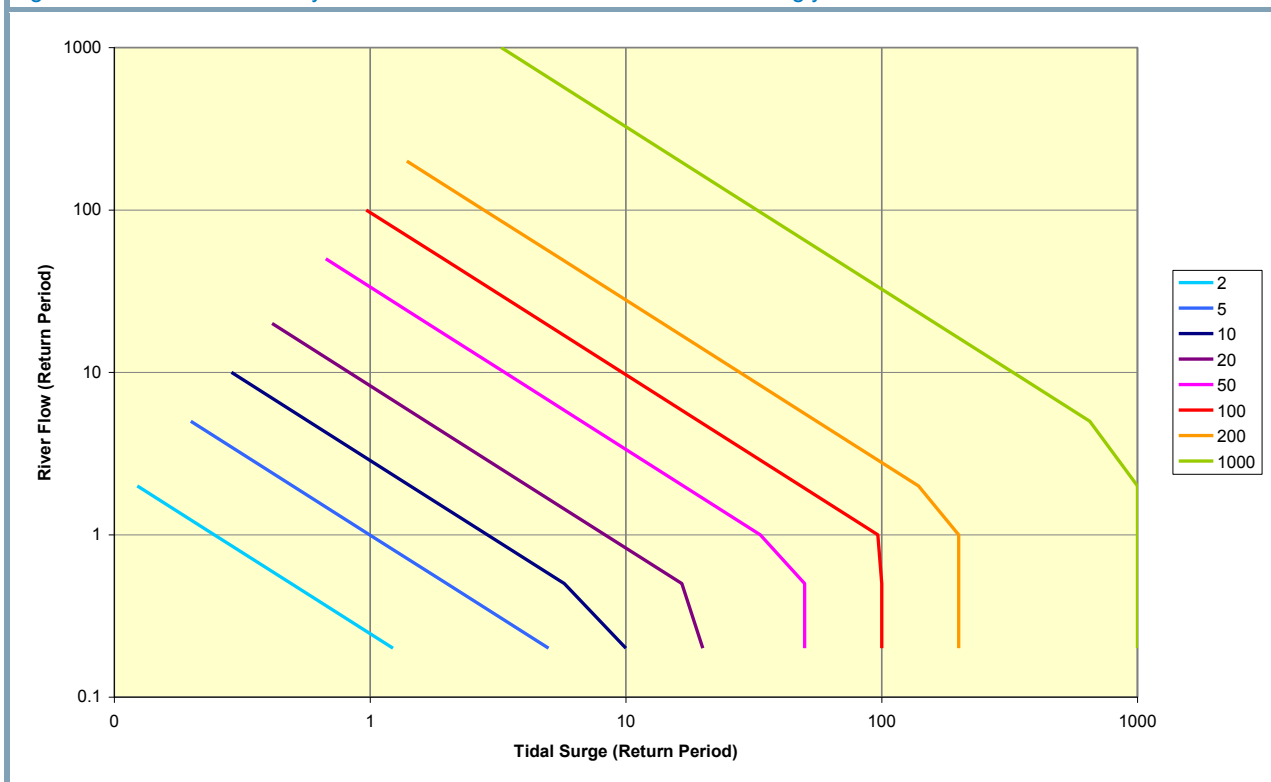
AFA			Target %AEP at downstream HEP on main watercourse							
			50%	20%	10%	5 %	2 %	1%	0.5%	0.1%
	Reach inflow	WP 3.4 Table 13.1 Scenario	Associated	%AEP of Tributary Inflow						
Bantry	Blue Hill South –Dromacoosane	Catchment centroid within 25km	71.0%	46.0%	35.0%	23.0%	10.0%	6.1%	3.8%	1.2%
	Adrnageeh – Bantry River	Significantly smaller catchment (Ratio of area greater than 2.7)								
	Sheskin – Bantry River	Difference in FARL less than 0.07								
	Carrignagat – Bantry River									
	Dromleigh – Bantry River									
	Reenrour – Bantry River									
	Doneelagh – River Mealagh									
	Raheen Beg – River Mealagh									
Durrus	Milleencolla East– River Mealagh									
	Clashadoo –Abanegavanagh	Catchment centroid within 25km	71.0%	46.0%	35.0%	23.0%	10.0%	6.1%	3.8%	1.2%
	Four Mile South –Four Mile North	Significantly smaller catchment (Ratio of area greater than 2.7)								
		Difference in FARL less than 0.07								
Kenmare	Lissaniska Stream – Finnihy River	Catchment centroid within 25km	71.0%	46.0%	35.0%	23.0%	10.0%	6.1%	3.8%	1.2%
	Gortamullin East - Finnhhy River	Significantly smaller catchment (Ratio of area greater than 2.7)								
		Difference in FARL less than 0.07								
Castletown	N/A Coastal Risk Only									
Berhaven										

10.3 Fluvial-Coastal Dependence

It is not possible to statistically assess the joint probability between fluvial and tidal events along the South West coast as there is limited concurrent river flow and tidal gauge data available at the same location. Therefore, the DEFRA FD2308_TR1 desk-based assessment was used to estimate the fluvial-tidal joint probability combinations.

The extreme flow estimates at Inchiclogh gauge and ICPSS total tide plus surge levels were used applied to the DEFRA FD2308_TR1 desk-based assessment tool in accordance with GN20⁵ based on the design hydrology outlines in Chapter 5. It was assumed that Kenmare, Bantry and Dunmanus Bays were similar to estuaries along the west and south-west coast of England in terms of orientation to the dominant storm track. Based on the FD2308 research, the dependence of river flow and storm surge in these estuaries tended to be “well” to “strongly” correlated. The strongly correlated CF (ratio of the actual frequency of occurrence of a particular joint exceedance event to its probability of occurrence if the two variables were independent) was applied to Kenmare, Bantry and Durrus as a conservative estimate in the absence of detailed concurrent gauge data. Figure 10.1 outlines the resultant joint probabilities.

Figure 10.1: Joint Probability Curves of Tidal and Fluvial Events for Strongly Correlated Estuaries



⁵ RPS(2012) CFRAM Guidance Note 20, Joint Probability Guidance.

Based on this analysis, there was some correlation between high flows and higher storm surges as the storm events that caused the surge. This agrees with the more detailed gauge analysis undertaken for nearby Cork Harbour as part of the Lee CFRAM pilot Study. Extensive sensitivity analysis was undertaken on the 0.5% AEP event as part of the pilot study and found the two main critical scenarios to be as follows:

- Target flow and the MHWS tide; and
- 50%AEP Flow and the target Total tide plus surge level.

This approach ensures easy interpretation of the maximum fluvial dominant flood and maximum coastal dominant flood for the design scenario. However, it is recommended to undertake sensitivity tests on alternative combinations to achieve the target 1%AEP in order to assess the impact on flood risk.

11 Future Scenarios

11.1 Potential Climate Changes

The range of potential impacts of climate change varies as there are significant uncertainties associated with global climate predictions and local hydrological variation for periods more than 20 years in the future. Therefore, two scenarios have been assessed to quantify the sensitivity of flood risk to potential climate change namely, the Mid-Range future scenario (MRFS) and the High-Range future scenario (HRFS) as detailed in Table 11.1.

Table 11.1: Allowance for Climate Change in Catchment Parameters Over 100 years

Catchment Parameter	MRFS	HRFS
Extreme Rainfall Depth	+20%	+30%
Flood Flows	+20%	+30%
Mean Sea Level Rise	+0.5m	+1.0m
Land Movement	-0.5mm/year i.e. +0.05m relative sea level rise over 100 years	-0.5mm/year i.e. +0.05m relative sea level rise over 100 years

Source: Reproduced from Appendix F of National Flood Risk Assessment and Management Programme, Catchment-Based Flood Risk Assessment and Management (CFRAM) Studies, Stage I Tender Documents: Project Brief.

The land movements quoted above refer to postglacial readjustment of the underlying tectonic plate since the last glacial period in Ireland. This readjustment is not a climatic change but it does alter the effective rate of sea level rise predicted with climate change. Hence, the rate of land movement has been added to the mean sea level rise. It is important to note that the increase in sea level and flood flows applies to the entire tidal curve and flood hydrograph, not just the peak.

11.2 Potential Catchment Changes

11.2.1 Urban Development

The way in which the land is used can significantly impact the flow routes across the catchment, how much rainfall is stored, how much infiltrates into the ground, and how much evaporates. Future urban development is likely to influence hydrology and flood risk in the following ways:

- Increase the surface runoff from the catchment by increasing the area covered by impermeable surfaces on previously undeveloped ("Greenfield") sites;
- Increase the proportion of surface runoff draining to urban drainage networks; and,
- Increase the proportion of the population, properties and infrastructure within areas of flood risk.

All of these changes cause more water to reach the river channels quicker and affect more people, property and environments. The greatest concentration of urban development is predicted around the existing towns in UoM21. However, the regional plans do not identify any focus growth areas (hubs) in UoM21.

Table 11.2 outlines the urban growth in housing units according to the South West Regional Authority Planning Guidelines and linear extrapolation to estimate urban growth for the MRFS and HEFS. The MRFS growth rate has been estimated on the projected increase in housing units between 2016 and 2022 accounting for the economic downturn. The HEFS growth rate has been estimated on the average projected increase from 2010 to 2022 as set out in the plan.

Table 11.2: Future Urban Growth

SWRA Plan Area	Housing Units Required				MRFS % Growth	HEFS % Growth
	2006	2010	2016	2022		
Cork Gateway	111,581	127,749	153,000	182,044	4.16%	4.54%
Mallow Hub	4,191	5,341	7,500	10,498	7.66%	9.05%
Ring towns and Rural areas	42,951	46,472	50,317	54,160	2.27%	2.38%
Greater cork area	154,532	174,221	203,317	236,203	3.70%	4.96%
Tralee Killarney Hub area	15,284	17,099	20,318	23,573	3.67%	4.16%
Kerry linked hub	29,565	33,541	39,855	46,239	3.67%	4.15%
Northern Area	33,497	37,993	43,885	46,186	1.87%	2.80%
Western area	36,606	41,745	47,989	50,729	1.95%	2.79%

Source: South West Regional Plan

In agreement with OPW, the forecast growth in housing units was assumed to be on previously undeveloped land as a conservative estimate of urbanisation over a 100 year timeframe. The MRFS and HEFS do not account for any beneficial impacts of Sustainable Drainage Systems in the future.

11.2.2 Land Use Change

The majority of the Bantry, Castletown Bearhaven, Durrus and Kenmare catchments are currently rural and dedicated to agricultural or pastoral use. The type of crops that are grown, the way the land is prepared and changes in land drainage practice all affect how quickly rainfall reaches the watercourses. Land management practices also affect the amount of silt that gets washed from the fields into the rivers during rainfall events. Given that these processes can influence flood risk, both in a positive and negative way, we need to consider how land use and land management may change in the future.

There are many uncertainties surrounding the future of agriculture within the catchment. Land use will depend upon society's aspirations and needs, and will be driven by policies being implemented by both the Irish government and the EU. The pressures and drivers that will affect how land is used in UoM21 include:

- change to agricultural policy and land management subsidies in the EU;
- opening of world markets making agriculture and pastoral activity less economically viable;
- growth in world population increasing demand for food production;
- change in typical annual temperatures with climate change resulting in changes in crop types grown;
- diversification to other land uses, particularly for tourist related attractions;
- drive to enhance and restore environmental habitats and landscapes;
- drive to reduce carbon dioxide emissions through the use of carbon sinks and biofuels; and,
- increasing energy prices could lead to increased biofuel use or make importing of produce uneconomic.

All of these changes can either lead to intensification of activities and associated increased land drainage and runoff or reduction in activities with associated increased infiltration and reduced runoff. There is very limited information on most of these land cover changes as they are often driven by economic factors which are rarely predicted beyond 5 years.

Deforestation to increase productivity of agricultural land can be a significant on rural land use in Europe under the EU Common Agricultural Policies. Forested areas intercept rainfall, increase storage and infiltration and slow surface water runoff into the river channels. The removal of natural forests can encourage greater runoff. There is only limited evidence to suggest the extent of forest cover is a significant controlling parameter on the regression equations used to estimate peak flood flows⁶. However, the OPW guidelines identify commercial afforestation to increase productivity as the significant pressure on rural land use in Ireland. Increased irrigation and drainage for the commercial forests can route more water to the rivers thus reducing the time to peak. The OPW future scenarios guidelines recommend that forestation can be reflected in a reduced time to peak due to these associated drainage works.

Less than 10% of the Kenmare, Bantry and Four Mile Water North catchments are covered by forest as defined by the Floods Studies Update. Therefore, any decrease in forested area is unlikely to impact future flood hydrographs as forest covers such a small proportion of the catchment at present. Therefore, changes to the hydrographs due to forestry cover have been discounted for these catchments. However, the Four Mile Water South catchment, which enters Durrus downstream of School Road, has up to 45% forest cover in its upper reaches. The projected decrease in forest cover in this area could reduce the time to peak by 17% and 33% for the MRFS and HEFS respectively.

There will be more localised schemes which may alter land use and hydrological response but not all of these schemes can be predicted. However, Cork County Council has provided details of a proposed water supply reservoir in the upper reaches of a tributary of the Mealagh catchment. The reservoir is still in the initial planning phases thus it cannot be considered as a future change until the scheme is under construction.

⁶ Institute of Hydrology (1991). Plynlimon research: The first two decades. Report No. 109, Institute of Hydrology.

11.3 Design Future Scenario Conditions

The present day design hydrology (derived in Chapter 5 of this report) was modified to consider the relevant catchment and climate changes discussed in the previous sections. Table 11.3 summarises the final Mid-Range and High-End Future Scenarios.

Table 11.3: Allowance for Future Condition in Catchment Parameters

Catchment Parameter	MRFS	HEFS
Flood Flows	+20%	+30%
Mean Sea Level Rise	+0.5m	+1.0m
Land Movement	-0.5mm/year i.e. -0.05m over 100 years	-0.5mm/year i.e. -0.05m over 100 years
Urbanisation	0.95%/year	1.79%/ year
Deforestation	- $\frac{1}{6}$ Tp	- $\frac{1}{3}$ Tp + 10% PR

The design hydrology under future conditions has been adjusted for the predicted decrease in forest cover in the relevant Four Mile Water South tributary catchment only.

The resultant future peak flood flows and future extreme sea levels based on the Mid-Range and High End Future Scenarios are provided in Appendix D. The predicted increase in river flows and sea level rise attributed to predicted climate change is the most significant factor that influences design peak flows and levels in UoM21. Urbanisation has a relatively small impact on design peak flows as the UoM21 catchments remain predominately rural in both the MRFS and HEFS. The degree to which the increased river flows and sea levels change flood risk to the AFAs will be assessed as part of the subsequent hydraulic modelling and mapping. The relative increase in flows and period of any tide-locking associated with the impacts of climate change should be considered in the sizing of any floodplain storage options and frequency of maintenance activities.

12 Conclusions, Key Findings and Recommendations

12.1 Conclusions and Key Findings

The design flows from this hydrology report inform the inflows to the hydraulic model to assess flood risk from the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP fluvial and tidal flood events. The key hydrological findings in UoM21 are as follows:

Historic flood events

- Seven major flood events were identified in UoM21 since 1980 from both extreme storm surges and fluvial floods at Bantry and Kenmare.
- No significant historic floods were identified at Castletown Bearhaven and Durrus.
- The calibration in Kenmare and Bantry will be based on the following events where there is sufficient information:
 - 23rd October 2008 – extreme fluvial event in Kenmare.
 - 17th October 2012 – extreme tidal event and surface water/fluvial event in Bantry.

Design flood flows

- The peak flood flows were derived in Bantry, Durrus and Kenmare catchments for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events using the recommended FSU methodology outlined in Work Package 2.2 and 2.3.
- The design flood hydrograph at Inchiclogh gauge and the Mealagh catchment was based on the median width exceedance flood hydrograph which was derived from gauged data.
- The design flood hydrograph for ungauged HEPs was based on the FSSR16 rainfall runoff methodology scaled to the design peak flows from the FSU approach. This approach was adopted because the FSSR16 best matched the Inchiclogh gauged hydrographs and the time to peak of the FSU UPO-ERR Gamma curve was not deemed representative of these wet rapid response catchments along the far west coast. The FSSR16 does not consider karstic influence but none of the catchments within the AFAs were found to be significantly affected by karstic geology.
- The joint probability between tributary inflows and the main watercourse was informed by FSU WP3.4. The joint probability of tributaries was found to be largely dictated by the size of the incoming catchment in UoM21.
- The combination of flows on the main watercourse and each tributary is unlikely to affect outfall and flood risk at the confluence in UoM21, since the tributaries are relatively steep compared with the main watercourse.
- The critical storm duration was derived for each AFA based on the FSSR16 approach assuming a single design storm event, which is appropriate as rainfall does not physically vary throughout these small coastal catchments (< 30 km²).

Design coastal conditions

- The design total tide plus surge level and design tidal curves were extracted from the ICPSS for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP tidal events. These levels were then transformed to Bantry, Castletown Bearhaven, Durrus and Kenmare based on available ICPSS data.

- Wave overtopping discharges were calculated for the quay in Castletown Bearhaven and three sections of coastline around Kenmare Harbour, as defined by the ICWWS analysis. Castletown Bearhaven was found to be at limited flood risk from wave overtopping with less than 0.18l/s/m overtopping the quay in the extreme 0.1%AEP event. Up to 20 l/s/m overtops the shingle beaches and quayside at Kenmare Harbour in the smaller events such as the 10%AEP event. However, still water overtopping dominates Kenmare for the 2%AEP and larger magnitude events.
- Storm surge events and river flows in Kenmare, Bantry and Dunmanus Bays were deemed to be strongly correlated due to their location on the west coast and orientation to incoming storms.
- Joint probability between the storm surge and river flood was calculated using the DEFRA FD2308 desk-based approach as per GN 22.

Uncertainty and Sensitivity

- Flows at Inchiclogh gauge could be reduced by 25% dependant on the extrapolation of the rating curve used. This 25% reduction in peak flow will inform the sensitivity tests in the Mealagh catchment.
- The uncertainty of the 1%AEP target peak flow was estimated to range up to +30% in UoM21 ungauged HEPs which will inform the sensitivity tests in the hydraulic modelling.
- The water level profiles in Kenmare, Bantry and Dunmanus Bays have a reasonable level of uncertainty associated with them due to the lack of gauge data to verify the progression of the tide up these ria-like estuaries. Therefore, a 0.5m increase in water level was recommended in accordance with GN22.

Hydrogeomorphology

- The current erosion and deposition processes were assessed for all AFAs based on site visits, survey OSi mapping and geological information.
- The upper reaches of the Finnihy, Four Mile Water and Mealagh were observed to be eroding their beds although the rate of erosion was low given the resistant underlying geology but was not deemed to present any immediate flood risk to the AFAs.
- The greatest deposition was observed in the tidal outfall of all rivers, although over-widening of the River Finnihy at key bridges has led to the deposition of gravel bars as a hydrogeomorphological response. The reduction in capacity at the bridges over time could contribute to flood risk upstream without human intervention.

Future conditions

- Two future scenarios were developed to assess potential future changes namely, the Mid-Range future scenario (MRFS) and the High-Range future scenario (HRFS).
- River flows were predicted to increase by 20% and 30% due to climatic changes under MRFS and HEFS respectively.
- Sea levels were predicted to rise by 0.55m and 1.05m for the MRFS and HEFS respectively, accounting for 0.5mm/year post-glacial rebound land movements.
- Urban extent was predicted to increase at 0.95%/year and 1.79%/year for the MRFS and HEFS respectively, based on the forecasted rates in the South West Regional Authority planning guidelines.

- Time to peak was predicted to reduce by 17% and 33% for the MRFS and HEFS respectively along the Four Mile Water South catchment due to deforestation of the upper catchments.
- The design peak flood flows and total tide plus surge levels were adjusted to represent the climatic and catchment changes above for the MRFS and HEFS future scenarios accordingly.

12.2 Recommendations

The following recommendations can be drawn from the key findings above for the subsequent hydraulic modelling, flood risk assessment, preliminary option development and FRMP:

- The design peak flows and design total tidal levels presented in Table 8.1 and 8.2 should be used to inform the subsequent hydraulic modelling in UoM21.
- The design hydrographs should be scaled to the design peak flows and applied to the relevant model inflows.
- Inflows for intervening catchments should be distributed across minor watercourses and overland flow paths identified from the survey based on the proportional increase in contributing area.
- The joint probability approach and analysis in Chapter 10 should be used to inform the combinations of inflows and coastal conditions for the model boundaries.
- The relevant hydraulic models should be calibrated as far as possible to these historic flood events;:
 - 23rd October 2008 – extreme fluvial event in Kenmare.
 - 17th October 2012 – extreme tidal event and surface water/fluvial event in Bantry.
- The remaining models in Durrus and Castletown Bearhaven which do not have sufficient historic information or gauge information should use reasonable hydraulic parameters and sensitivity testing to establish model robustness.
- The following sensitivity tests should be considered to assess the impact of hydrological assumptions on flood extent and levels in the subsequent hydraulic modelling:
 - Peak flow
 - Downstream total tide plus surge levels
 - Joint-probability combinations of fluvial and coastal %AEP event to achieve the target %AEP.
- The wave overtopping discharges provided in Chapter 5 should be considered in relation to critical discharges for pedestrians, vehicles and property damages as provided in industry guidance (EurOtop and the Rock Manual).

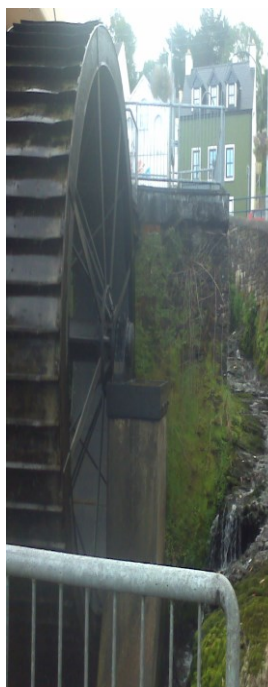
The following recommendations can be drawn from the hydrological analysis for future analysis in the catchment:

- Additional high flow monitoring at Inchiclogh gauge as the only gauge within an AFA catchment would be beneficial to confirm the extension of the rating curve at this location and improve the estimate of flood flows in the Mealagh catchment.
- Additional spot gaugings and a review of high flow ratings at all Irish gauge records following the CFRAM study analysis would improve the estimate of flood flows nationally.
- Continued efforts to collate historic flood evidence for past and any new flood events is critical to improve the hydrological and hydraulic outputs in Durrus and Castletown Bearhaven.

Glossary

AEP	Annual Exceedance Probability; this represents the probability of an event being exceeded in any one year and is an alternative method of defining flood probability to 'return periods'. The 10%, 1% and 0.1% AEP events are equivalent to 10-year, 100-year and 1000-year return period events respectively.
AFA	Area for Further Assessment – Areas where, based on the Preliminary Flood Risk Assessment and the CFRAM STUDY Flood Risk Review, the risks associated with flooding are potentially significant, and where further, more detailed assessment is required to determine the degree of flood risk, and develop measures to manage and reduce the flood risk.
AMAX	Annual Maximum Flood
BFISOILS	Baseflow index from Irish Geological Soils dataset. Often used as a permeability indicator.
CFRAM	Catchment Flood Risk Assessment and Management – The 'CFRAM' Studies will develop more detailed flood mapping and measures to manage and reduce the flood risk for the AFAs.
DAD	Defence Asset Database
DAS	Defence Asset Survey
EU	European Union
EPA	Environmental Protection Agency
FARL	Index of flood attenuation due to reservoirs and lakes
FRMP	Flood Risk Management Plan. This is the final output of the CFRAM study. It will contain measures to mitigate flood risk in the AFAs.
FRR	Flood Risk Review – an appraisal of the output from the PFRA involving on site verification of the predictive flood extent mapping, the receptors and historic information.
FSU (WP)	Flood Studies Update (Work Package) (2008 to 2011)
FSR	Flood Studies Report (HR Wallingford, 1975)
GIS	Geographical Information Systems
HA	Hydrometric Area. Ireland is divided up into 40 Hydrometric Areas.
HEFS	High-End Future Scenario to assess climate and catchment changes over the next 100 years assuming high emission predictions from the International Panel on Climate Change.
HEP	Hydrological Estimation Point
HPW	High Priority Watercourse. A watercourse within an AFA.
ICPSS	Irish Coastal Protection Strategy Study (2012)
ICWWS	Irish Coastal Water Level and Wave Study (2013)
ING	Irish National Grid system, Ordnance Survey of Ireland

MPW	Medium Priority Watercourse. A watercourse between AFAs, and between an AFA and the sea.
MRFS	Mid-Range Future Scenario to assess climate and catchment changes over the next 100 years assuming medium emission predictions from the International Panel on Climate Change.
ODM	Ordnance Datum Malin. The current geodetic datum of Irish National Grid which references the mean sea level at Malin Head between 1960 and 1969.
OPW	Office of Public Works, Ireland
OSi	Ordnance Survey Ireland
PFRA	Preliminary Flood Risk Assessment – A national screening exercise, based on available and readily-derivable information, to identify areas where there may be a significant risk associated with flooding.
QMED	Median annual flood used as the index flood in the Flood Studies Update. The QMED flood has an approximate 50%AEP.
QMED_{amax}	QMED derived from the annual maximum series at a gauged location
QMED_{rural}	QMED derived from physical catchment descriptors according to the Flood Studies Update methodology.
QMED_{adj}	QMED adjusted by the ratio of QMED _{amax} :QMED _{rural} at a hydrologically similar Pivotal site.
QMED_{urban}	QMED adjusted to account for the impacts of urban areas according to the Flood Studies Update methodology.
S1085	Typical slope of the river reach between 10%ile and 85%ile along its length.
SAAR	Standard average annual rainfall 1961 to 1990
SEA	Strategic Environmental Assessment. A high level assessment of the potential of the FRMPs to have an impact on the Environment within a UoM.
SW CFRAM	South Western Catchment Flood Risk Assessment and Management study
UoM	Unit of Management. The divisions into which the RBD is split in order to study flood risk. In this case a HA.
WFD	Water Framework Directive. A European Directive for the protection of water bodies that aims to, prevent further deterioration of our waters, to enhance the quality of our waters, to promote sustainable water use, and to reduce chemical pollution of our waters.



South Western CFRAM Study

Hydrology Report Appendices
Unit of Management 21
June 2016

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South Western CFRAM Study

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C	June 2016	M Piggott	B O'Connor	B O'Connor	Final (no amendments)	

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Appendix D.	Future Peak Flows and Water Levels _____	48

Appendix A. Available Data

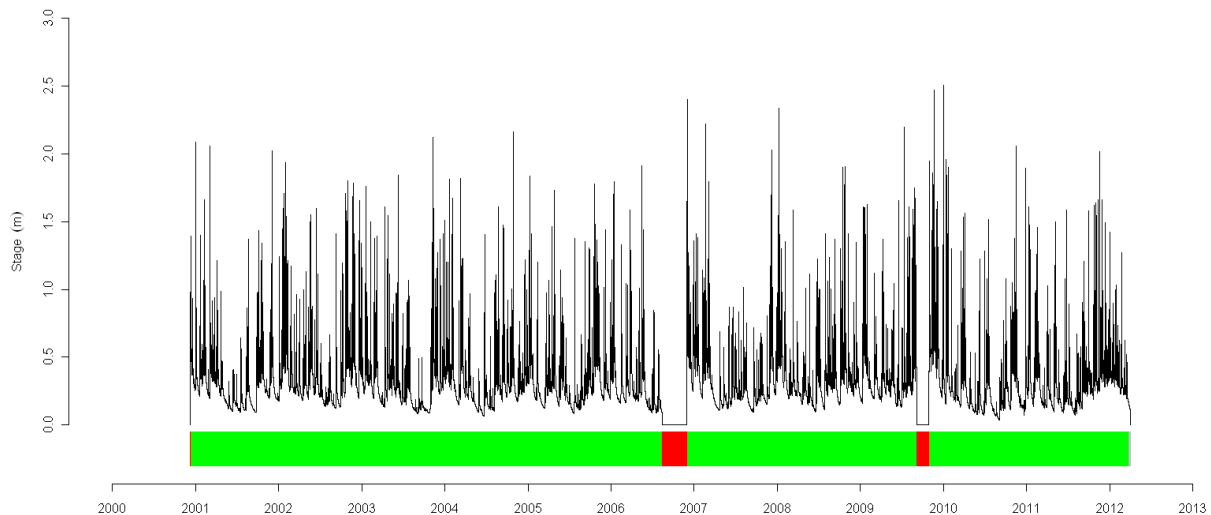
Table A.1: Selected Hydrometric Gauge Data

Stn_No.	Station_Name	Gauge Type	Easting	Northing	Record_Start	Years Data	Owner	Comments	Fit for Calibration Purposes?	Fit for Statistical Analysis?
21004	Inchiclogh (Mealagh)	Water level and flow	102681	51200	02/07/1975	35	EPA	Significant data gaps in 2007 and 2009 including the 2009 calibration event, peaks flow available prior to 2000 but not 15 min data series	Yes pre-2007	Yes pre-2007
21002	Coomhola	Water level and flow	54762	69360	08/07/1975	25	EPA	AMAX series has been checked through FSU and is consistent with flood events at Inchiclogh. This gauge would be suitable for calibration however it is not required as Inchiclogh is available.	No	AMAX series has been checked through FSU, 13 years incomplete so discarded
21003	Ballylickey	Water level and flow	101071	53469	01/07/1976	25	EPA	AMAX series has been checked through FSU and is consistent with flood events at Inchiclogh. Data available does not cover calibration period. This gauge would be suitable for calibration however it is not required as Inchiclogh is available.	Not required	Use truncated series with caution.
305	Valentia Observatory	Hourly Rainfall	107800	107300	1866	144	Met Eireann	Data quality reasonable and covers periods of calibration events- Transformation needs to be considered for remote AFAs No significant gaps identified and no localised trend (from urbanisation, tree cover etc.) identified from record	Yes- with caution	Not required
1801	Bantry (Dromleigh)	Daily Rainfall	99800	47800	1992	6	Met Eireann	Record is short and does not cover calibration period		Not required
2201	Bantry (Shandrum)	Daily Rainfall	102000	52000	8	13	Met Eireann	Relatively short record but largely complete except February 2008 which is missing	Yes	Not required
1201	Bantry (St. Joseph's Hosp.)	Daily Rainfall	100100	49000	1974	19	Met Eireann	Reasonable data quality but months data missing in July 1976, February 1977, October 1989, August 1990 and Oct 1990 onwards. Does not cover calibration period	No	Not required
101	Bantry (The Rectory)	Daily Rainfall	98600	48900	1936	4	Met Eireann	Record is short and does not cover calibration period	No	Not required
301	Bantry (Voc.Sch.)	Daily Rainfall	99600	48600	1941	32	Met Eireann	Reasonable long term record with only minor data gaps < 10 days but does not cover the calibration period	No	Not required
601	Castletownbere (Filane West)	Daily Rainfall	71500	47800	1948	64	Met Eireann	Good quality data with no observed trending. Minor gaps in 1952 and a month gap in Sept. 1995	Not required coastal flood risk	Not required coastal flood risk
1401	Castletownbere (South Drum)	Daily Rainfall	66900	45000	1981	1	Met Eireann	Record is short and does not cover calibration period	Not required coastal flood risk	Not required coastal flood risk
1001	Castletownbere G.S.	Daily Rainfall	67600	45900	1952	46	Met Eireann	Good quality data with no observed trending with minor gaps in the record	Not required coastal flood risk	Not required coastal flood risk
1501	Castletownbere Southdroum li	Daily Rainfall	67000	45000	1982	30	Met Eireann	Good quality data with no observed trending with minor gaps in the record except June and December 2001 which are missing	Not required coastal flood risk	Not required coastal flood risk
801	Durrus G.S.	Daily Rainfall	94500	41900	1950	40	Met Eireann	Reasonable data record but with large gaps in October 1970 and May 1986 onwards	Not required as no historic events identified.	Not required
1903	Kenmare	Daily Rainfall	90700	71200	1994	18	Met Eireann	Good quality data with only minor gaps in 1994-1995. Covers calibration period	Yes	Not required
203	Kenmare (Sheen Falls)	Daily Rainfall	92500	70000	1916	77	Met Eireann	Record is short and does not cover calibration period in 2008	No	Not required

The following figures have classified gauge data into the following categories:

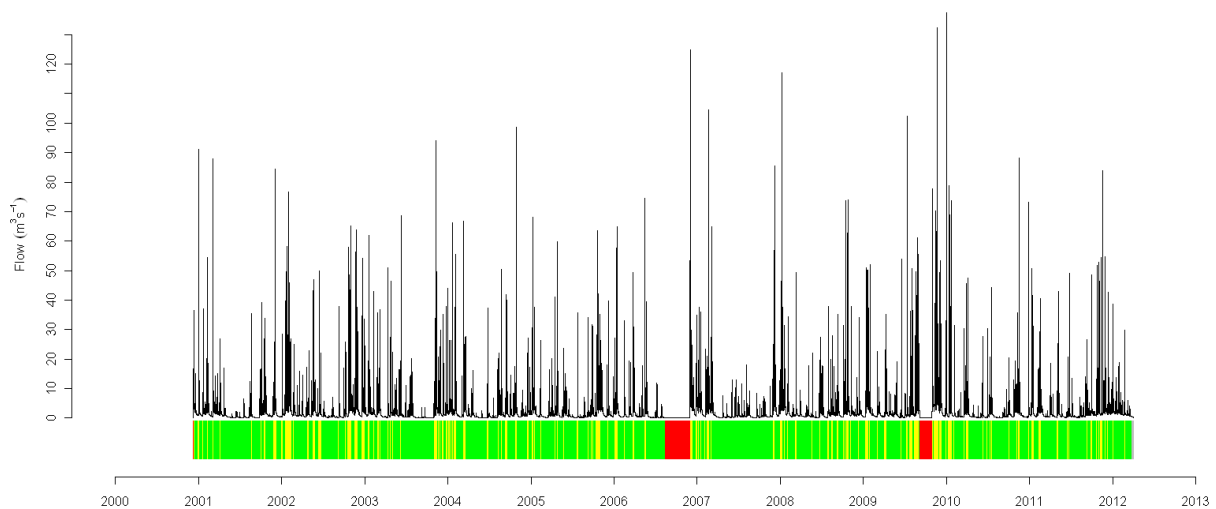
Missing	Data is missing, erroneous or of unacceptable quality for use (e.g. equipment error or readings during drainage works).
Suspect	Data may contain a significant degree of error due to extrapolation using a poor rating curve or extrapolated beyond reliable data range as identified by OPW or EPA. Alternatively data that has been derived from incomplete records.
Fair	Data derived from a corrected water level series or a fair rating curve as identified by OPW or EPA.
Good	Data has been inspected and is deemed consistent and without significant error as identified by OPW and EPA.
Unchecked	Unchecked data – Data is provisional only and must be used with caution. Frequently applies to most recent data.

Figure A.1: Water Level Data Quality Plot for Mealagh @ Inchiclogh Gauge (EPA – 21004)



Where: Red is missing, Orange is suspect, Yellow is Edited, Green is good and Grey is unchecked based on OPW and EPA data quality flags.

Figure A.2: Flow Data Quality Plot for Mealagh @ Inchiclogh Gauge (EPA – 21004)



Where: Red is missing, Orange is suspect, Yellow is Edited, Green is good and Grey is unchecked based on OPW and EPA data quality flags.

Figure A.3: Daily Rainfall Comparative Plot Between Valentia and Bantry

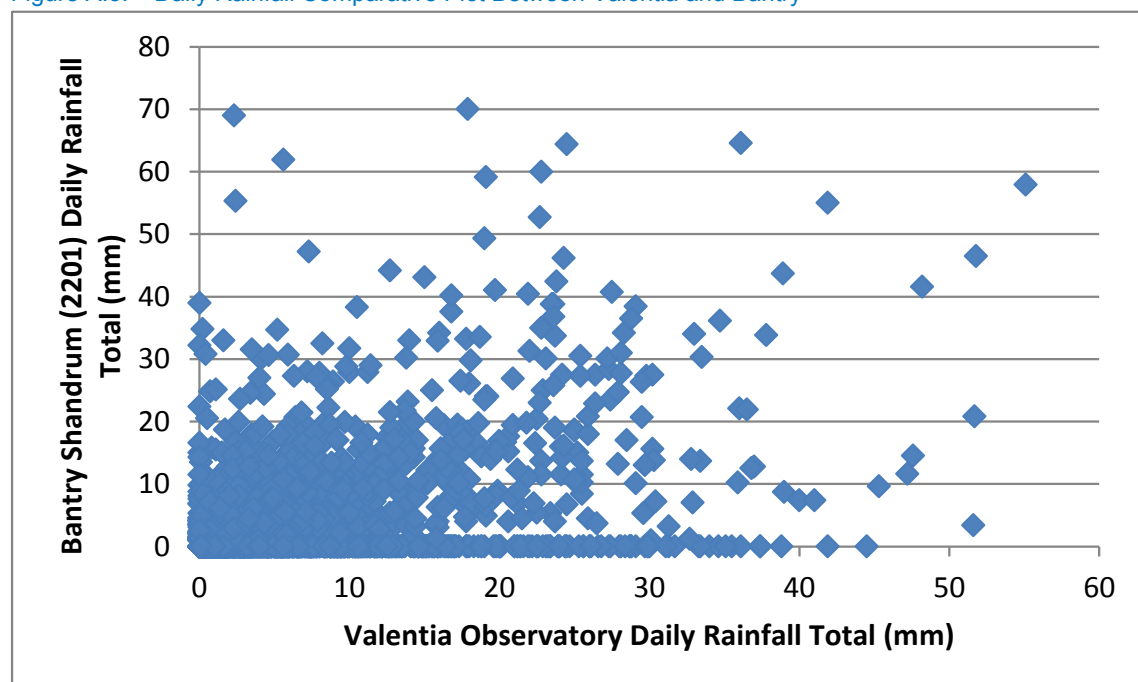


Figure A.4: Daily Rainfall Comparative Plot Between Valentia and Durrus

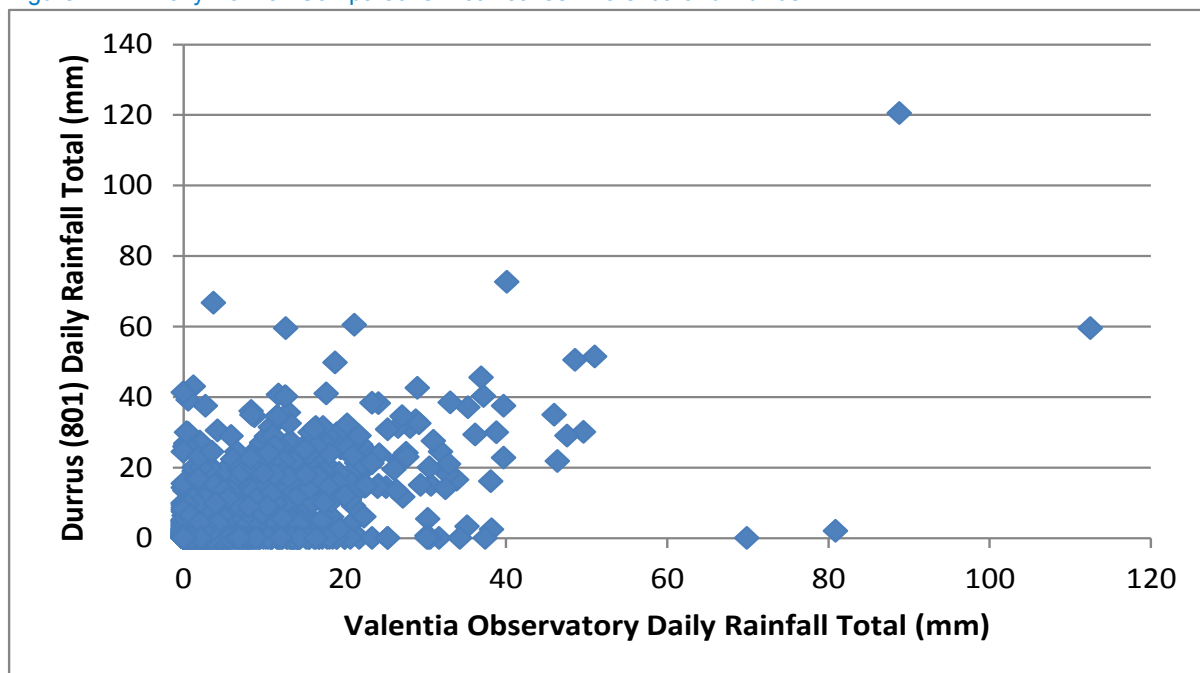
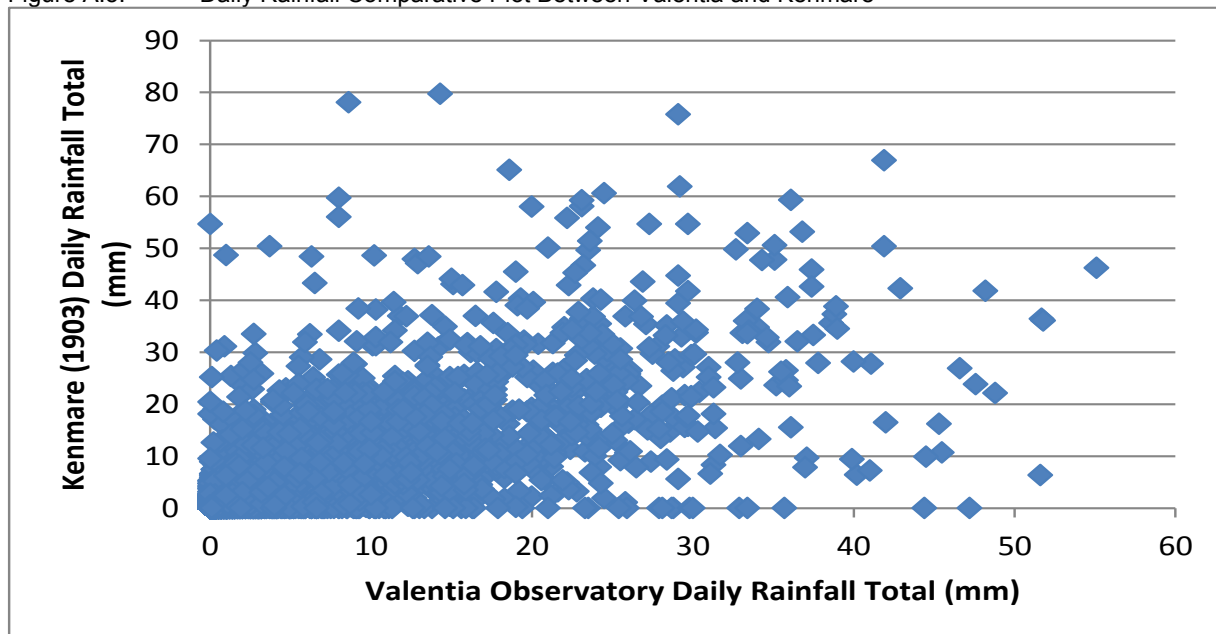
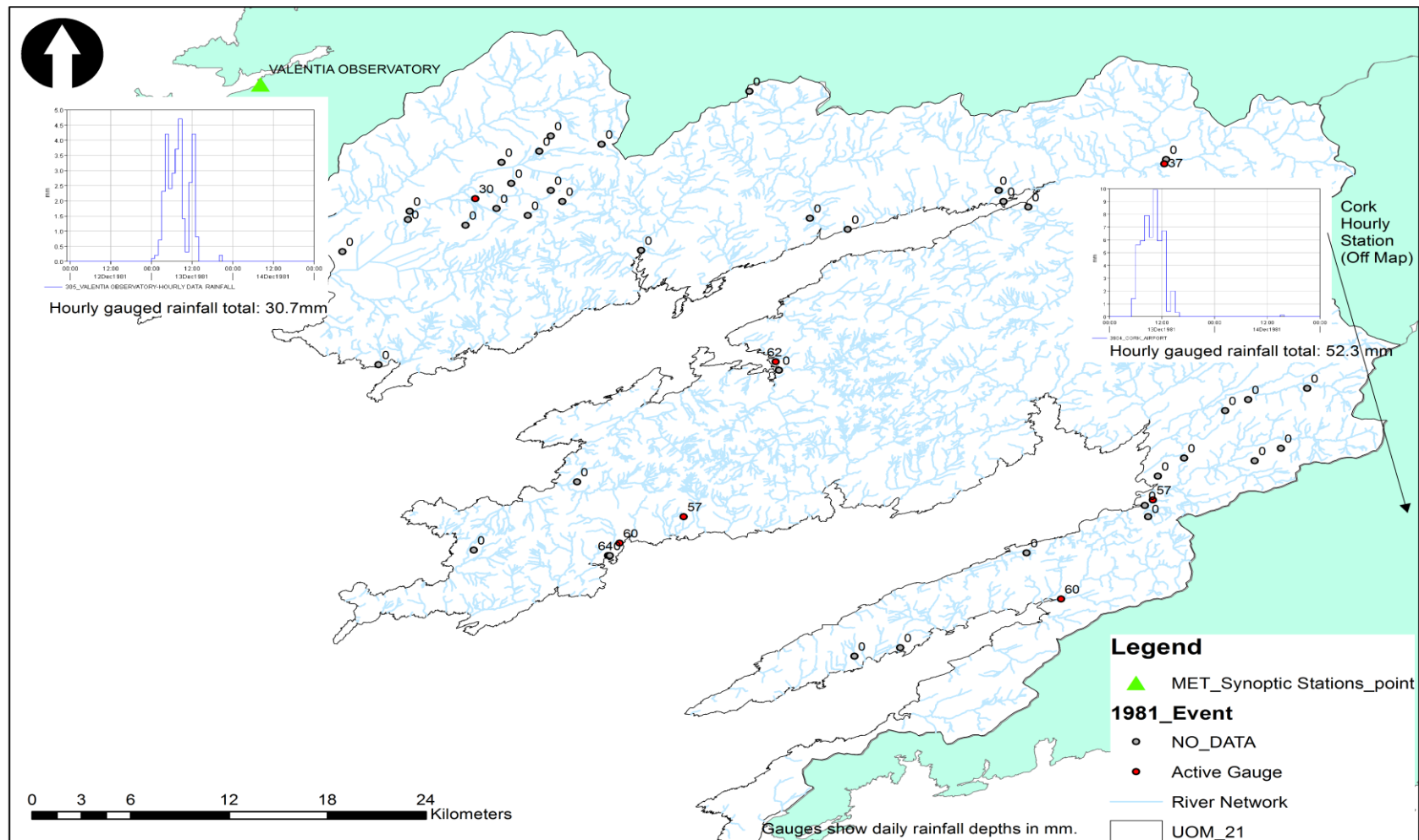


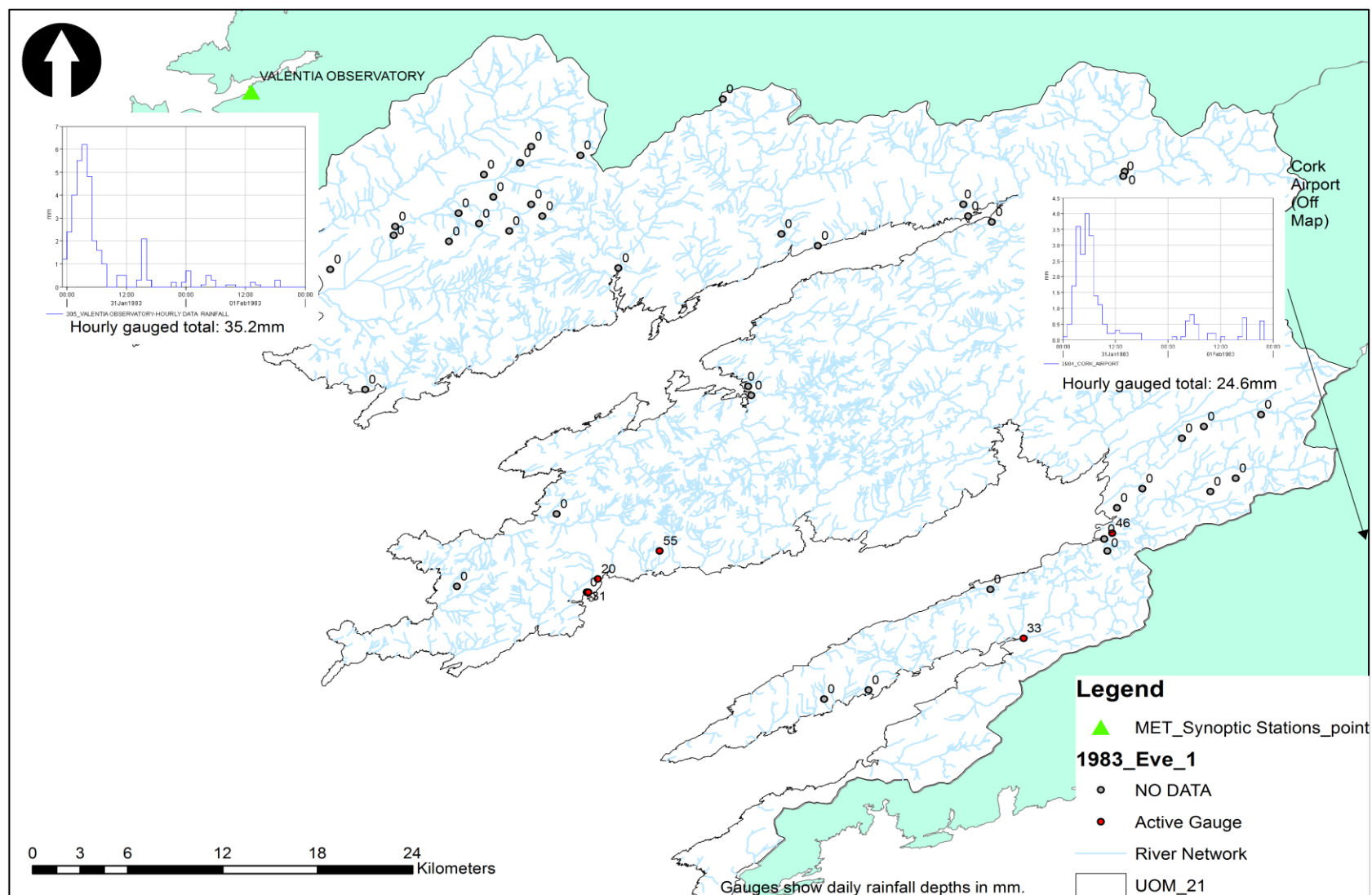
Figure A.5: Daily Rainfall Comparative Plot Between Valentia and Kenmare



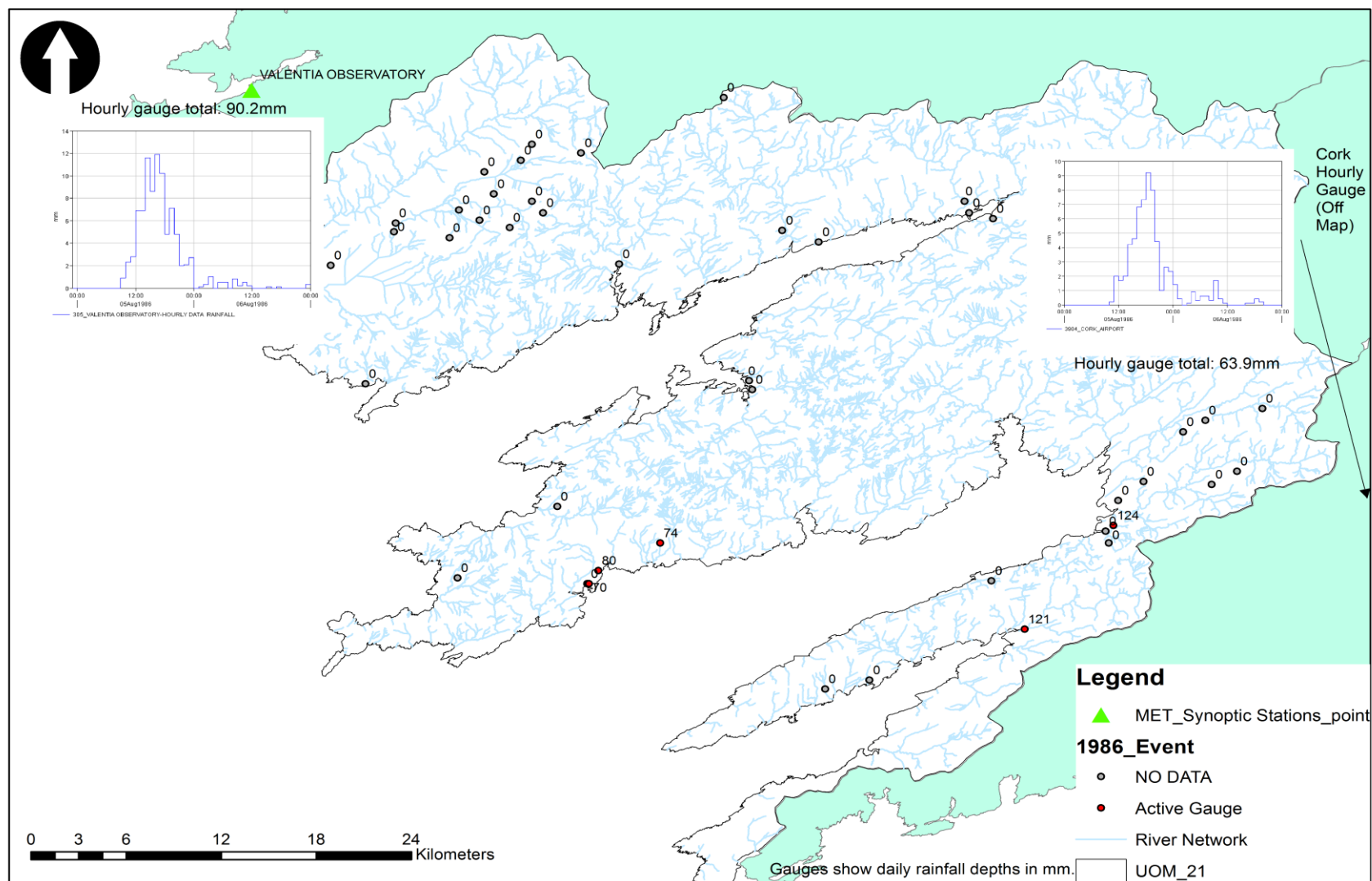
Map A.1: Rainfall Variation on 25th December 1981



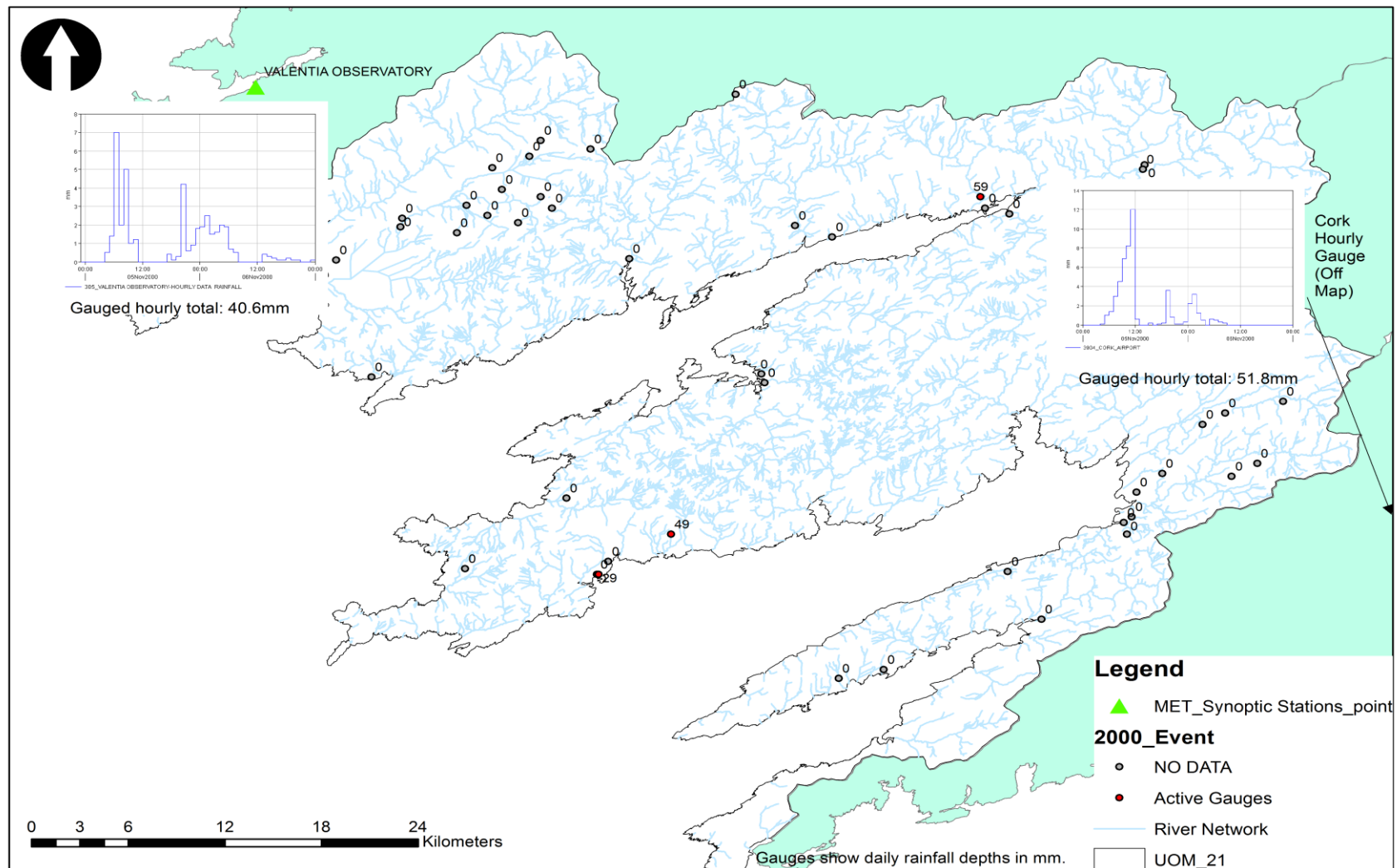
Map A.2: Rainfall Variation on 31st January 1983



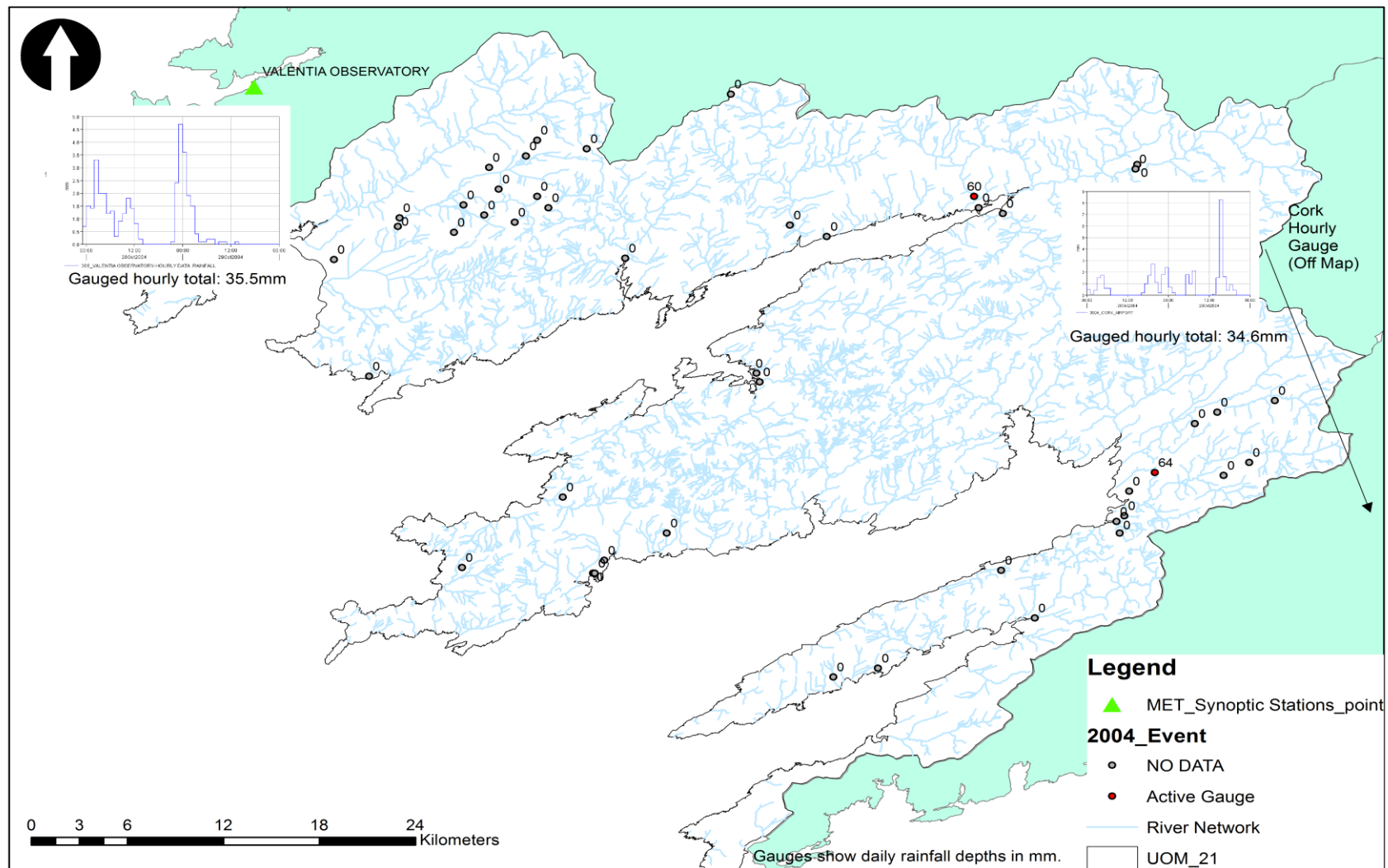
Map A.3: Rainfall Variation on 5th August 1986



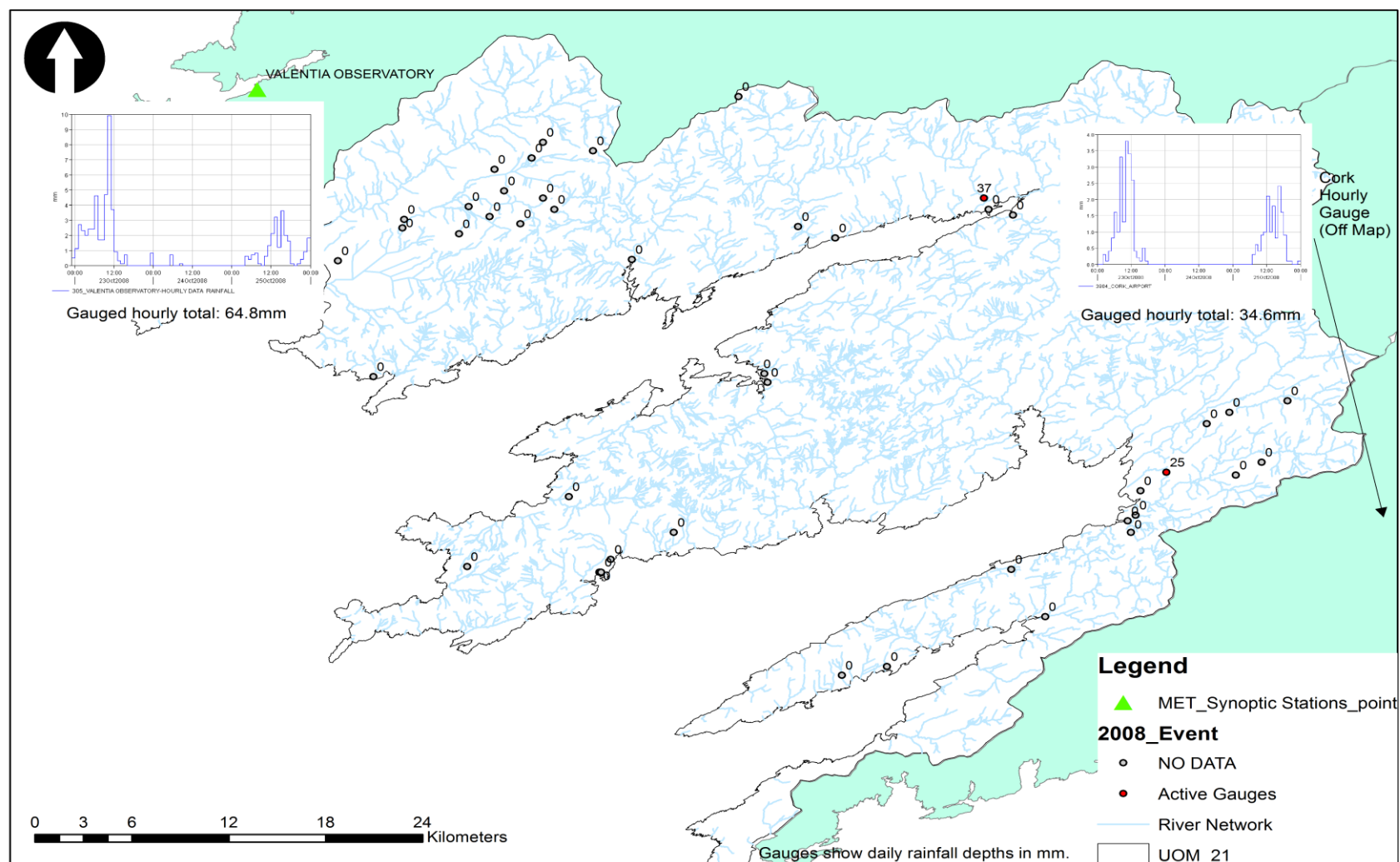
Map A.4: Rainfall Variation on 5th November 2000



Map A.5: Rainfall Variation on 28th October 2004



Map A.6: Rainfall Variation on 23rd October 2008



Appendix B. Hydrological Estimation Points

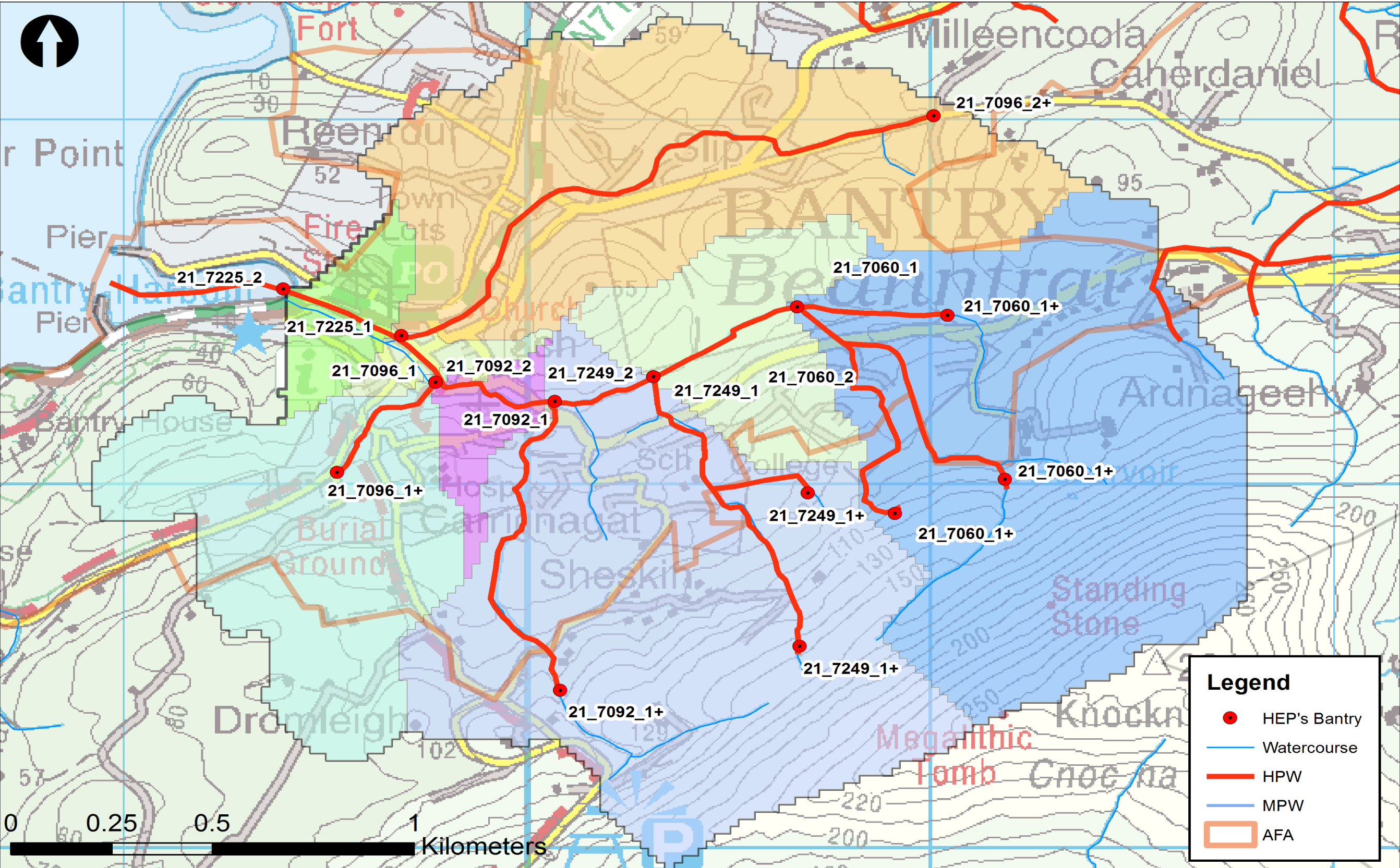
Table B.1: Bantry AFA Physical Catchment Descriptors

LOCATION	HEP	DTM_AREA	MSL	NETLEN	STMFQ	DRAIND	S1085	ARTDRAIN2	FARL	SAAR	FORMWET	URBEXT	PEAT	ALLUV	FOREST	PASTURE	BFISOILS
Bantry Main downstream Sheskin	21_7060_1	1.11	1.38	3.13	7.0	2.8	102.58	0.0	1.000	1859	0.69	16.95	39.2	0.0	0.6	43.9	0.59
Bantry Main upstream School	21_7060_2	1.39	1.80	3.54	7.0	2.5	96.34	0.0	1.000	1859	0.69	23.55	31.1	0.0	1.0	45.4	0.57
Bantry Main	21_7249_1	1.71	1.80	4.95	13.0	2.9	96.34	0.0	1.000	1859	0.69	24.70	30.3	0.0	1.0	45.0	0.57
Bantry Main	21_7249_2	2.04	2.01	5.16	13.0	2.5	87.64	0.0	1.000	1859	0.69	29.38	26.4	0.0	0.9	44.2	0.57
Bantry Main	21_7092_1	2.55	2.06	7.30	19.0	2.9	87.38	0.0	1.000	1859	0.69	25.54	28.5	0.0	1.1	45.9	0.57
Bantry Main	21_7092_2	2.63	2.38	7.62	19.0	2.9	67.18	0.0	1.000	1859	0.69	27.42	27.7	0.0	1.6	44.9	0.57
Bantry Main downstream Scart Road	21_7096_1	3.19	2.38	8.02	21.0	2.5	67.18	0.0	1.000	1859	0.69	24.16	22.9	0.0	2.0	52.9	0.57
Bantry Main	21_7225_1	4.13	2.55	10.08	25.0	2.4	65.06	0.0	1.000	1859	0.69	30.26	17.7	0.0	1.5	52.1	0.59
Bantry Main downstream Survey Extent	21_7225_2	4.24	2.83	10.4	25.0	2.4	60.31	0.0	1.000	1859	0.69	30.92	17.2	0.0	1.5	51.9	0.57
Sheskin Stream	21_7249_1+	0.31	1.80	6.00	2.0	2.6	96.34	0.0	1.000	1859	0.69	23.76	30.9	0.0	1.0	45.3	0.57
Carrignagat Stream	21_7092_1+	0.50	2.06	1.00	2.0	2.6	87.59	0.0	1.000	1859	0.69	28.71	26.8	0.0	1.0	44.5	0.57
Dromleigh Stream	21_7096_1+	0.56	2.38	1.00	2.0	2.9	87.38	0.0	1.000	1859	0.69	25.54	22.9	0.0	2.0	52.9	0.57
Reenrour Stream	21_7096_2+	0.90	2.06	1.00	2.0	2.4	67.18	0.0	1.000	1859	0.69	24.16	28.5	0.0	1.1	45.92	0.57
Ardnageehy Stream	21_48_1+	0.74	3.11	3.61	14.0	1.5	29.49	0.0	0.917	1695	0.68	0.00	46.0	0.0	9.1	53.5	0.55
Doneelagh	21_51_2	3.94	3.11	5.54	13	1.4	29.894	0.0	0.915	1692	0.69	0.00	46.6	0.0	9.4	52.9	0.54
Ardnageehy	21_48_1	4.67	3.11	9.15	27	2.0	29.489	0.0	0.928	1712	0.68	0.00	42.7	0.0	7.9	56.8	0.59
Doneelagh upstream Mealagh	21_2187_2	6.30	4.58	13.1	37	2.1	30.152	0.0	0.937	1718	0.68	0.00	43.7	0.0	6.1	56.0	0.59
Mealagh at Inchiclogh - GAUGED	21_5827_3	45.10	16.18	84.1	157	1.9	11.156	0.0	0.985	1881	0.68	0.00	37.7	2.9	14.2	53.6	0.46
Mealagh upstream Survey Extent	21_5826_1	47.42	17.83	88.5	166	1.9	10.248	0.0	0.985	1882	0.68	0.00	35.9	2.9	14.1	55.9	0.47
Mealagh downstream Mealagh Tributary	21_6183_1	47.75	18.58	90.0	168	1.9	10.028	0.0	0.985	1882	0.68	0.00	35.6	3.1	14.0	56.2	0.47
Mealagh	21_6412_1	54.05	18.703	103.2	206	1.9	9.888	0.0	0.980	1863	0.68	0.00	36.4	2.8	13.1	56.4	0.49
Mealagh	21_6412_2	54.48	19.098	103.6	206	1.9	9.645	0.0	0.980	1863	0.68	0.02	35.9	2.8	12.9	57.0	0.49
Mealagh downstream Milleencolla	21_6258_1	55.05	19.10	104.9	210	1.9	9.645	0.0	0.980	1863	0.68	0.02	35.9	2.8	12.9	57.0	0.49
Milleagh downstream Survey Extent	21_6258_3	55.53	19.79	105.6	210	1.9	9.248	0.0	0.980	1863	0.68	0.05	35.6	2.9	12.8	57.3	0.49
Raheen Beg	21_6183_1+	0.28	18.58	0.12	1	1.9	10.027	0.0	0.985	1882	0.68	0.00	35.6	3.1	14.0	56.2	0.47

LOCATION	HEP	DTM_AREA	MSL	NETLEN	STMFQ	DRAIND	S1085	ARTDRAIN2	FARL	SAAR	FORMWET	URBEXT	PEAT	ALLUV	FOREST	PASTURE	BFISOILS
Milleencolla East Stream	21_6258_1+	0.57	18.66	1.73	4	1.9	9.858	0.0	0.977	1858	0.68	0.00	36.3	2.8	13.0	56.2	0.48
Blue Hill South	21_7668_1+	0.92	2.11	3.64	19	3.0	25.159	0.0	1.000	1805	0.69	0.000	21.0	0.0	7.7	73.6	0.58
Dromacoosane upstream	21_1091_1	1.04	1.42	3.03	19	2.9	29.740	0.0	1.000	1757	0.69	0.000	31.1	0.0	9.5	60.9	0.58
Dromacoosane at Blue Hill Confluence	21_1091_3+	1.34	1.92	3.99	19	2.8	26.657	0.0	1.000	1777	0.69	0.000	25.7	0.0	7.9	67.7	0.57
Blue Hill South/Cappana loha and Dromacoosane	21_7668_1	2.27	2.39	7.63	38	3.4	22.986	0.0	1.000	1845	0.69	0.000	14.3	0.0	7.5	82.1	0.60
Dromacoosane downstream extent	21_7668_2	2.38	2.75	7.99	38	3.4	27.348	0.0	1.000	1850	0.69	0.000	13.6	0.0	8.8	82.7	0.60
Kilnaruane	21_6264_3	1.19	1.14	1.14	1.0	1.0	60.699	0.0	1.000	1847	0.69	0.000	39.2	0.0	10.6	60.8	0.58

Yellow text denotes HEPs derived from the upstream and downstream FSU nodes to establish incoming catchment parameters. Green text denotes a change from the original FSU parameters (original value in brackets).

Map B.1: Bantry AFA Bantry Sub-Catchments



The map displays the Bann Valley area, including the towns of Bantry, Carrigboy, and Dromdoneen. The Meallagh HEP's are marked with red dots and labeled with numbers such as 21_5826_1, 21_6258_3, 21_6142_1, 21_6183_2, 21_6183_1+, 21_2187_2, 21_6142_2, 21_6258_1+, 21_6258_1+, 21_51_2, 21_48_1, 21_48_1+, and 21_48_1+. The map also shows the Bann River, various lakes (e.g., Dromdoneen Lake, Raheen Lough, Lough Bofinna), and other geographical features like the Carrigboy Reservoir and the Carrigboy Industrial Estate. The legend identifies the Meallagh HEP's (red dots), Watercourse (blue line), HPW (red line), MPW (blue line), and AFA (orange line). A scale bar at the bottom indicates distances up to 2 Kilometers.

Map B.3: Bantry AFA Dromacoosane Sub-Catchments

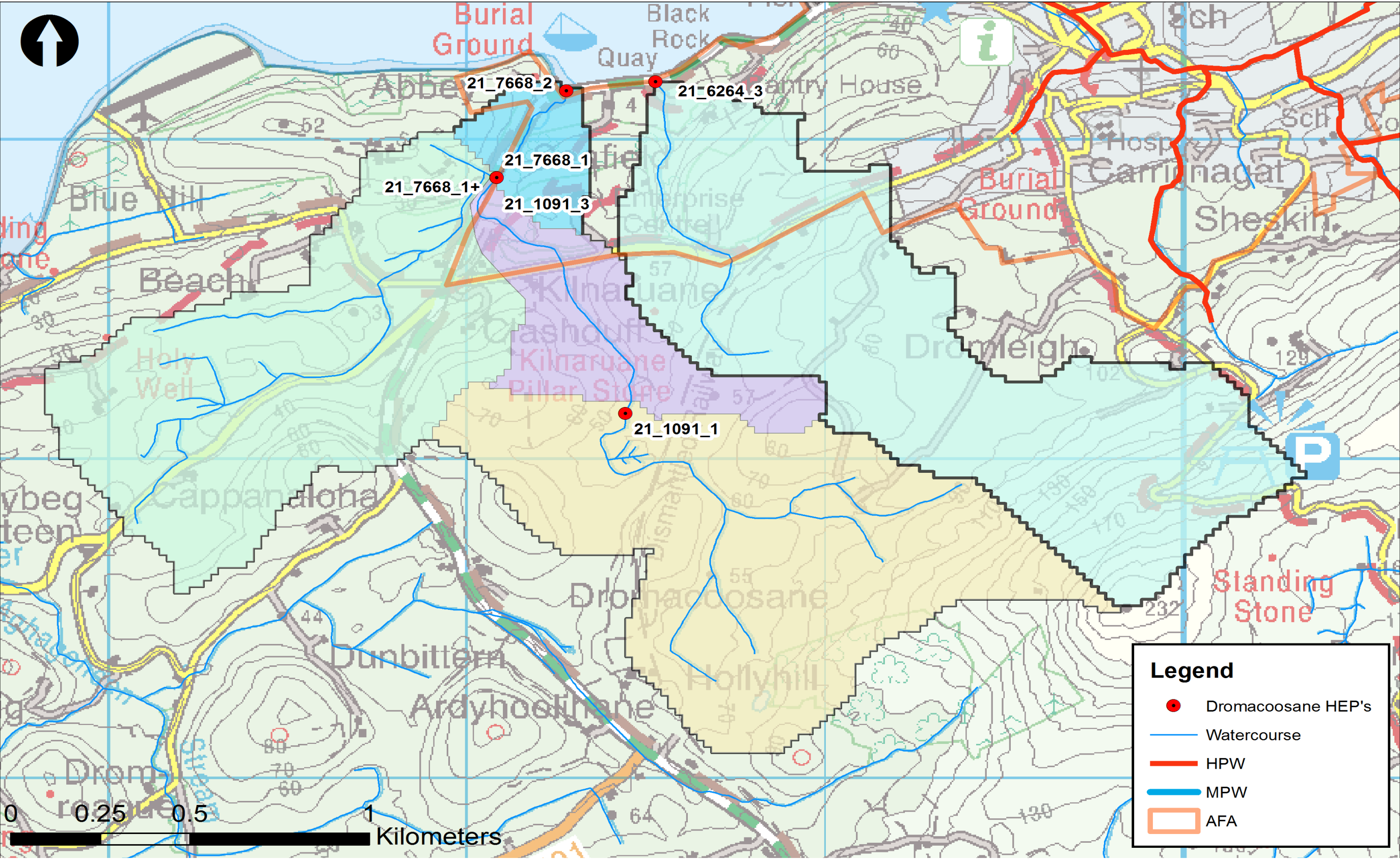


Table B.2: Durrus AFA Physical Catchment Descriptors

LOCATION	HEP	DTM_AREA	MSL	NETLEN	STMFIQ	DRAIN2	S1085	ARTDRAIN2	FARL	SAAR	FORMWET	URBEXT	PEAT	ALLUV	FOREST	PASTURE	BFISOILS
Clashadoo	21_6225_1+	1.0	4.18	1.7	2	1.830	36.706	0	1	1806	0.69	0	0	0.47	0	99.53	0.438
Ahanegavanagh upstream Survey Extent	21_5338_5	5.2	4.177	9.575	23	1.856	38.227	0	1	1806	0.69	0	0	0.49	1.52	43.33	0.428
Ahanegavanagh upstream Clashadoo	21_5338_6	6.2	4.543	9.943	23	1.595	32.118	0	1	1806	0.69	0	0	0.40	1.3	47.96	0.516
Ahanegavanagh downstream Clashadoo	21_6225_1	6.2	4.543	11.622	25	1.862	32.118	0	1	1806	0.69	0	0	0.40	1.33	48.03	0.517
Ahanegavanagh	21_6225_2	6.4	4.802	11.88	25	1.867	29.106	0	1	1805	0.69	0	0	0.39	1.45	49.03	0.520
Four Mile South upstream Survey Extent	21_8046_2	4.7	4.987	8.396	9	1.786	41.133	0	1	1597	0.69	0	37.43	0.00	42.84	26.63	0.591
Four Mile South	21_8046_3	4.9	5.485	8.896	9	1.810	38.856	0	1	1598	0.69	0	35.81	0.26	41.6	29.79	0.610
Four Mile North upstream Survey Extent	21_7736_3	26.7	13.182	43.333	95	1.623	9.231	0	1	1659	0.69	0	14.65	3.22	12.99	64.93	0.602
Four Mile North	21_7736_5	27.4	14.182	44.334	95	1.618	8.803	0	1	1659	0.69	0	14.28	3.33	12.84	65.83	0.601
Four Mile downstream Survey Extent	21_8044_2	32.6	14.748	54.157	106	1.663	8.972	0	1	1650	0.69	0	17.42	2.94	17.11	60.65	0.602

Yellow text denotes HEPs derived from the upstream and downstream FSU nodes to establish incoming catchment parameters. Green text denotes a change from the original FSU parameters (original value in brackets).

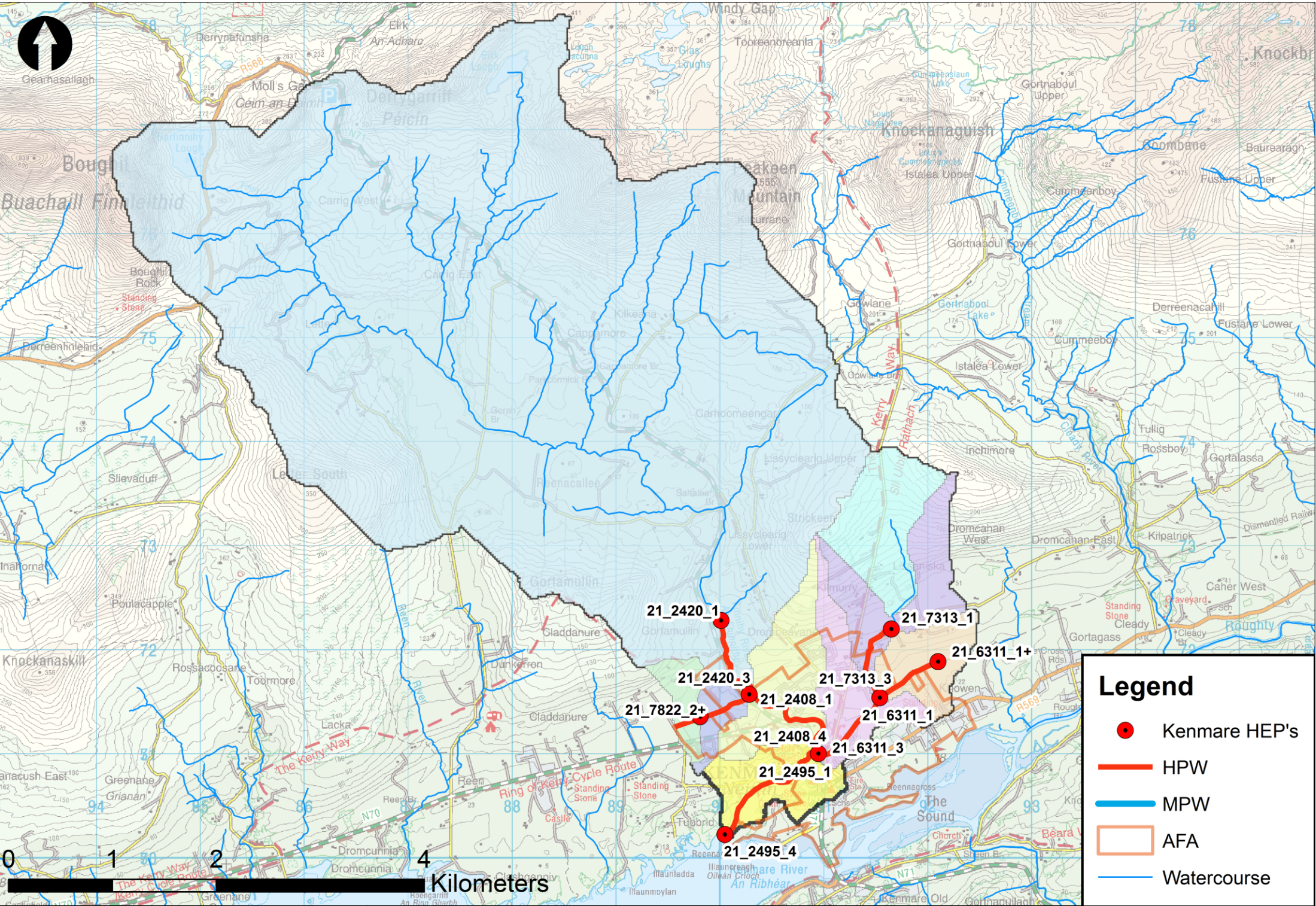
The map displays the Durrus area in County Wick, Ireland, with a focus on the Durrus HEP's (red dots) and the HPW (red line). The HPW runs along the coast, while the MPW (blue line) follows the shoreline. The AFA (orange outline) is a large area in the center of the map. The map includes a scale bar (0 to 3 Kilometers) and a north arrow. The Durrus HEP's are located near the coast, with the HPW and MPW running along the shoreline. The AFA is a large area in the center of the map.

Table B.3: Kenmare AFA Physical Catchment Descriptors

LOCATION	HEP	DTM_AREA	MSL	NETLEN	STMFG	DRAIND	\$1085	ARTDRAIN2	FARL	SAAR	FORMWET	URBEXT	PEAT	ALLUV	FOREST	PASTURE	BFISOILS
Kilowen	21_6311_1+	0.69	1.7	1.2	1	0.92	67.05	0	1.000	2270	0.69	0.000	19.95	8.26	9.96	73.04	0.49
Lissaniska upstream Survey Extent	21_7313_1	1.00	1.1	1.1	1	1.08	97.98	0	1.000	2387	0.69	0.000	44.29	2.23	13.64	48.97	0.42
Lissaniska upstream Kilowen	21_7313_3	2.54	2.1	2.1	1	0.82	61.13	0	1.000	2236	0.69	0.000	19.95	6.76	9.96	73.04	0.61
Lissaniska downstream Kilowen	21_6311_1	2.55	2.1	2.8	3	1.10	61.13	0	0.000	2236	0.69	0.000	19.95	6.79	9.96	73.05	0.61
Kilowen upstream Finnihy	21_6311_3	3.30	3.0	3.7	3	1.12	36.73	0	1.000	2207	0.69	3.180	16.16	9.46	8.31	74.27	0.58
Finnihy downstream Kilmurray	21_2420_1	25.51	9.1	45.0	77	1.77	15.09	0	0.971	2859	0.69	0.000	55.59	0.38	7.94	24.31	0.50
Finnihy upstream Gortamullin East	21_2420_3	26.24	10.1	46.0	77	1.72	14.12	0	0.973	2823	0.69	0.060	53.51	0.52	7.57	27.26	0.47
Finnihy downstream Gortamullin East excluding Gortamullin West	21_2408_1	26.47 (27.16)	10.1	46.5	79	1.74	14.12	0	0.973	2823	0.69	0.060	53.51	0.52	7.57	27.26	0.47
Finnihy upstream Lissaniska - excluding Gortamullin West	21_2408_4	27.50 (28.19)	11.3	47.7	79	1.71	13.95	0	0.974	2796	0.69	0.330	51.57	0.57	7.29	29.44	0.47
Finnihy downstream Lissaniska - excluding Gortamullin West	21_2495_1	30.80 (31.49)	11.3	51.4	83	1.65	13.95	0	0.976	2733	0.69	0.670	47.80	1.51	7.39	34.19	0.44
Finnihy downstream Survey Extent - excluding Gortamullin West	21_2495_4	31.55 (32.24)	12.6	52.7	83	1.65	13.95	0	0.977	2719	0.69	1.120	46.71	1.49	7.22	35.21	0.44

Yellow text denotes HEPs derived from the upstream and downstream FSU nodes to establish incoming catchment parameters. Green text denotes a change from the original FSU parameters (original value in brackets).

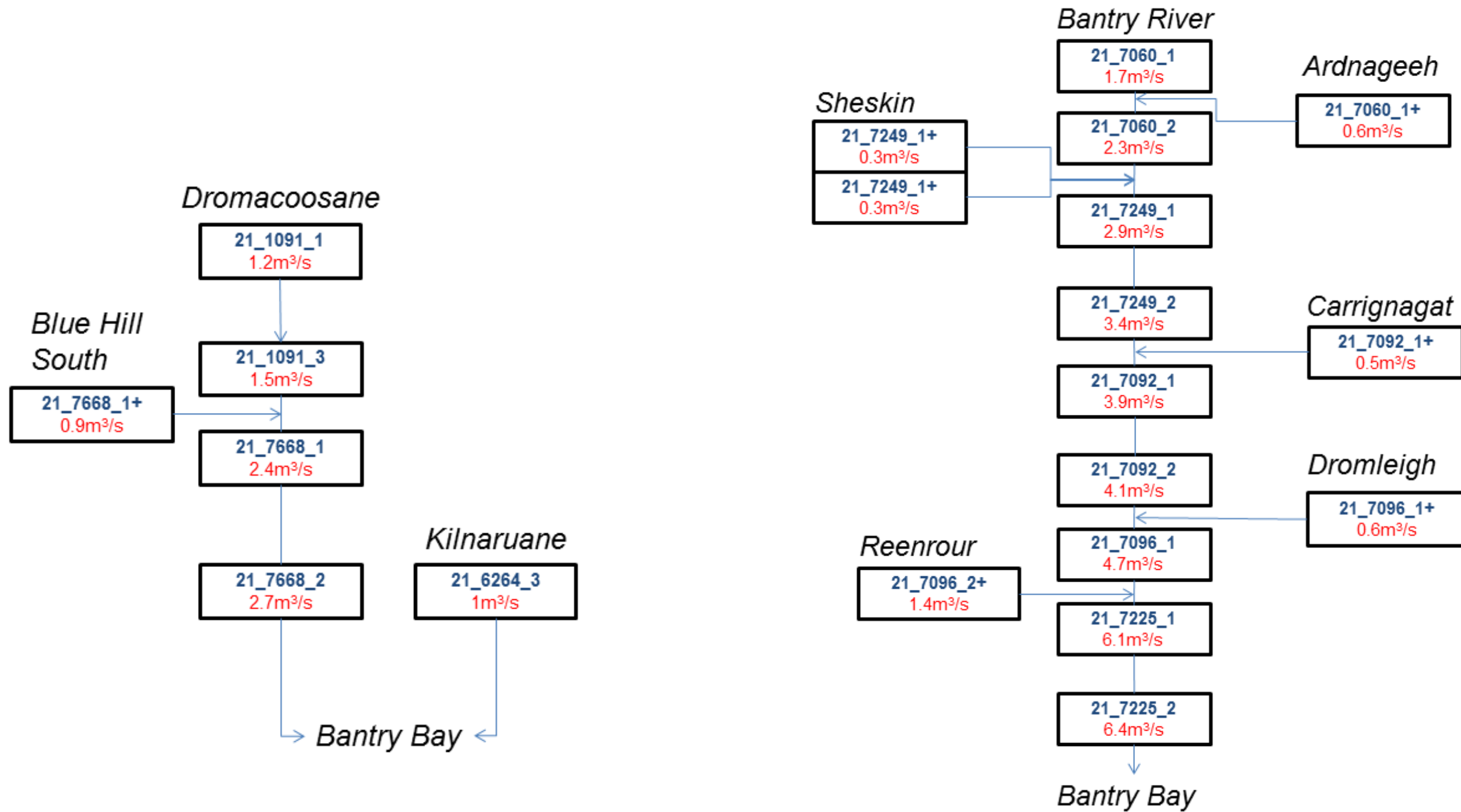
Map B.5: Kenmare AFA Sub-Catchments



Appendix C. Design Hydrology

C.1 Bantry AFA

Figure C.1: Bantry AFA Schematic of QMED



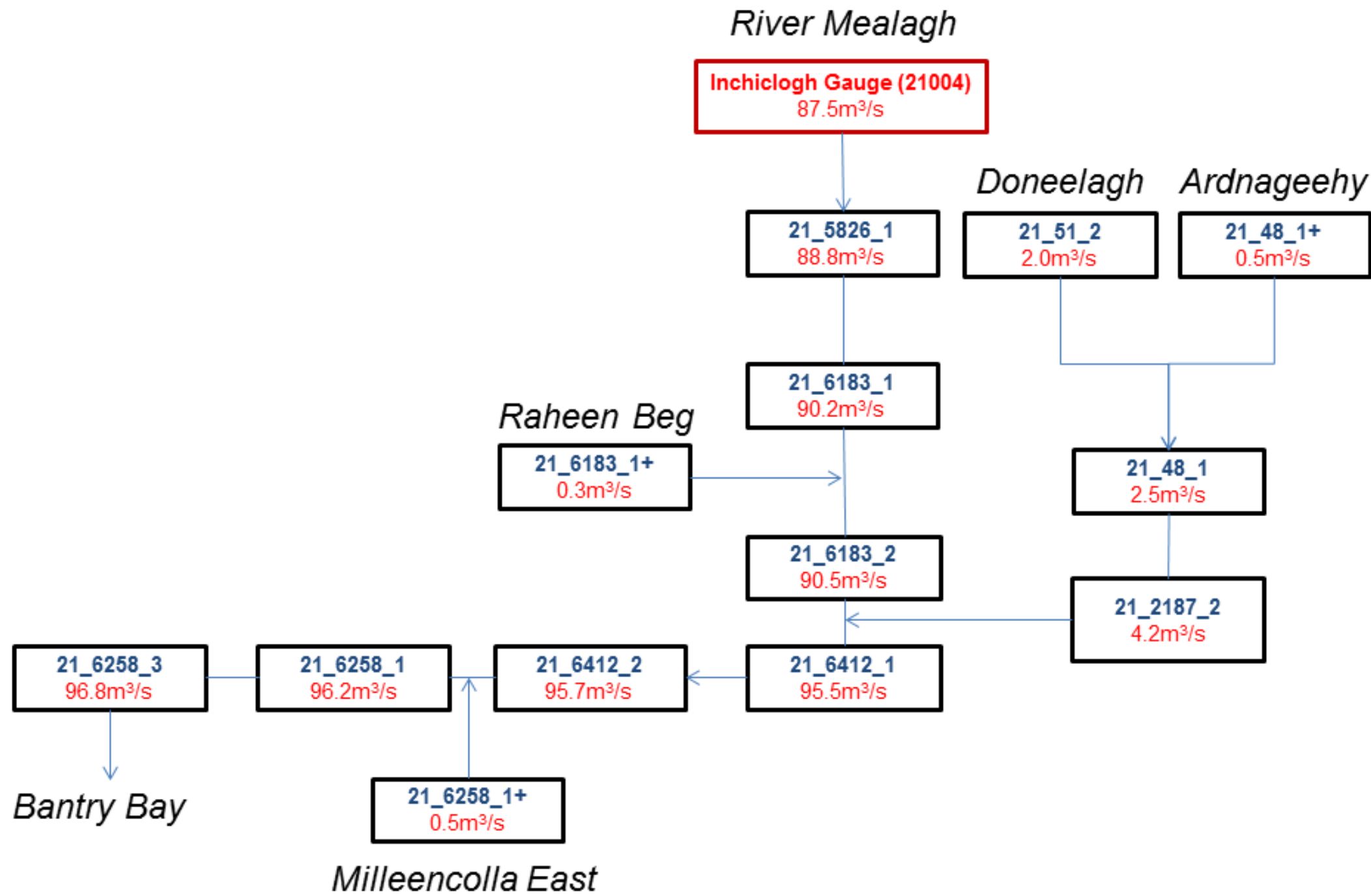


Table C.1: Dromcoosane Catchment Pooling Group

Rank	Pooling Station No.	Record Length	Cumulative Years	Pooling Years Count	Discordancy (Di)	Effective record length	FARL	URBEXT	FLATWET	S1085	AREA	BFI	SAAR	FSU Class	Karstic Catchment?	HGF/QMED	Additional Comments
1	10004	14	14	14	1.627	14	0.986	0.000	0.54	25.037	30.57	0.517	1700	B	Locally Important Aquifer	0.705	N/A
2	6030	27	41	41	0.515	54	0.972	0.000	0.61	20.091	10.40	0.625	1157	B	Poor Aquifer	0.701	N/A
3	20006	35	76	76	0.184	105	1.000	0.000	0.67	6.390	77.55	0.600	1463	B	Locally Important Aquifer	0.574	N/A
4	25034	26	102	102	0.496	104	1.000	0.000	0.65	2.572	10.77	0.698	969	A2	Locally Important Aquifer	1.182	N/A
5	16013	33	135	135	0.119	165	0.993	0.000	0.58	24.556	93.58	0.531	1471	B	Poor Aquifer	0.488	N/A
6	35002	34	169	169	0.147	204	0.986	0.000	0.72	13.263	88.82	0.523	1381	A2	Poor Aquifer	0.792	N/A
7	19020	28	197	197	0.204	196	1.000	0.000	0.63	11.017	73.95	0.687	1179	A2	Locally Important Aquifer	1.116	N/A
8	25044	40	237	237	0.041	320	0.997	0.000	0.59	2.666	92.55	0.575	1187	A2	Locally Important Aquifer	1.256	N/A
9	16006	33	270	270	0.198	297	0.994	0.000	0.59	5.763	75.80	0.591	1116	B	Locally Important Aquifer	0.562	Gauge within Karstic zone. But this makes up only a very small fraction of the catchment.
10	16005	30	300	300	0.082	300	1.000	0.330	0.59	6.524	84.00	0.542	1154	A2	Locally Important Aquifer	1.071	N/A
11	13002	19	319	319	0.023	209	1.000	0.000	0.56	4.953	62.96	0.657	1044	B	Poor Aquifer	0.645	N/A
12	24022	20	339	339	0.050	240	1.000	0.330	0.60	3.291	41.21	0.620	942	A2	Locally Important Aquifer	0.791	N/A
13	6031	18	357	357	0.839	234	1.000	1.540	0.63	8.102	46.17	0.552	931	A2	Poor Aquifer	1.049	N/A
14	26010	35	392	392	0.052	490	0.937	0.000	0.69	1.906	94.53	0.578	1064	B	Locally Important Aquifer	0.919	N/A
15	14033	9	401	401	1.151	135	1.000	0.850	0.59	11.379	78.89	0.441	1145	B	Locally Important Aquifer	0.515	N/A
16	34024	28	429	429	0.294	448	0.922	0.750	0.73	1.518	127.23	0.522	1177	A2	Locally Important Aquifer	0.962	N/A
17	26058	24	453	453	0.217	408	0.995	1.040	0.65	5.535	59.98	0.697	974	B	Locally Important Aquifer	0.548	Gauge situated on very minor Karstic zone within catchment.
18	34009	33	486	486	0.037	594	1.000	1.070	0.73	3.325	117.11	0.443	1257	A2	Locally Important Aquifer	1.309	N/A
19	29001	40	526	526	0.056	760	0.998	0.660	0.65	2.220	115.48	0.581	1090	A1	Locally Important Aquifer	1.560	Gauge on Karstic Zone. Majority of catchment is locally important aquifer.

Figure C.2: Flood Growth Curve Plot

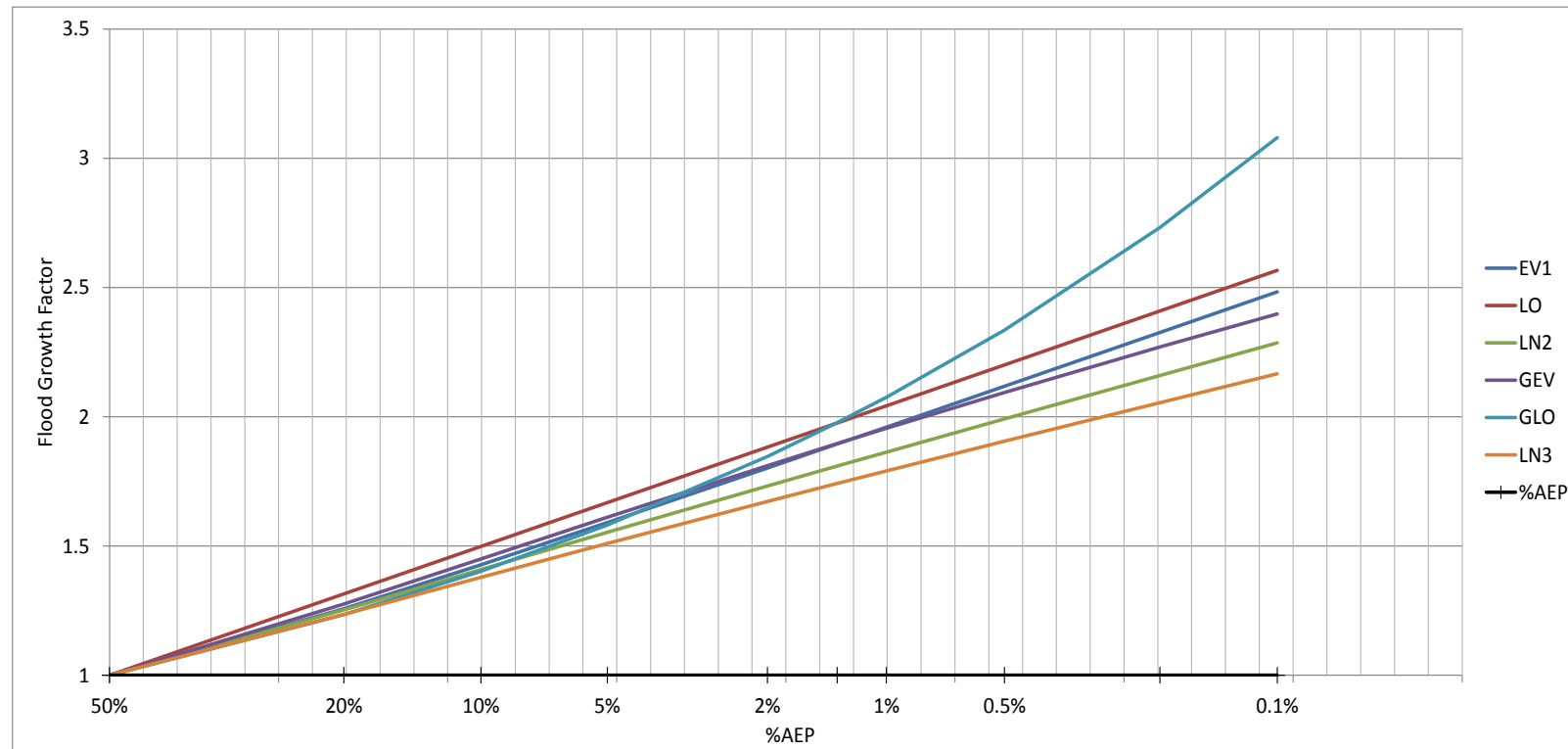


Figure C.3: L Moment Plot

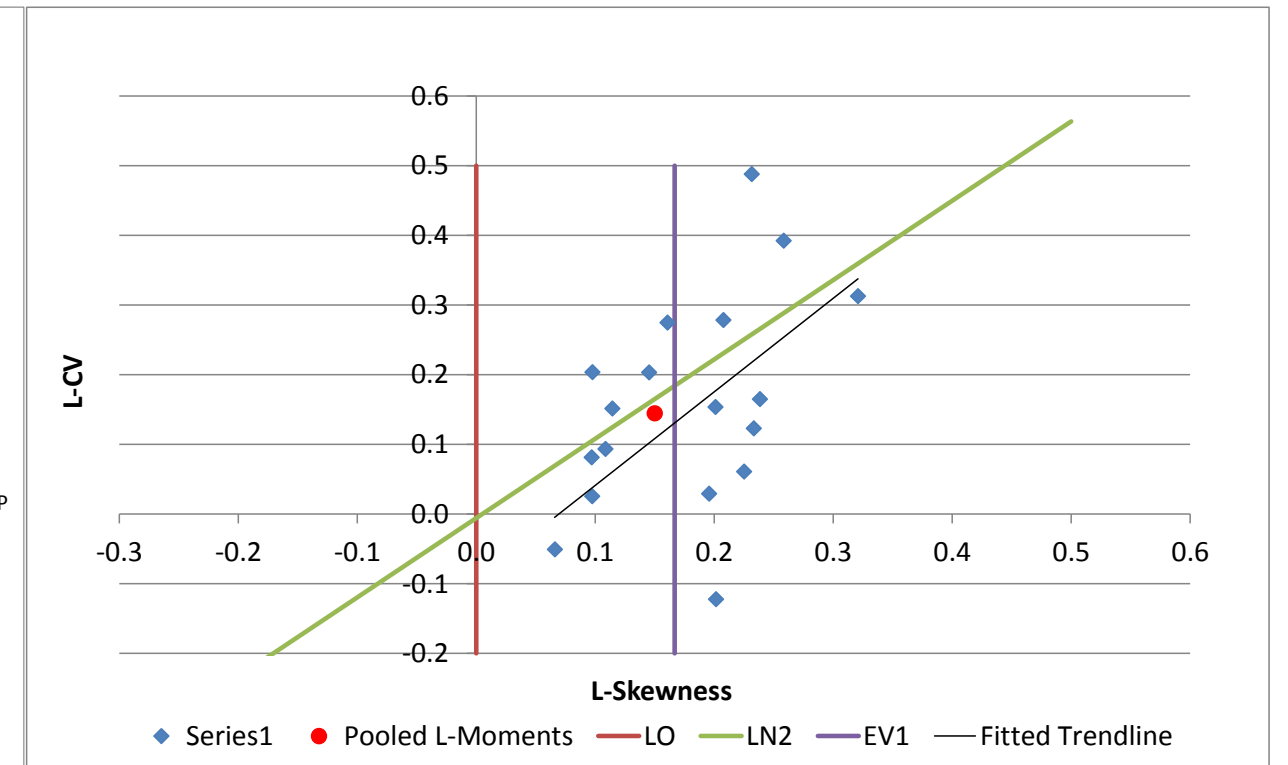


Table C.2: Bantry River Catchment Flood Frequency Analysis

Rank	Pooling Station No.	Record Length	Cumulative Years	Pooling Years Count	Discordancy (Di)	Effective record length	FARL	URBEX T	FLATWET	S1085	AREA	BFI	SAAR	FSU Class	Karstic Catchment?	HGF/QMED	Additional Comments
1	10004	14	14	14	2.160	14	0.986	0.000	0.54	25.037	30.57	0.517	1700	B	Locally Important Aquifer	0.705	N/A
2	20006	35	49	49	0.244	70	1.000	0.000	0.67	6.390	77.55	0.600	1463	B	Locally Important Aquifer	0.574	N/A
3	16013	33	82	82	0.158	99	0.993	0.000	0.58	24.556	93.58	0.531	1471	B	Poor Aquifer	0.488	N/A
4	35002	34	116	116	0.196	136	0.986	0.000	0.72	13.263	88.82	0.523	1381	A2	Poor Aquifer	0.792	N/A
5	25040	19	135	135	0.106	95	1.000	6.180	0.60	13.494	28.02	0.576	990	A2	Locally Important Aquifer	1.322	N/A
6	36021	27	162	162	0.113	162	0.995	0.000	0.69	19.110	23.41	0.330	1570	A2	Poor Aquifer	0.749	Gauge situated on Karstic zone. Majority of catchment is of Poor Aquifer.
7	25044	40	202	202	0.055	280	0.997	0.000	0.59	2.666	92.55	0.575	1187	A2	Locally Important Aquifer	1.256	N/A
8	16005	30	232	232	0.109	240	1.000	0.330	0.59	6.524	84.00	0.542	1154	A2	Locally Important Aquifer	1.071	N/A
9	16006	33	265	265	0.263	297	0.994	0.000	0.59	5.763	75.80	0.591	1116	B	Locally Important Aquifer	0.562	Gauge within Karstic zone. But this makes up only a very small fraction of the catchment.
10	13002	19	284	284	0.031	190	1.000	0.000	0.56	4.953	62.96	0.657	1044	B	Poor Aquifer	0.645	N/A
11	24022	20	304	304	0.067	220	1.000	0.330	0.60	3.291	41.21	0.620	942	A2	Locally Important Aquifer	0.791	N/A
12	26010	35	339	339	0.069	420	0.937	0.000	0.69	1.906	94.53	0.578	1064	B	Locally Important Aquifer	0.919	N/A
13	27001	9	348	348	0.211	117	0.987	0.000	0.61	4.448	46.70	0.331	1477	A2	Locally Important Aquifer	1.255	N/A
14	39001	31	379	379	0.206	434	0.987	0.000	0.70	12.506	50.71	0.320	1764	B	Poor Aquifer	0.818	N/A
15	32011	25	404	404	0.119	375	0.986	0.150	0.69	13.428	70.10	0.337	1613	B	Poor Aquifer	0.689	N/A
16	6031	18	422	422	1.114	288	1.000	1.540	0.63	8.102	46.17	0.552	931	A2	Poor Aquifer	1.049	N/A
17	10028	16	438	438	0.441	272	1.000	0.480	0.54	7.901	202.92	0.695	1397	B	Poor Aquifer	0.567	N/A
18	16051	13	451	451	0.565	234	1.000	0.000	0.58	1.615	34.19	0.593	895	B	Locally Important Aquifer	0.945	N/A
19	12013	30	481	481	0.107	570	0.999	0.470	0.54	3.850	204.39	0.707	1383	B	Locally Important Aquifer	0.905	N/A

Figure C.4: Flood Growth Curve Plot

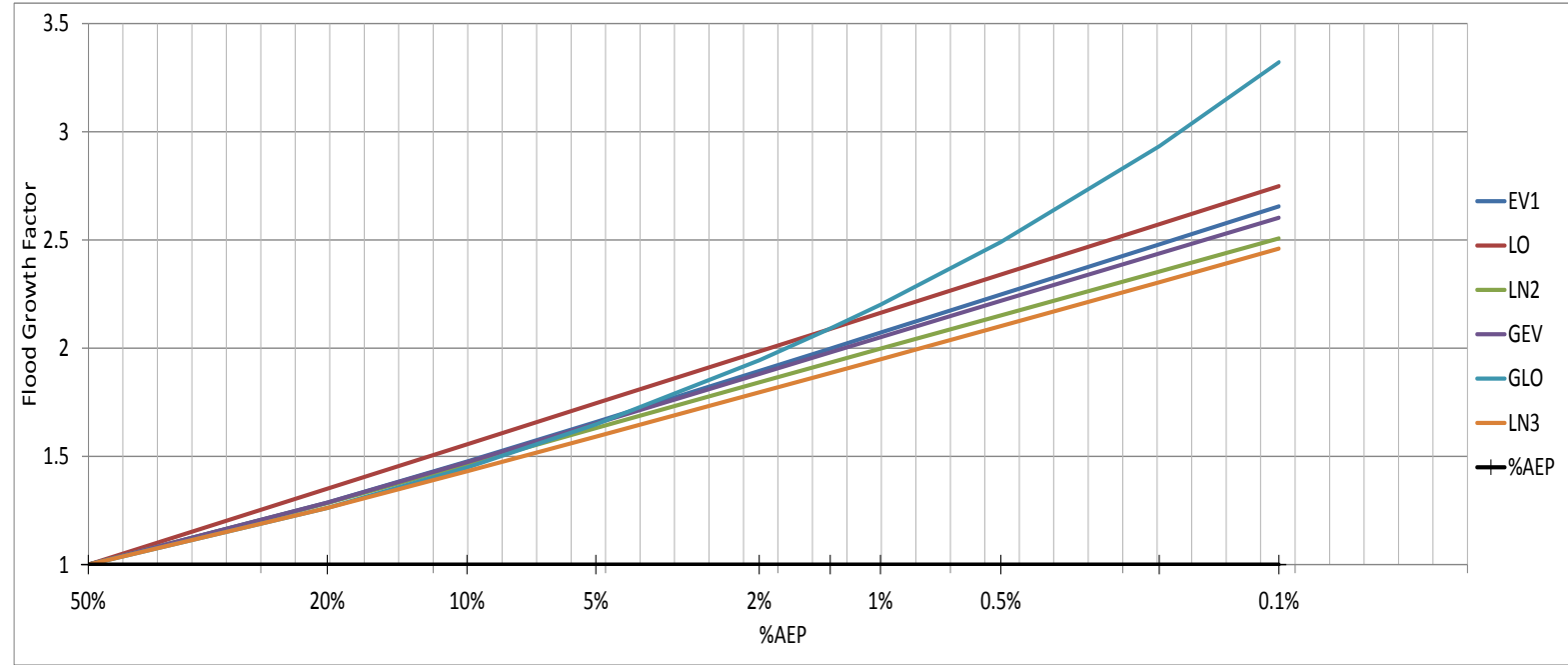


Figure C.5: L Moment Plot

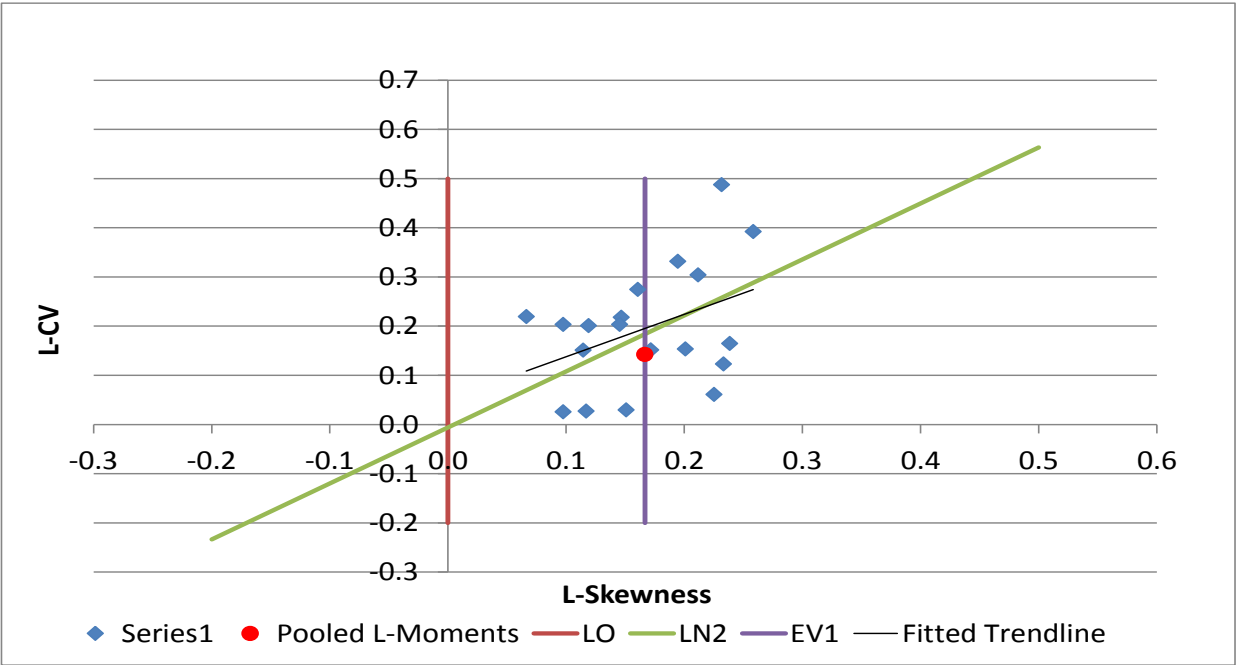


Table C.3: Inchiclogh Gauge and Mealagh Catchment Flood Frequency Analysis

Rank	Pooling Station No.	Record Length	Cumulative Years	Pooling Years Count	Discordancy (Di)	Effective record length	FARL	URBEX T	FLATWET	S1085	AREA	BFI	SAAR	FSU Class	Karstic Catchment?	HGF/ QMED	Additional Comments
1	30001	18	18	18	1.392	18	0.935	0.000	0.70	5.168	121.02	0.436	1787	A2	Locally Important Aquifer	1.022	N/A
2	16013	33	51	51	0.212	66	0.993	0.000	0.58	24.556	93.58	0.531	1471	B	Poor Aquifer	0.488	N/A
3	35002	34	85	85	0.263	102	0.986	0.000	0.72	13.263	88.82	0.523	1381	A2	Poor Aquifer	0.792	N/A
4	25158	18	103	103	0.888	72	1.000	0.000	0.59	6.973	109.55	0.514	1377	A1	Locally Important Aquifer	1.364	N/A
5	10002	46	149	149	0.636	230	0.932	0.170	0.54	6.899	230.89	0.516	1530	B	Locally Important Aquifer	0.721	Including large areas of Poor Aquifer strata.
6	22006	57	206	206	0.065	342	0.961	0.540	0.66	9.421	328.81	0.414	1819	B	Locally Important Aquifer	0.625	Only minor Karstic coverage, vast majority is of locally important aquifer.
7	32011	25	231	231	0.159	175	0.986	0.150	0.69	13.428	70.10	0.337	1613	B	Poor Aquifer	0.689	N/A
8	20006	35	266	266	0.328	280	1.000	0.000	0.67	6.390	77.55	0.600	1463	B	Locally Important Aquifer	0.574	N/A
9	39001	31	297	297	0.276	279	0.987	0.000	0.70	12.506	50.71	0.320	1764	B	Poor Aquifer	0.818	N/A
10	34007	53	350	350	0.085	530	0.978	0.000	0.73	4.569	151.71	0.349	1590	B	Poor Aquifer	0.489	Mix. Majority of region is of Poor quality aquifer. Gauge sits on Karstic zone.
11	34009	33	383	383	0.066	363	1.000	1.070	0.73	3.325	117.11	0.443	1257	A2	Locally Important Aquifer	1.309	N/A
12	36021	27	410	410	0.151	324	0.995	0.000	0.69	19.110	23.41	0.330	1570	A2	Poor Aquifer	0.749	Gauge situated on Karstic zone. Majority of catchment is of Poor Aquifer.
13	1041	32	442	442	0.168	416	1.000	0.860	0.69	7.227	116.18	0.379	1329	B	Locally Important Aquifer	0.424	N/A
14	38001	33	475	475	0.206	462	0.922	0.290	0.70	5.950	111.25	0.313	1753	B	Poor Aquifer	0.292	N/A
15	25002	51	526	526	0.938	765	0.999	0.180	0.59	6.877	221.61	0.542	1300	A2	Locally Important Aquifer	0.988	N/A

Figure C.6: Flood Growth Curve Plot

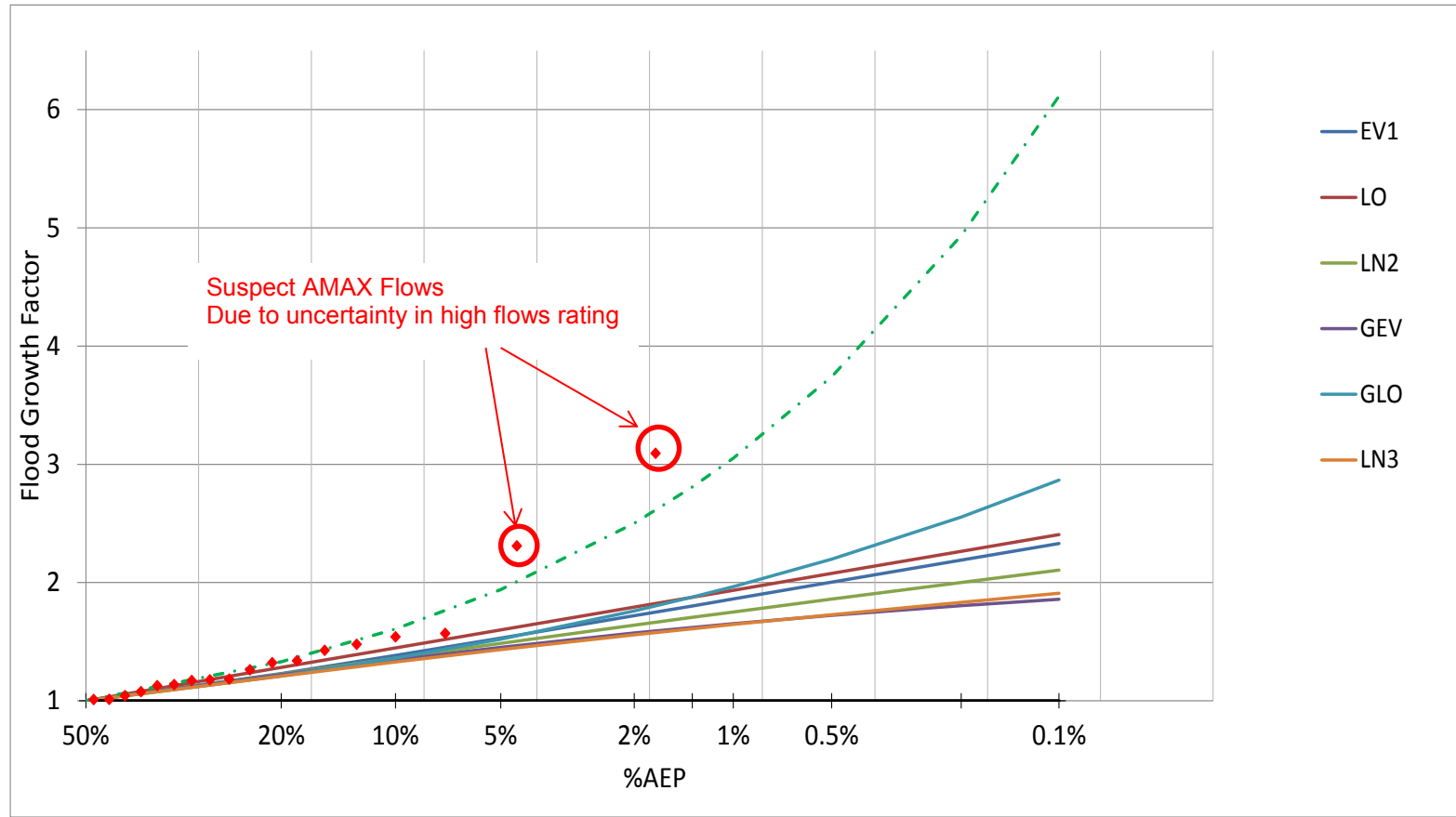
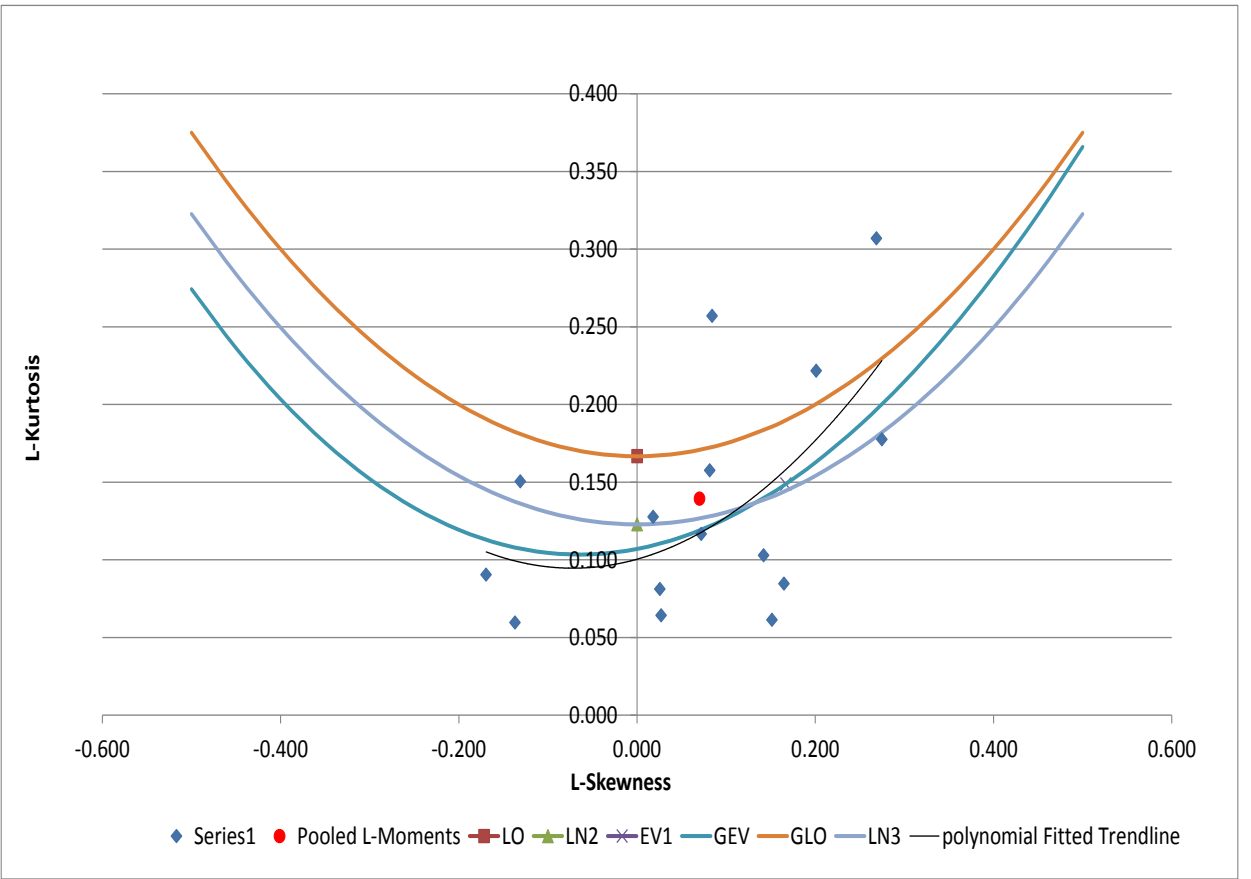


Figure C.7: L Moment Plot



Please note that the Inchiclogh Gauge (21004) has not been included in the pooling group as the pooling analysis is independent of the site specific data.

Figure C.8: Median Width Exceedance Flood Hydrograph at Inchiclogh Gauge, Mealagh Catchment

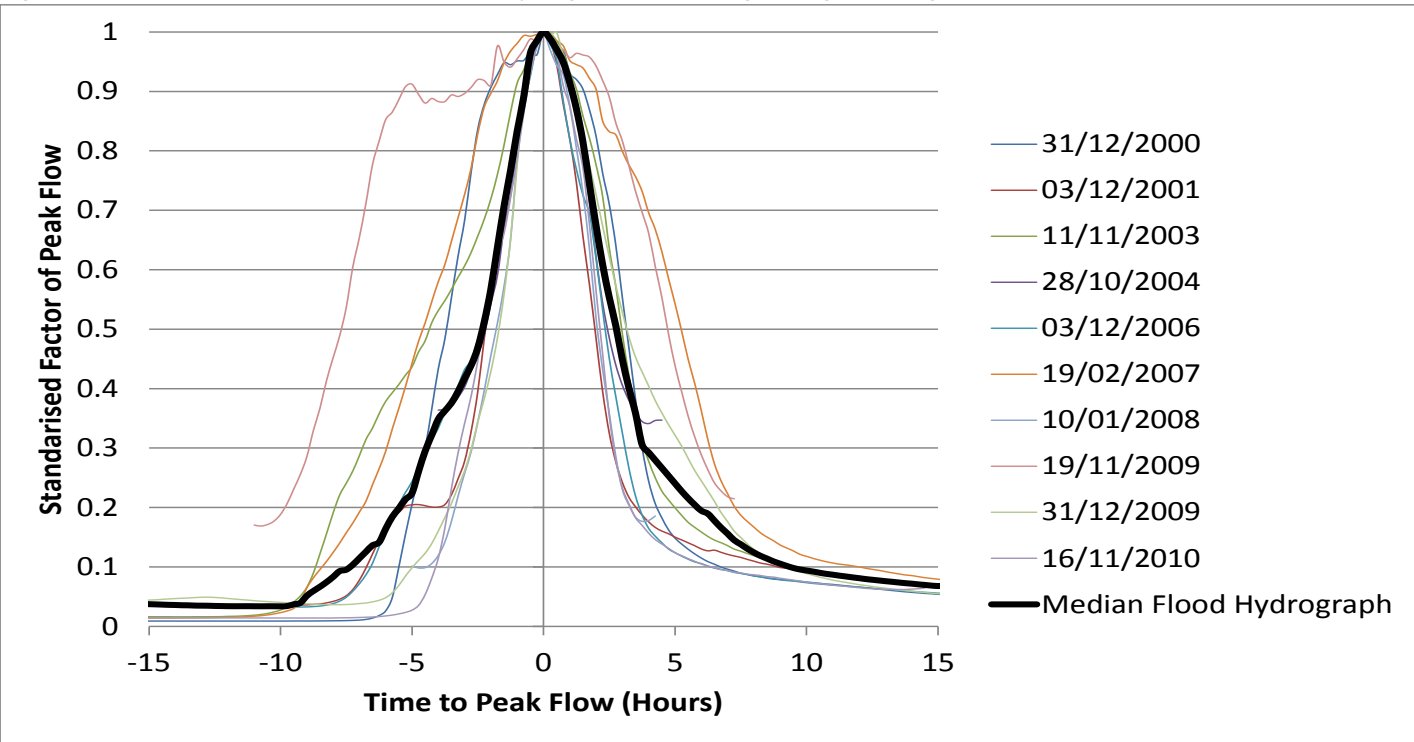
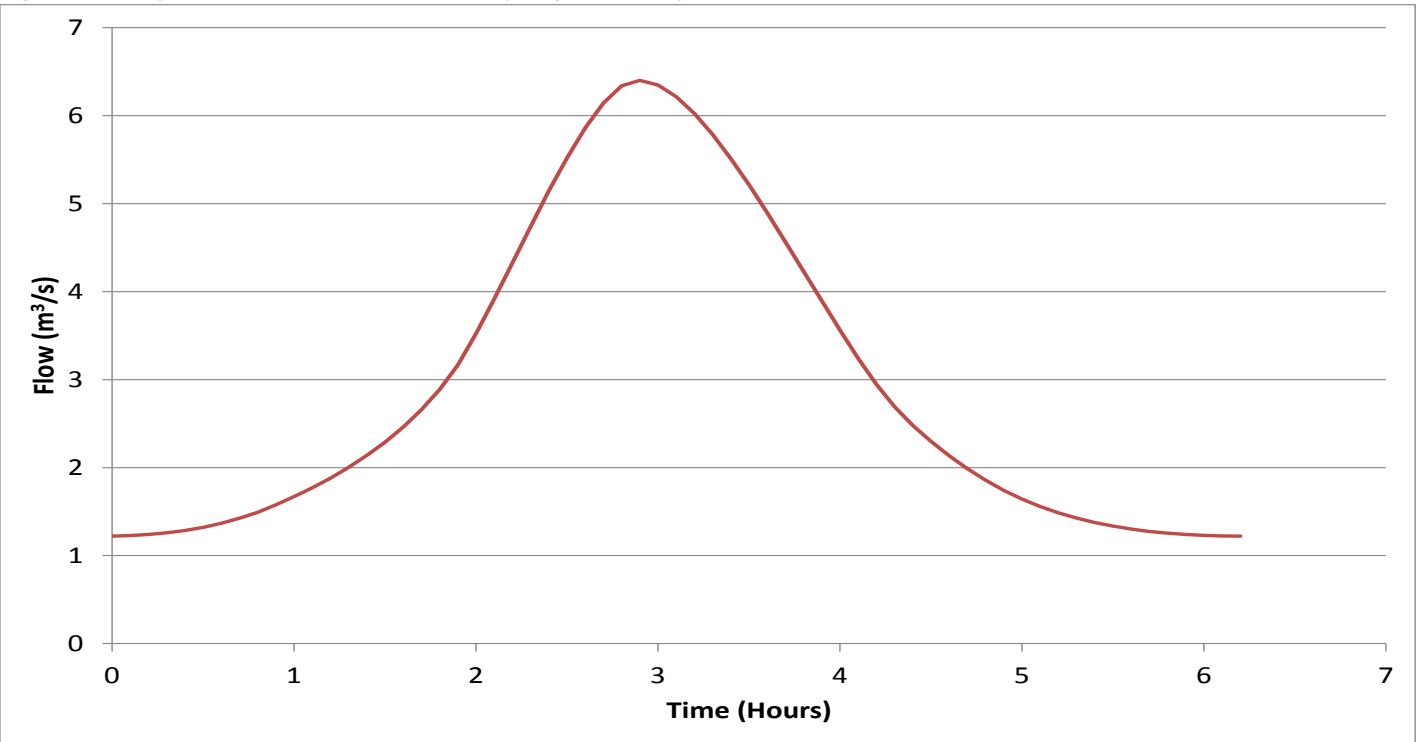


Figure C.9: Typical FSSR16 Rainfall Runoff Hydrograph Bantry Catchment



FSSR 16 Parameter	Bantry Catchment	Dromcoosane Catchment	Mealagh Catchment
M5 - 60 min (mm)	18.8	18.5	18.8
M5 - 2 day (mm)	92.1	90.7	92.1
M5 -25 day (mm)	324.5	319.5	324.5
Jenkinson's <i>r</i>	0.204	0.204	0.204
Catchment Wetness Index (CWI)	126	126	125
Critical Storm Duration, D (hours)	3.9	7.3	13.3
Time to Peak, Tp (hours)	1.3	2.0	4.6

Figure C.10: Typical FSSR16 Rainfall Runoff Hydrograph Dromacoosane Catchment

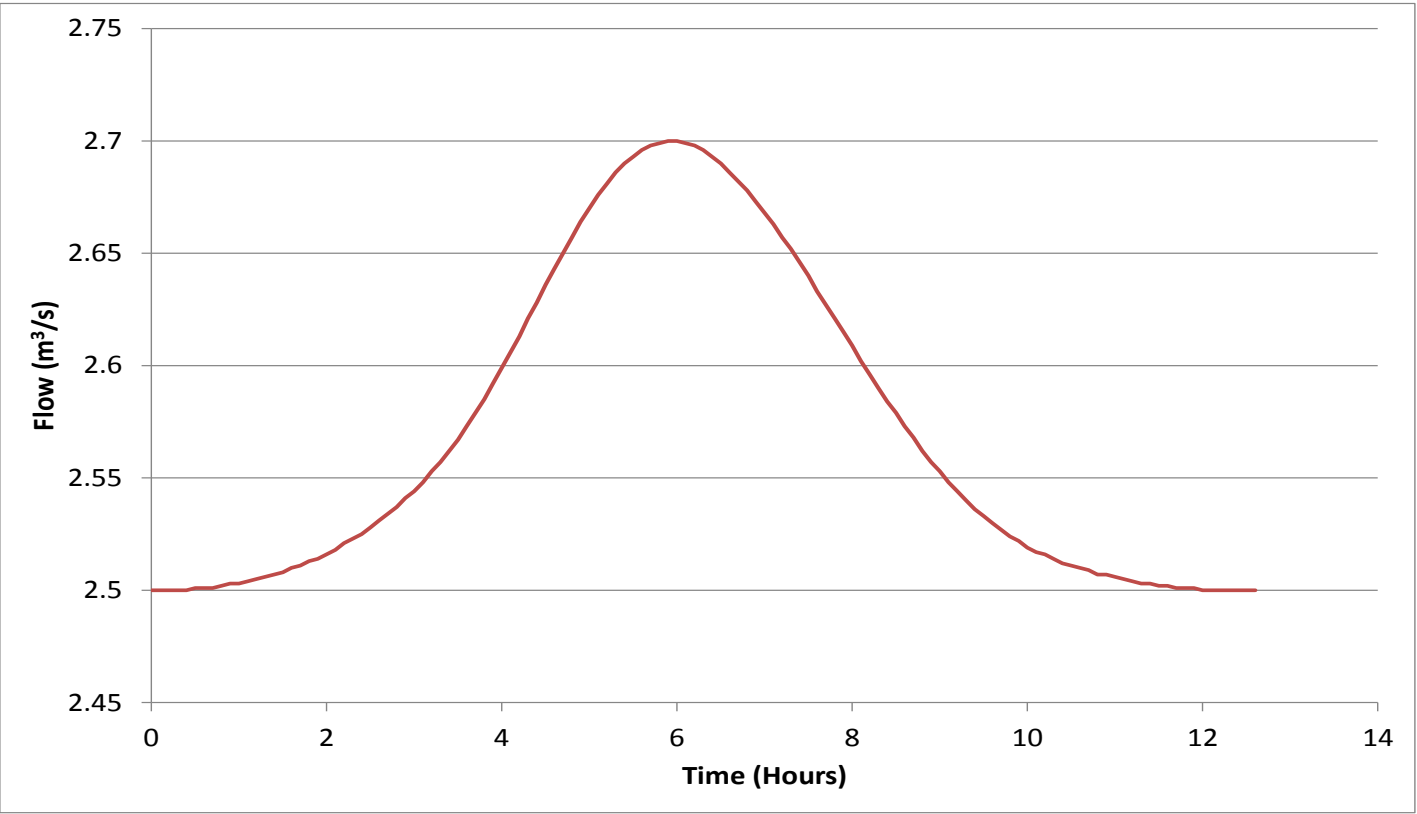


Table C.4: Bantry AFA Design Peak Flows

LOCATION	HEP	AREA	SAAR	BFI	Pivotal Site	QMED	95% Confidence Limit	QME D/	Flood Growth Curve	Flood Growth Factor								Design Flows								Hydrograph Pivotal Site
										50	20	10	5	2	1	0.5	0.1	50	20	10	5	2	1	0.5	0.1	
Blue Hill South	21_7668_1+	0.92	1805	0.581	20006	0.93	1.74	10	GLO	1.00	1.26	1.44	1.63	1.92	2.17	2.46	3.27	0.9	1.2	1.3	1.5	1.8	2.0	2.3	3.0	FSR Rainfall-Runoff
Dromacoosane upstream	21_1091_1	1.04	1757	0.576	20006	1.15	2.16	11	GLO	1.00	1.26	1.44	1.63	1.92	2.17	2.46	3.27	1.2	1.4	1.7	1.9	2.2	2.5	2.8	3.8	FSR Rainfall-Runoff
Dromacoosane at Blue Hill Confluence	21_1091_3	1.34	1777	0.570	20006	1.45	2.73	12	GLO	1.00	1.26	1.44	1.63	1.92	2.17	2.46	3.27	1.5	1.8	2.1	2.4	2.8	3.2	3.6	4.7	FSR Rainfall-Runoff
Blue Hill South/Cappanaloa and Dromacoosane	21_7668_1	2.27	1845	0.597	20006	2.19	4.12	12	GLO	1.00	1.26	1.44	1.63	1.92	2.17	2.46	3.27	2.2	2.8	3.2	3.6	4.2	4.8	5.4	7.2	FSR Rainfall-Runoff
Dromacoosane downstream extent	21_7668_2	2.38	1850	0.597	20006	2.68	5.03	14	GLO	1.00	1.26	1.44	1.63	1.92	2.17	2.46	3.27	2.7	3.4	3.9	4.4	5.2	5.8	6.6	8.8	FSR Rainfall-Runoff
Kilnaruane	21_6264_3	1.19	1847	0.577	20006	0.97	1.81	8	GLO	1.00	1.26	1.44	1.63	1.92	2.17	2.46	3.27	1.0	1.2	1.4	1.6	1.9	2.1	2.4	3.2	FSR Rainfall-Runoff
Knocknaveagharea upstream	21_7060_1+	0.37	1859	0.567	20005	0.57	1.07	12	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	0.6	0.7	0.8	0.9	1.1	1.2	1.4	1.5	FSR Rainfall-Runoff
Bantry Main d/s Sheskin	21_7060_1	1.11	1859	0.594	20005	1.71	3.20	16	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	1.7	2.2	2.5	2.8	3.2	3.5	4.2	4.5	FSR Rainfall-Runoff
Bantry Main u/s School	21_7060_2	1.39	1859	0.568	20005	2.28	4.28	18	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	2.3	2.9	3.4	3.8	4.3	4.7	5.6	6.0	FSR Rainfall-Runoff
Bantry Main	21_7249_1	1.71	1859	0.568	20005	2.93	5.50	19	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	2.9	3.8	4.3	4.8	5.5	6.0	7.2	7.7	FSR Rainfall-Runoff
Bantry Main	21_7249_2	2.04	1859	0.567	20005	3.44	6.46	20	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	3.4	4.4	5.1	5.7	6.5	7.1	8.5	9.1	FSR Rainfall-Runoff
Bantry Main	21_7092_1	2.55	1859	0.566	20005	4.10	7.39	19	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	3.9	5.1	5.8	6.5	7.4	8.1	9.7	10.4	FSR Rainfall-Runoff
Bantry Main	21_7092_2	2.63	1859	0.567	20005	4.25	7.98	20	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	4.2	5.5	6.3	7.0	8.0	8.7	10.5	11.2	FSR Rainfall-Runoff
Bantry Main d/s Scart Road	21_7096_1	3.19	1859	0.567	20005	4.67	8.76	19	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	4.7	6.0	6.9	7.7	8.8	9.6	11.5	12.3	FSR Rainfall-Runoff
Bantry Main	21_7225_1	4.13	1859	0.586	20005	6.09	11.43	20	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	6.1	7.8	9.0	10.1	11.5	12.5	15.0	16.0	FSR Rainfall-Runoff
Bantry Main d/s Survey Extent	21_7225_2	4.24	1859	0.567	20005	6.40	12.01	21	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	6.4	8.2	9.4	10.6	12.1	13.2	15.8	16.9	FSR Rainfall-Runoff
Sheskin	21_7249_1+	0.31	1859	0.568	20005	0.29	0.54	7	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.8	FSR Rainfall-Runoff

LOCATION	HEP	AREA	SAAR	BFI	Pivotal Site	QMED	95% Confidence Limit	QME D/	Flood Growth Curve	Flood Growth Factor								Design Flows								Hydrograph Pivotal Site
										50	20	10	5	2	1	0.5	0.1	50	20	10	5	2	1	0.5	0.1	
Carrignagat	21_7092_1+	0.50	1859	0.567	20005	0.92	0.94	9	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.3	FSR Rainfall-Runoff
Dromleigh	21_7096_1+	0.56	1859	0.566	20005	1.02	1.07	9	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	0.6	0.7	0.8	0.9	1.1	1.2	1.4	1.5	FSR Rainfall-Runoff
Reenrour	21_7096_2+	0.90	1859	0.567	20005	1.39	2.61	15	EV1	1.00	1.28	1.47	1.65	1.88	2.06	2.46	2.63	1.4	1.8	2.0	2.3	2.6	2.9	3.4	3.7	FSR Rainfall-Runoff
Ardnageehy Stream	21_48_1+	0.74	1695	0.552	19014	0.41	0.78	5	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.2	FSR Rainfall-Runoff
Doneelagh	21_51_2	3.94	1692	0.544	19014	1.96	3.68	7	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	2.0	2.4	2.7	3.0	3.5	3.9	4.4	5.8	FSR Rainfall-Runoff
Ardnageehy	21_48_1	4.67	1712	0.591	19014	2.49	4.68	8	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	2.5	3.0	3.4	3.9	4.5	5.0	5.6	7.4	FSR Rainfall-Runoff
Doneelagh upstream Mealagh	21_2187_2	6.30	1718	0.590	19014	4.23	7.94	10	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	4.2	5.2	5.8	6.5	7.6	8.5	9.5	12.5	FSR Rainfall-Runoff
Mealagh at Inchiclogh - GAUGED	21_5827_3	45.99	1881	0.462	21004	87.53	164.28	46	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	87.5	106.8	120.6	135.3	157.1	175.9	197.3	258.5	21004 Median width exceedance
Mealagh upstream Survey Extent	21_5826_1	47.42	1882	0.465	21004	88.79	166.64	45	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	88.8	108.3	122.3	137.2	159.4	178.5	200.1	262.2	21004
Mealagh downstream Mealagh Tributary	21_6183_1	47.75	1882	0.466	21004	90.19	169.27	46	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	90.2	110.0	124.3	139.4	161.9	181.3	203.3	266.3	21004
Mealagh	21_6412_1	54.05	1863	0.486	21004	95.48	179.20	44	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	95.5	116.5	131.6	147.6	171.4	191.9	215.2	282.0	21004
Mealagh	21_6412_2	54.48	1863	0.487	21004	95.69	179.61	44	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	95.7	116.8	131.9	147.9	171.7	192.4	215.7	282.6	21004
Mealagh downstream Milleencolla	21_6258_1	55.05	1863	0.487	21004	96.18	180.51	44	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	96.2	117.4	132.5	148.7	172.6	193.3	216.7	284.0	21004
Mealagh downstream Survey Extent	21_6258_3	55.53	1863	0.488	21004	96.76	181.62	44	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	96.8	118.1	133.3	149.6	173.7	194.5	218.1	285.7	21004
Raheen Beg	21_6183_1+	0.28	1882	0.466	20005	0.26	0.49	7	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.8	FSR Rainfall-Runoff
Milleencolla East Stream	21_6258_1+	0.57	1858	0.485	20005	0.47	0.88	7	GLO	1.00	1.22	1.38	1.55	1.79	2.01	2.25	2.95	0.5	0.6	0.6	0.7	0.8	0.9	1.1	1.4	FSR Rainfall-Runoff

C.2 Durrus AFA

Figure C.11: Durrus AFA Schematic of QMED

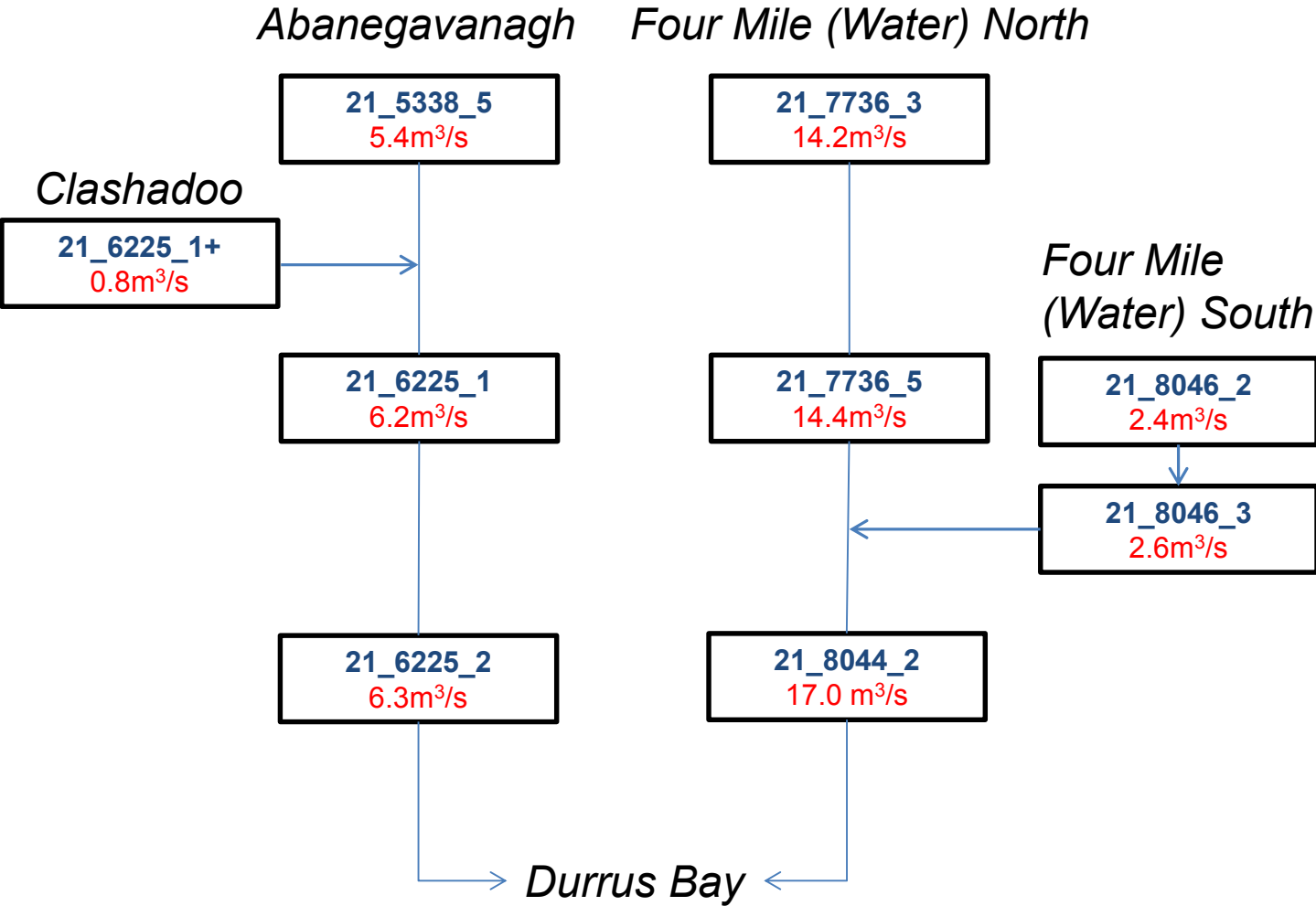


Table C.5: Ahanegavanagh Catchment Flood Frequency Analysis

Rank	Pooling Station No.	Record Length	Cumulative Years	Pooling Years Count	Discordancy (Di)	Effective record length	FARL	URBEXT	FLATWET	S1085	AREA	BFI	SAAR	FSU Class	Karstic Catchment?	HGF/QMED	Additional Comments
1	10004	14	14	14	1.783	14	0.986	0.000	0.54	25.037	30.57	0.517	1700	B	Locally Important Aquifer	0.705	N/A
2	6030	27	41	41	0.564	54	0.972	0.000	0.61	20.091	10.40	0.625	1157	B	Poor Aquifer	0.701	N/A
3	20006	35	76	76	0.202	105	1.000	0.000	0.67	6.390	77.55	0.600	1463	B	Locally Important Aquifer	0.574	N/A
4	16013	33	109	109	0.130	132	0.993	0.000	0.58	24.556	93.58	0.531	1471	B	Poor Aquifer	0.488	N/A
5	35002	34	143	143	0.161	170	0.986	0.000	0.72	13.263	88.82	0.523	1381	A2	Poor Aquifer	0.792	N/A
6	36021	27	170	170	0.093	162	0.995	0.000	0.69	19.110	23.41	0.330	1570	A2	Poor Aquifer	0.749	Gauge situated on Karstic zone. Majority of catchment is of Poor Aquifer.
7	16005	30	200	200	0.090	210	1.000	0.330	0.59	6.524	84.00	0.542	1154	A2	Locally Important Aquifer	1.071	N/A
8	25044	40	240	240	0.045	320	0.997	0.000	0.59	2.666	92.55	0.575	1187	A2	Locally Important Aquifer	1.256	N/A
9	34009	33	273	273	0.041	297	1.000	1.070	0.73	3.325	117.11	0.443	1257	A2	Locally Important Aquifer	1.309	N/A
10	16006	33	306	306	0.217	330	0.994	0.000	0.59	5.763	75.80	0.591	1116	B	Locally Important Aquifer	0.562	Gauge within Karstic zone. But this makes up only a very small fraction of the catchment.
11	19046	9	315	315	0.317	99	1.000	0.250	0.64	10.136	63.21	0.698	1196	B	Locally Important Aquifer	0.436	N/A
12	1041	32	347	347	0.103	384	1.000	0.860	0.69	7.227	116.18	0.379	1329	B	Locally Important Aquifer	0.424	N/A
13	19016	15	362	362	0.954	195	1.000	0.070	0.66	4.554	117.82	0.687	1267	ESB stn	Locally Important Aquifer	1.001	Gauge within Karstic zone. But this makes up only a small fraction of the catchment.
14	35004	14	376	376	0.460	196	0.994	0.290	0.72	2.285	116.96	0.488	1103	A1	Locally Important Aquifer	1.289	N/A
15	26010	35	411	411	0.057	525	0.937	0.000	0.69	1.906	94.53	0.578	1064	B	Locally Important Aquifer	0.919	N/A
16	13002	19	430	430	0.026	304	1.000	0.000	0.56	4.953	62.96	0.657	1044	B	Poor Aquifer	0.645	N/A
17	25002	51	481	481	0.695	867	0.999	0.180	0.59	6.877	221.61	0.542	1300	A2	Locally Important Aquifer	0.988	N/A

Figure C.12: Flood Growth Curve Plot

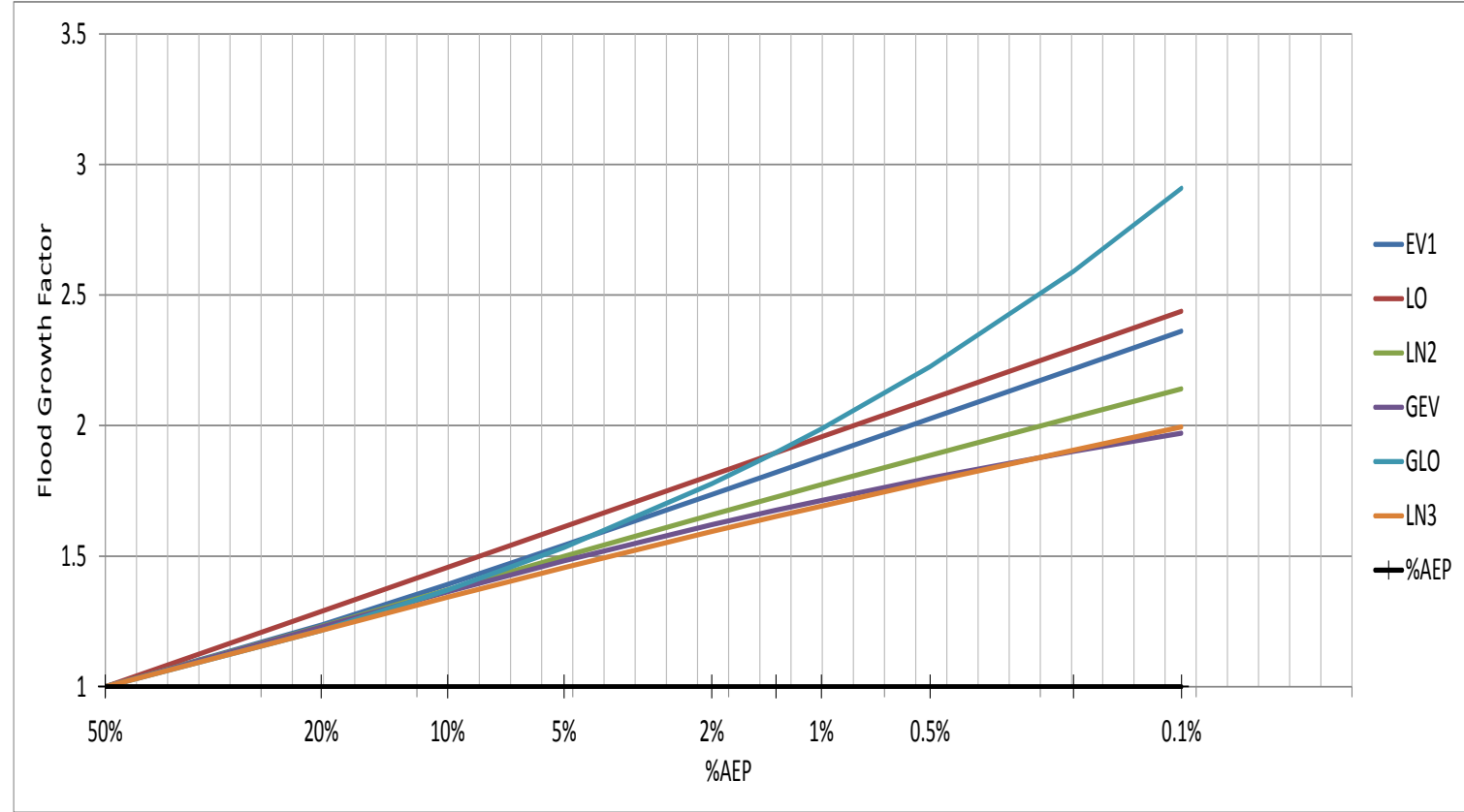


Figure C.13: L Moment Plot

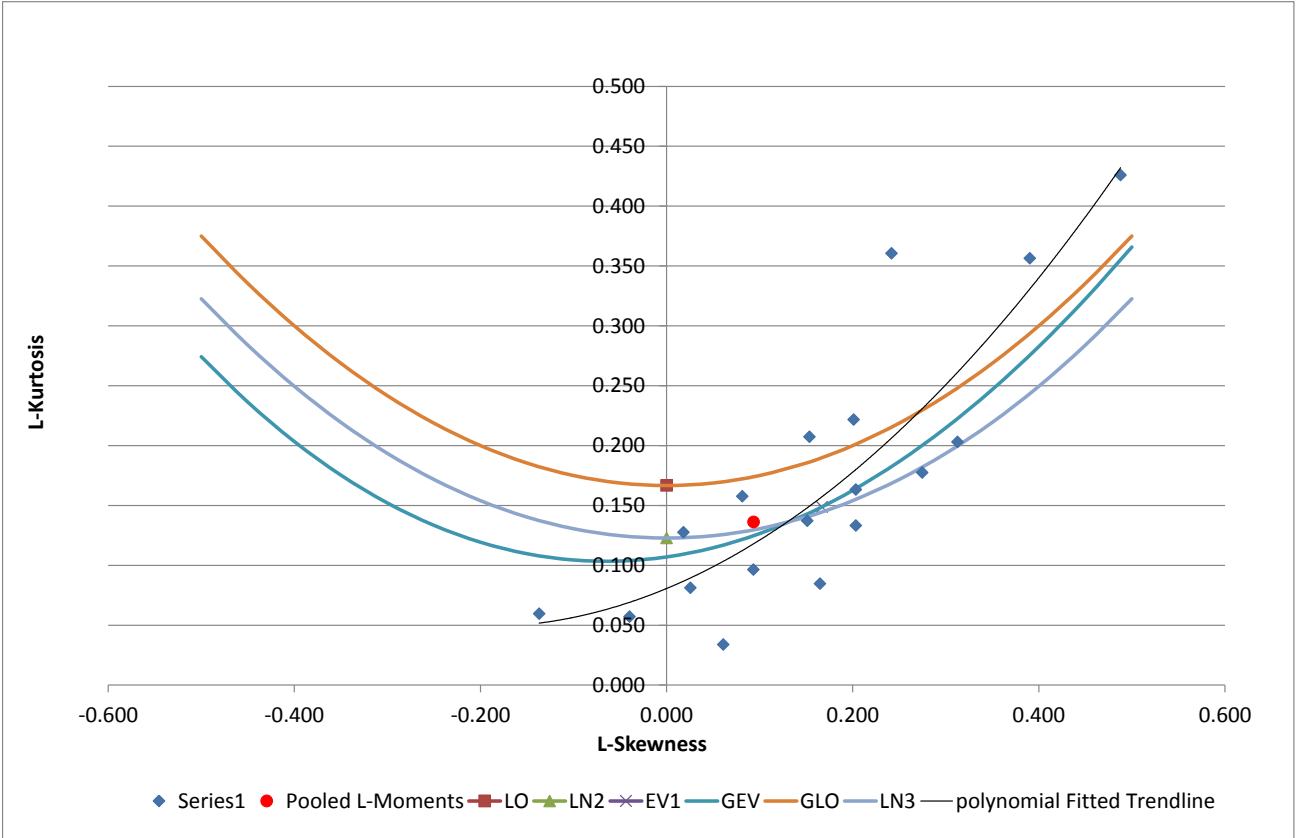


Table C.6: Four Mile Water Catchment Flood Frequency Analysis

Rank	Pooling Station No.	Record Length	Cumulative Years	Pooling Years Count	Discordancy (Di)	Effective record length	FARL	URBEX T	FLATWET	S1085	AREA	BFI	SAAR	FSU Class	Karstic Catchment?	HGF/QMED	Additional Comments
1	10004	14	14	14	2.180	14	0.986	0.000	0.54	25.037	30.57	0.517	1700	B	Locally Important Aquifer	0.705	N/A
2	20006	35	49	49	0.246	70	1.000	0.000	0.67	6.390	77.55	0.600	1463	B	Locally Important Aquifer	0.574	N/A
3	31002	26	75	75	0.368	78	0.632	0.000	0.65	9.590	71.35	0.503	1530	A1	Poor Aquifer	1.012	N/A
4	16013	33	108	108	0.159	132	0.993	0.000	0.58	24.556	93.58	0.531	1471	B	Poor Aquifer	0.488	N/A
5	33070	28	136	136	0.049	140	0.677	0.000	0.73	2.804	87.90	0.526	1422	A1	Poor Aquifer	1.216	N/A
6	32012	24	160	160	0.224	144	0.843	0.000	0.72	4.102	146.16	0.645	1784	A2	Locally Important Aquifer	1.106	N/A
7	35002	34	194	194	0.197	238	0.986	0.000	0.72	13.263	88.82	0.523	1381	A2	Poor Aquifer	0.792	N/A
8	27003	48	242	242	0.049	384	0.922	0.150	0.62	4.150	166.42	0.639	1567	A2	Regionally Important Aquifer - Karstified	1.370	N/A
9	30020	16	258	258	0.062	144	1.000	0.990	0.72	2.891	21.41	0.610	1191	B	Regionally Important Aquifer - Karstified	0.882	N/A
10	25158	18	276	276	0.667	180	1.000	0.000	0.59	6.973	109.55	0.514	1377	A1	Locally Important Aquifer	1.364	N/A
11	1055	9	285	285	0.285	99	0.737	0.000	0.69	13.632	9.69	0.508	1976	B	Poor Aquifer	0.881	N/A
12	19031	9	294	294	0.023	108	0.999	0.670	0.66	4.732	216.11	0.558	1775	ESB stn	Poor Aquifer	0.874	N/A
13	19046	9	303	303	0.388	117	1.000	0.250	0.64	10.136	63.21	0.698	1196	B	Locally Important Aquifer	0.436	N/A
14	25044	40	343	343	0.055	560	0.997	0.000	0.59	2.666	92.55	0.575	1187	A2	Locally Important Aquifer	1.256	N/A
15	25038	17	360	360	0.058	255	1.000	0.210	0.59	7.336	136.10	0.591	1249	B	Locally Important Aquifer	0.725	N/A
16	19016	15	375	375	1.167	240	1.000	0.070	0.66	4.554	117.82	0.687	1267	ESB stn	Locally Important Aquifer	1.001	Gauge seated on Karstic area but this covers only the minority of the catchment
17	34011	30	405	405	0.093	510	0.867	0.890	0.72	0.630	143.01	0.572	1248	A2	Regionally Important Aquifer - Karstified	1.078	N/A
18	29071	26	431	431	0.014	468	0.804	0.000	0.6	5.230	123.84	0.565	1212	A2	Poor Aquifer	0.815	N/A
19	39008	33	464	464	0.045	627	0.781	0.000	0.7	10.543	77.39	0.441	1796	A2	Poor Aquifer	0.851	N/A

Figure C.14: Flood Growth Curve Plot

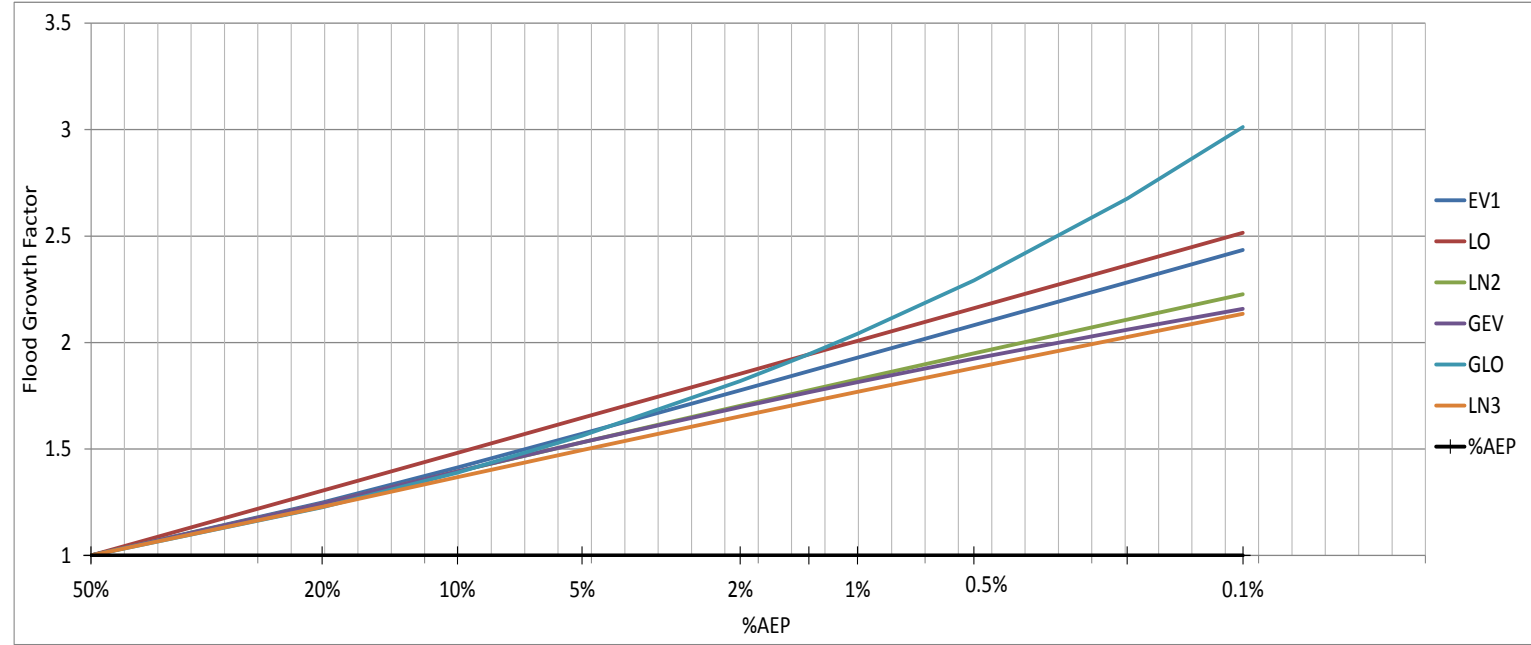


Figure C.15: L Moment Plot

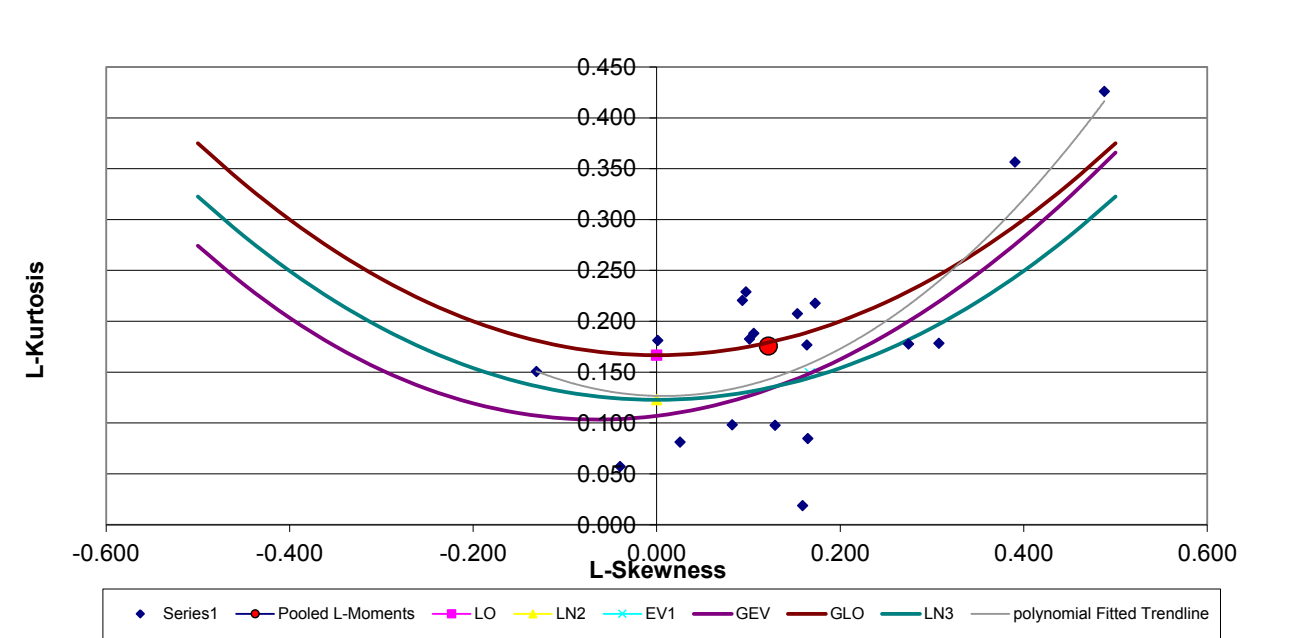


Figure C.16: Typical FSSR16 Hydrograph Four Mile Water Catchment

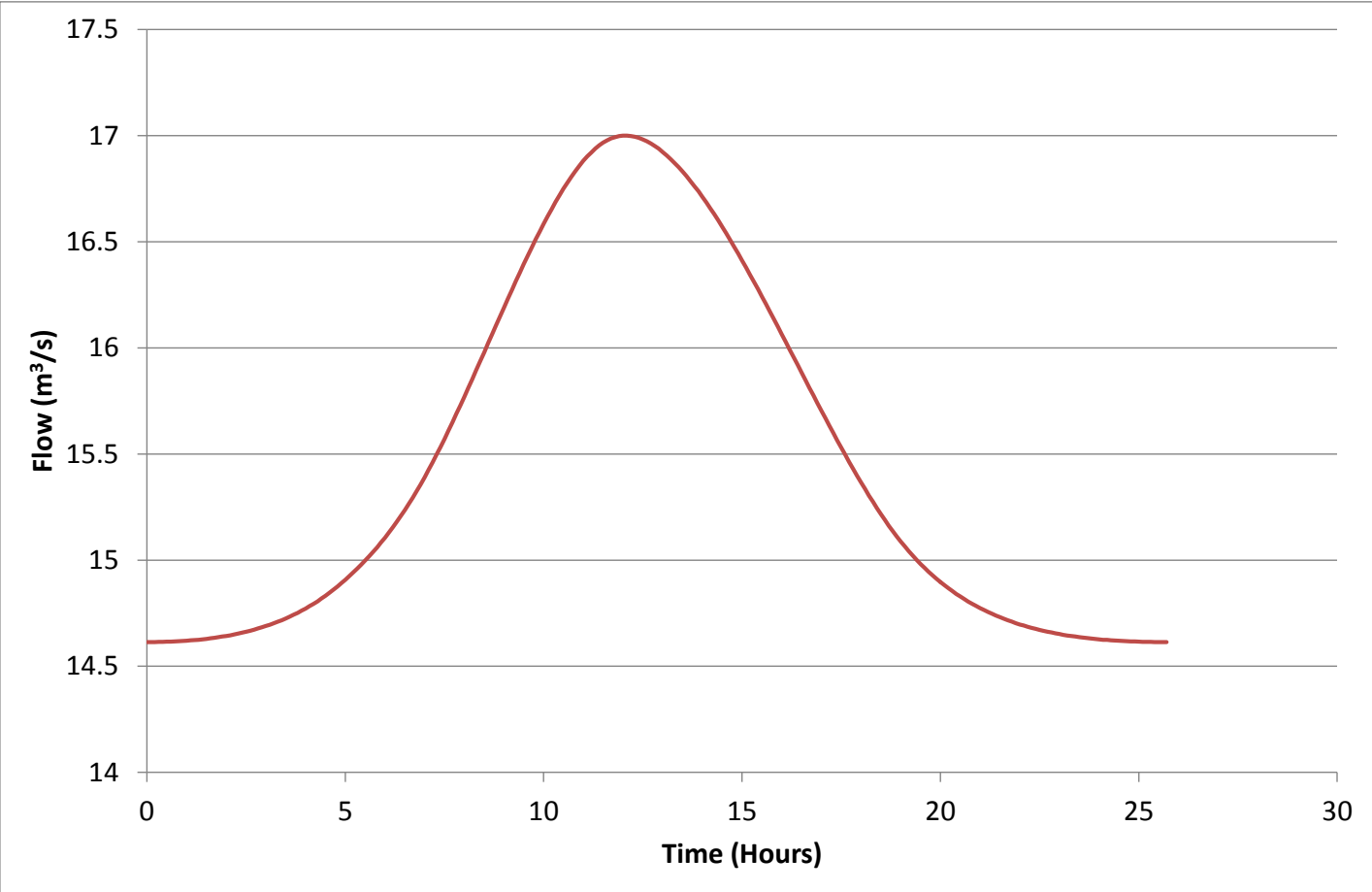
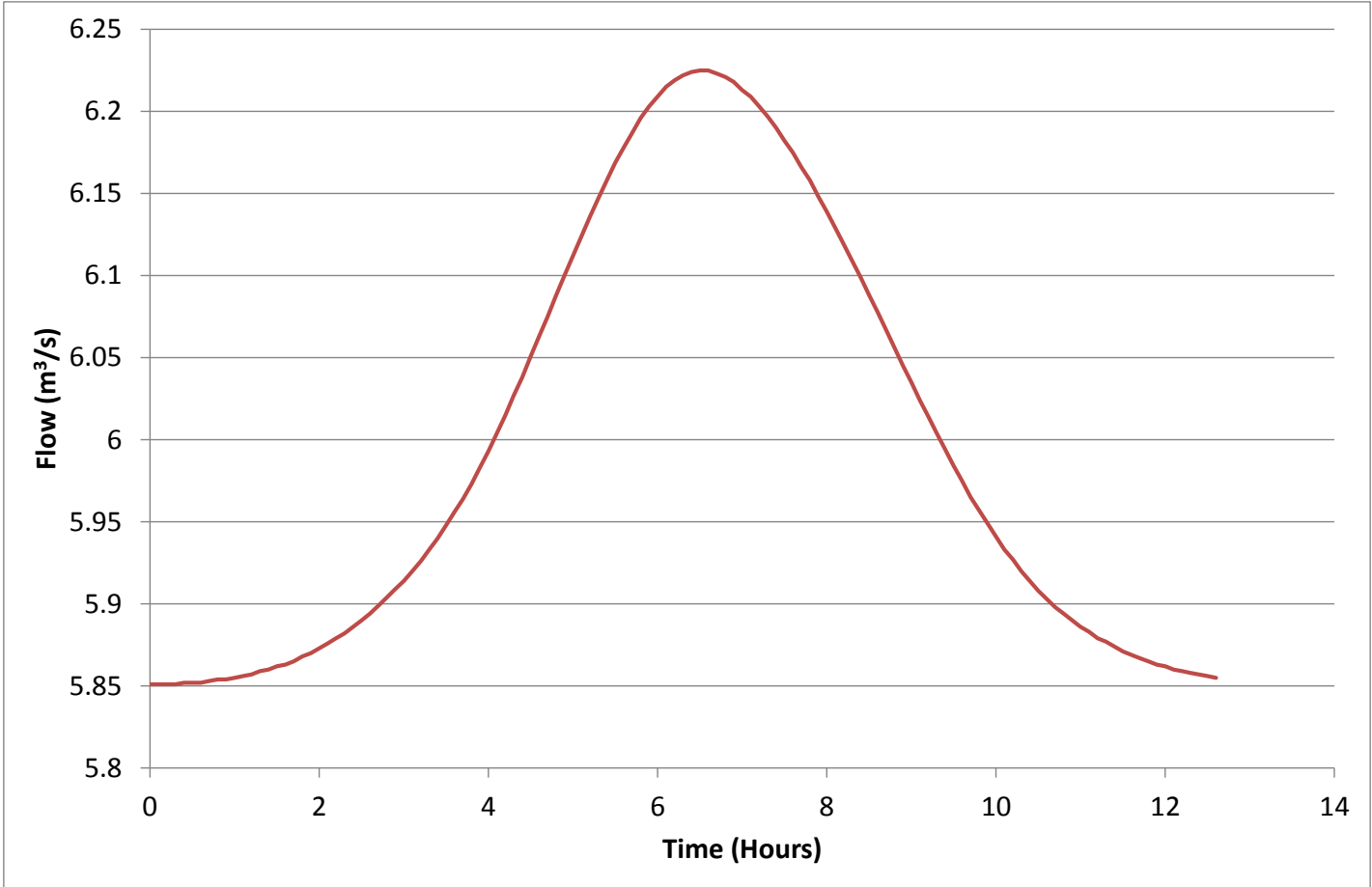


Figure C.17: Typical FSSR16 Hydrograph Abanegavanagh Catchment



FSSR 16 Parameter	Four Mile Water Catchment	FSSR 16 Parameter	Abanegavanagh Catchment
M5 - 60 min (mm)	17.6	M5 - 60 min (mm)	17.6
M5 - 2 day (mm)	85.1	M5 - 2 day (mm)	85.1
M5 -25 day (mm)	296.4	M5 -25 day (mm)	296.4
Jenkinson's <i>r</i>	0.207	Jenkinson's <i>r</i>	0.207
Catchment Wetness Index (CWI)	125	Catchment Wetness Index (CWI)	125
Critical Storm Duration, D (hours)	5.7	Critical Storm Duration, D (hours)	5.7
Time to Peak, T _p (hours)	4.6	Time to Peak, T _p (hours)	4.6

Table C.7: Durrus AFA Design Peak Flows

LOCATION	HEP	AREA	SAAR	BFI	Pivotal Site	QMED	95% Confidence Limit	QMED/ AREA ^{0.077}	Flood Growth Curve	Flood Growth Factor								Design Flows (m ³ /s)								Hydrograph Pivotal Site
										50	20	10	5	2	1	0.5	0.1	50	20	10	5	2	1	0.5	0.1	
Clashadoo	21_6225_1+	0.99	1806	0.438	20006	0.76	2.46	8	GLO	1.00	1.23	1.40	1.57	1.84	2.06	2.32	3.05	0.8	0.9	1.1	1.2	1.4	1.6	1.8	2.3	FSR Rainfall-Runoff
Ahanegavanagh upstream Survey Extent	21_5338_5	5.16	1806	0.428	20006	5.39	10.30	15	GLO	1.00	1.23	1.40	1.57	1.84	2.06	2.32	3.05	5.4	6.6	7.5	8.5	9.9	11.1	12.5	16.4	FSR Rainfall-Runoff
Ahanegavanagh upstream Clashadoo	21_5338_6	6.23	1806	0.516	20006	5.65	10.60	14	GLO	1.00	1.23	1.40	1.57	1.84	2.06	2.32	3.05	5.6	7.0	7.9	8.9	10.4	11.6	13.1	17.2	FSR Rainfall-Runoff
Ahanegavanagh downstream Clashadoo	21_6225_1	6.24	1806	0.517	20006	6.17	11.58	15	GLO	1.00	1.23	1.40	1.57	1.84	2.06	2.32	3.05	6.2	7.6	8.6	9.7	11.3	12.7	14.3	18.8	FSR Rainfall-Runoff
Ahanegavanagh	21_6225_2	6.36	1805	0.520	20006	6.25	11.72	15	GLO	1.00	1.23	1.40	1.57	1.84	2.06	2.32	3.05	6.2	7.7	8.7	9.8	11.5	12.9	14.5	19.1	FSR Rainfall-Runoff
Four Mile South upstream Survey Extent	21_8046_2	4.70	1597	0.591	20006	2.42	6.77	7	GLO	1.00	1.25	1.42	1.61	1.89	2.13	2.41	3.19	2.4	3.0	3.4	3.9	4.6	5.2	5.8	7.7	FSR Rainfall-Runoff
Four Mile South	21_8046_3	4.91	1598	0.610	20006	2.57	6.94	8	GLO	1.00	1.25	1.42	1.61	1.89	2.13	2.41	3.19	2.6	3.2	3.7	4.1	4.9	5.5	6.2	8.2	FSR Rainfall-Runoff
Four Mile North upstream Survey Extent	21_7736_3	26.69	1659	0.602	20006	14.18	26.61	11	GLO	1.00	1.25	1.42	1.61	1.89	2.13	2.41	3.19	14.2	17.7	20.2	22.9	26.8	30.2	34.1	45.2	FSR Rainfall-Runoff
Four Mile North	21_7736_5	27.40	1659	0.601	20006	14.41	27.04	11	GLO	1.00	1.25	1.42	1.61	1.89	2.13	2.41	3.19	14.4	18.0	20.5	23.2	27.2	30.7	34.7	46.0	FSR Rainfall-Runoff
Four Mile downstream Survey Extent	21_8044_2	32.56	1650	0.602	20006	17.01	31.93	12	GLO	1.00	1.25	1.42	1.61	1.89	2.13	2.41	3.19	17.0	21.2	24.2	27.4	32.2	36.3	40.9	54.3	FSR Rainfall-Runoff

C.3 Kenmare AFA

Figure C.18: Kenmare AFA Schematic of QMED

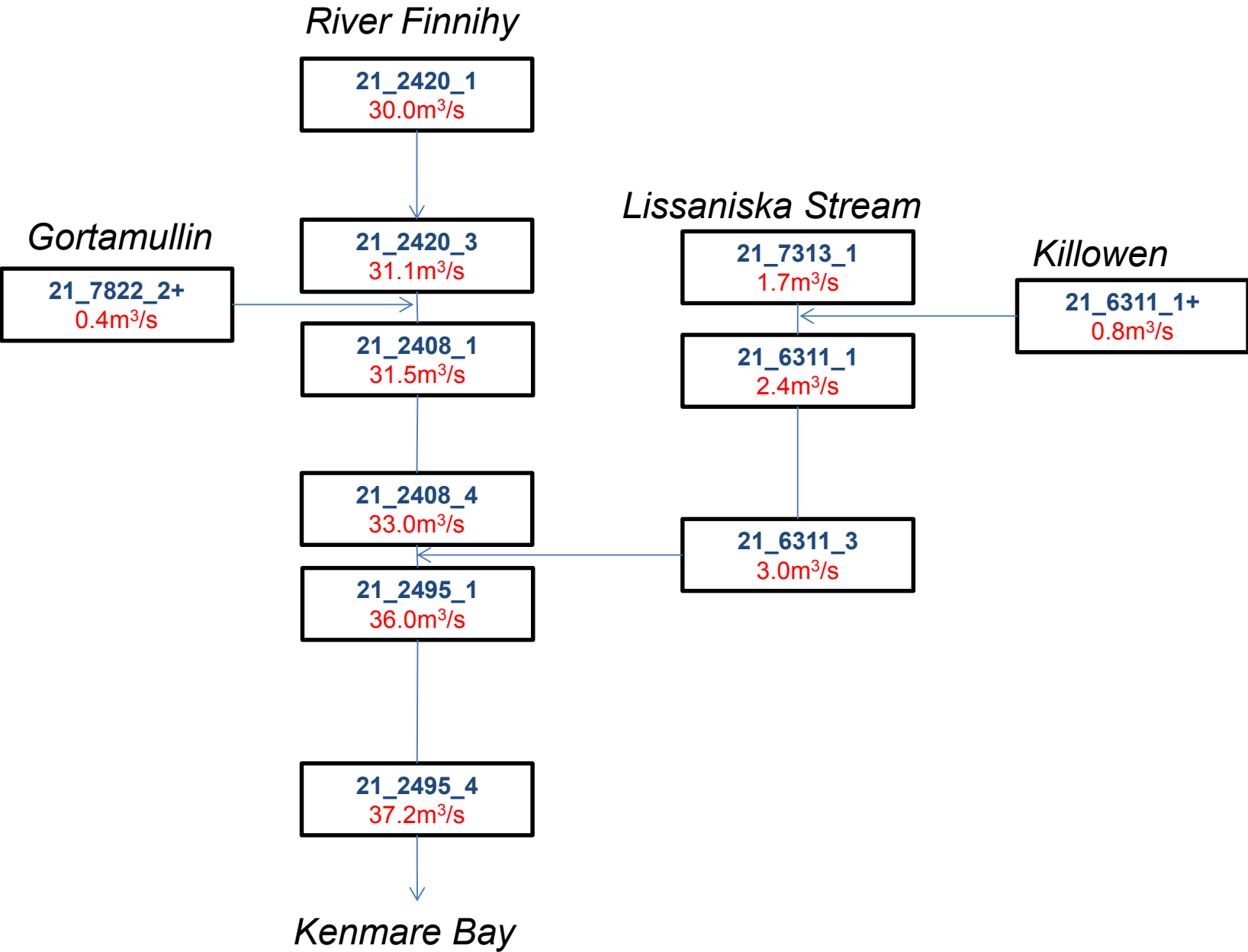


Table C.8: Lissaniska Catchment Flood Frequency Analysis

Rank	Pooling Station No.	Record Length	Cumulative Years	Pooling Years Count	Discordancy (Di)	Effective record length	FARL	URBEX T	FLATWET	S1085	AREA	BFI	SAAR	FSU Class	Karstic Catchment?	HGF/QMED	Additional Comments
1	10004	14	14	14	2.246	14	0.986	0.000	0.54	25.037	30.57	0.517	1700	B	Locally Important Aquifer	0.705	10004
2	6030	27	41	41	0.711	54	0.972	0.000	0.61	20.091	10.40	0.625	1157	B	Poor Aquifer	0.701	6030
3	31002	26	67	67	0.379	78	0.632	0.000	0.65	9.590	71.35	0.503	1530	A1	Poor Aquifer	1.012	31002
4	20006	35	102	102	0.254	140	1.000	0.000	0.67	6.390	77.55	0.600	1463	B	Locally Important Aquifer	0.574	20006
5	16013	33	135	135	0.164	165	0.993	0.000	0.58	24.556	93.58	0.531	1471	B	Poor Aquifer	0.488	16013
6	35002	34	169	169	0.203	204	0.986	0.000	0.72	13.263	88.82	0.523	1381	A2	Poor Aquifer	0.792	35002
7	25158	18	187	187	0.688	126	1.000	0.000	0.59	6.973	109.55	0.514	1377	A1	Locally Important Aquifer	1.364	25158
8	36021	27	214	214	0.117	216	0.995	0.000	0.69	19.110	23.41	0.330	1570	A2	Poor Aquifer	0.749	36021
9	25044	40	254	254	0.057	360	0.997	0.000	0.59	2.666	92.55	0.575	1187	A2	Locally Important Aquifer	1.256	25044
10	16005	30	284	284	0.114	300	1.000	0.330	0.59	6.524	84.00	0.542	1154	A2	Locally Important Aquifer	1.071	16005
11	16006	33	317	317	0.274	363	0.994	0.000	0.59	5.763	75.80	0.591	1116	B	Locally Important Aquifer	0.562	16006
12	39001	31	348	348	0.214	372	0.987	0.000	0.70	12.506	50.71	0.320	1764	B	Poor Aquifer	0.818	39001
13	25038	17	365	365	0.060	221	1.000	0.210	0.59	7.336	136.10	0.591	1249	B	Locally Important Aquifer	0.725	25038
14	32011	25	390	390	0.123	350	0.986	0.150	0.69	13.428	70.10	0.337	1613	B	Poor Aquifer	0.689	32011
15	27001	9	399	399	0.219	135	0.987	0.000	0.61	4.448	46.70	0.331	1477	A2	Locally Important Aquifer	1.255	27001
16	34009	33	432	432	0.051	528	1.000	1.070	0.73	3.325	117.11	0.443	1257	A2	Locally Important Aquifer	1.309	34009
17	13002	19	451	451	0.032	323	1.000	0.000	0.56	4.953	62.96	0.657	1044	B	Poor Aquifer	0.645	13002
18	34024	28	479	479	0.405	504	0.922	0.750	0.7	1.518	127.23	0.522	1177	A2	Locally Important Aquifer	0.962	34024
19	39009	33	512	512	0.021	627	0.816	0.400	0.7	5.223	206.83	0.404	1570	A2	Poor Aquifer	1.021	39009

Figure C.19: Flood Growth Curve Plot

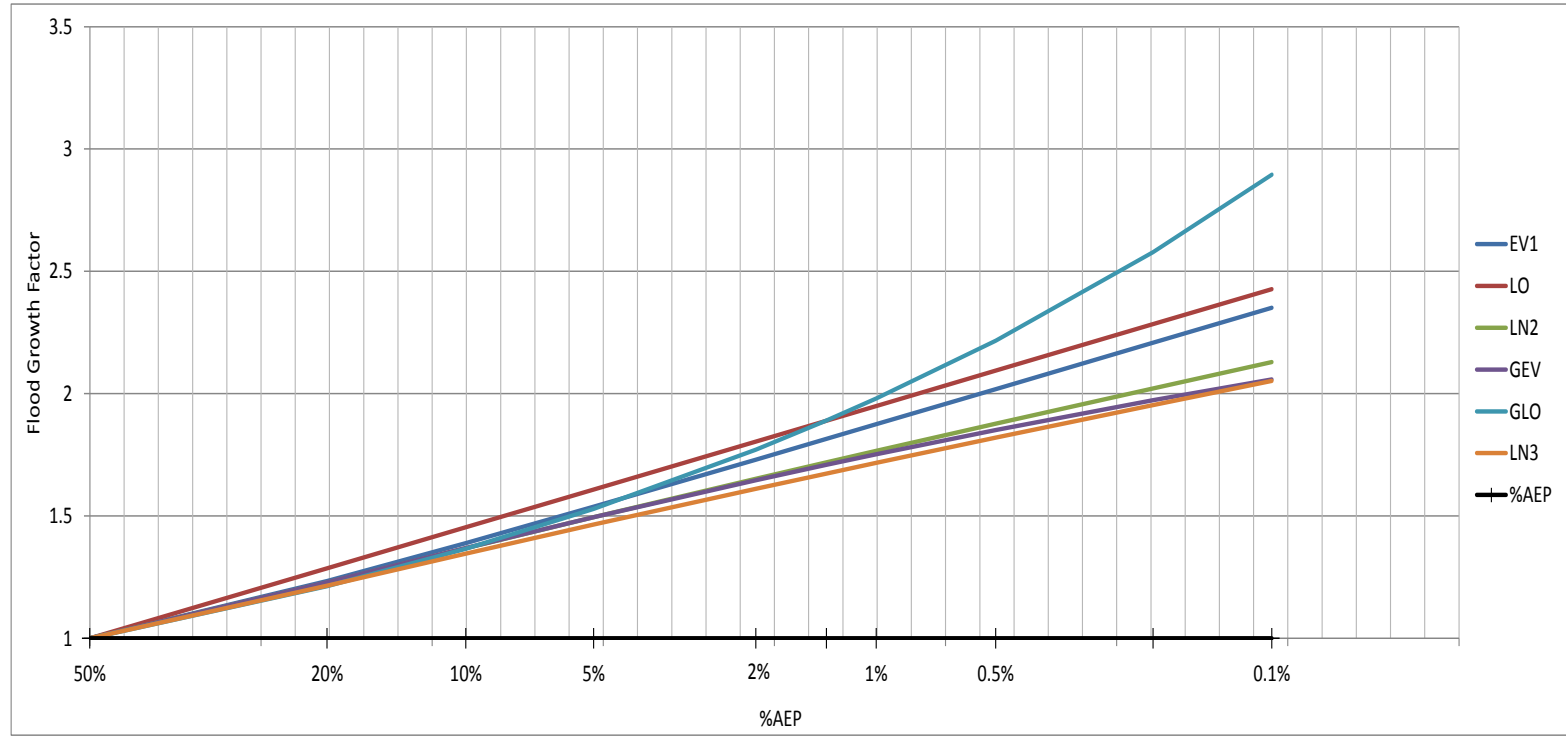


Figure C.20: L Moment Plot

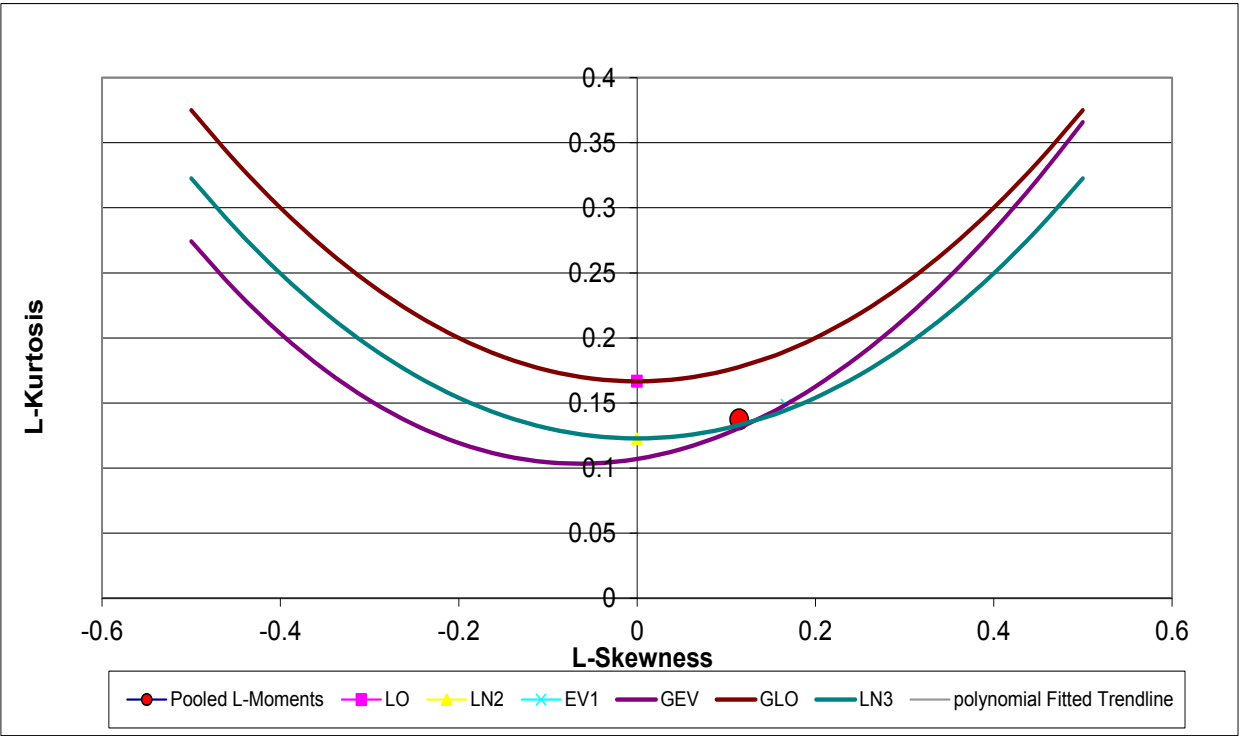


Table C.9: River Finnihy Catchment Flood Frequency Analysis

Rank	Pooling Station No.	Record Length	Cumulative Years	Pooling Years Count	Discordancy (Di)	Effective record length	FARL	URBEX T	FLATWET	S1085	AREA	BFI	SAAR	FSU Class	Karstic Catchment?	HGF/QMED	Additional Comments
1	10004	14	14	14	1.583	14	0.986	0.000	0.54	25.037	30.57	0.517	1700	B	Locally Important Aquifer	0.705	N/A
2	39001	31	45	45	0.151	62	0.987	0.000	0.70	12.506	50.71	0.320	1764	B	Poor Aquifer	0.818	N/A
3	22006	57	102	102	0.036	171	0.961	0.540	0.66	9.421	328.81	0.414	1819	B	Locally Important Aquifer	0.625	Only minor Karstic coverage, vast majority is of locally important aquifer.
4	31002	26	128	128	0.267	104	0.632	0.000	0.65	9.590	71.35	0.503	1530	A1	Poor Aquifer	1.012	N/A
5	32011	25	153	153	0.087	125	0.986	0.150	0.69	13.428	70.10	0.337	1613	B	Poor Aquifer	0.689	N/A
6	38001	33	186	186	0.113	198	0.922	0.290	0.70	5.950	111.25	0.313	1753	B	Poor Aquifer	0.292	N/A
7	36021	27	213	213	0.083	189	0.995	0.000	0.69	19.110	23.41	0.330	1570	A2	Poor Aquifer	0.749	Gauge situated on Karstic zone. Majority of catchment is of Poor Aquifer.
8	34007	53	266	266	0.047	424	0.978	0.000	0.73	4.569	151.71	0.349	1590	B	Poor Aquifer	0.489	Mix. Majority of region is of Poor quality aquifer. Gauge sits on Karstic zone.
9	16013	33	299	299	0.116	297	0.993	0.000	0.58	24.556	93.58	0.531	1471	B	Poor Aquifer	0.488	N/A
10	27001	9	308	308	0.155	90	0.987	0.000	0.61	4.448	46.70	0.331	1477	A2	Locally Important Aquifer	1.255	N/A
11	35002	34	342	342	0.143	374	0.986	0.000	0.72	13.263	88.82	0.523	1381	A2	Poor Aquifer	0.792	N/A
12	20006	35	377	377	0.179	420	1.000	0.000	0.67	6.390	77.55	0.600	1463	B	Locally Important Aquifer	0.574	N/A
13	18016	20	397	397	0.229	260	1.000	0.780	0.64	4.884	116.73	0.348	1441	B	Locally Important Aquifer	0.804	N/A
14	1041	32	429	429	0.092	448	1.000	0.860	0.69	7.227	116.18	0.379	1329	B	Locally Important Aquifer	0.424	N/A
15	33001	25	454	454	0.050	375	0.998	0.000	0.73	10.449	76.12	0.294	1467	B	Poor Aquifer	0.708	N/A
16	28001	17	471	471	2.005	272	0.938	0.050	0.62	2.199	169.42	0.329	1423	B	Locally Important Aquifer	0.608	N/A

Figure C.21: Flood Growth Curve Plot

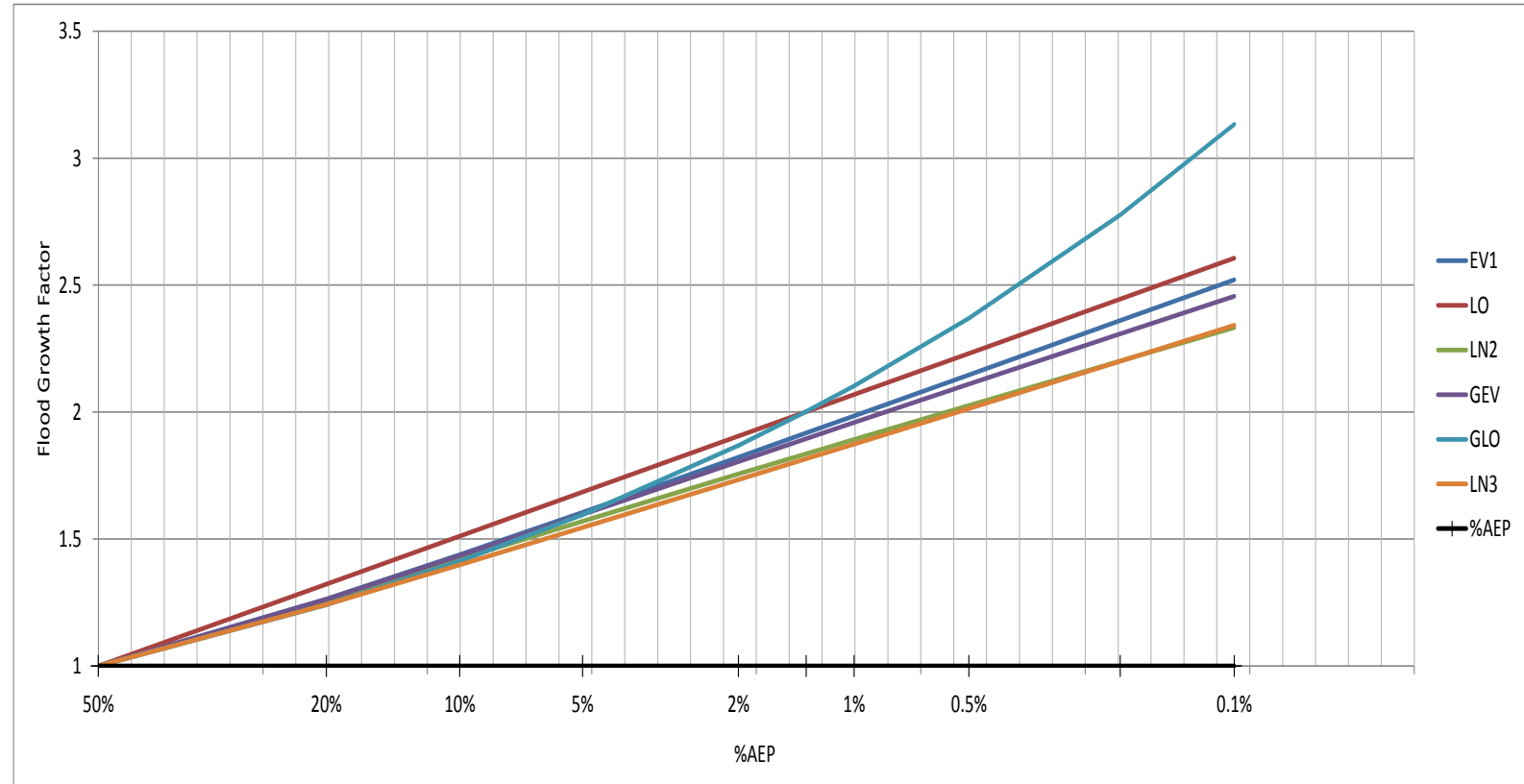


Figure C.22: L Moment Plot

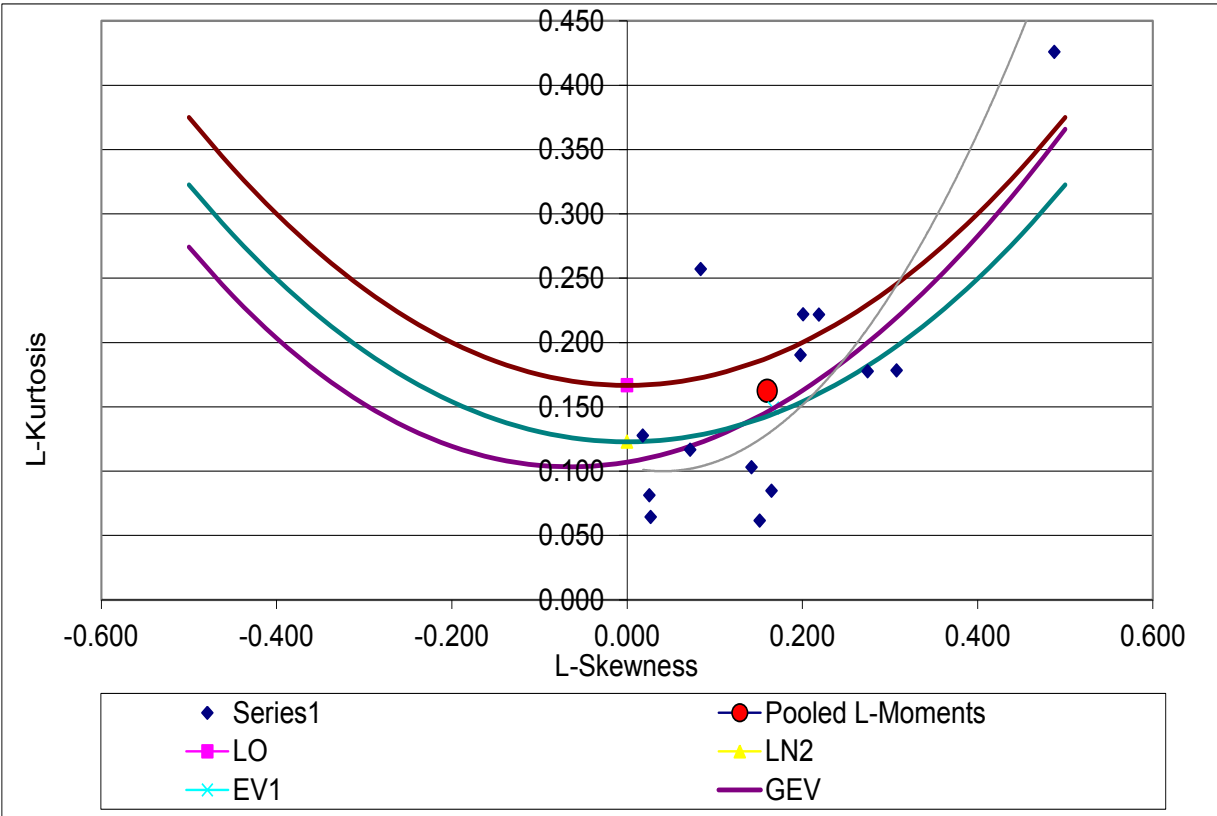
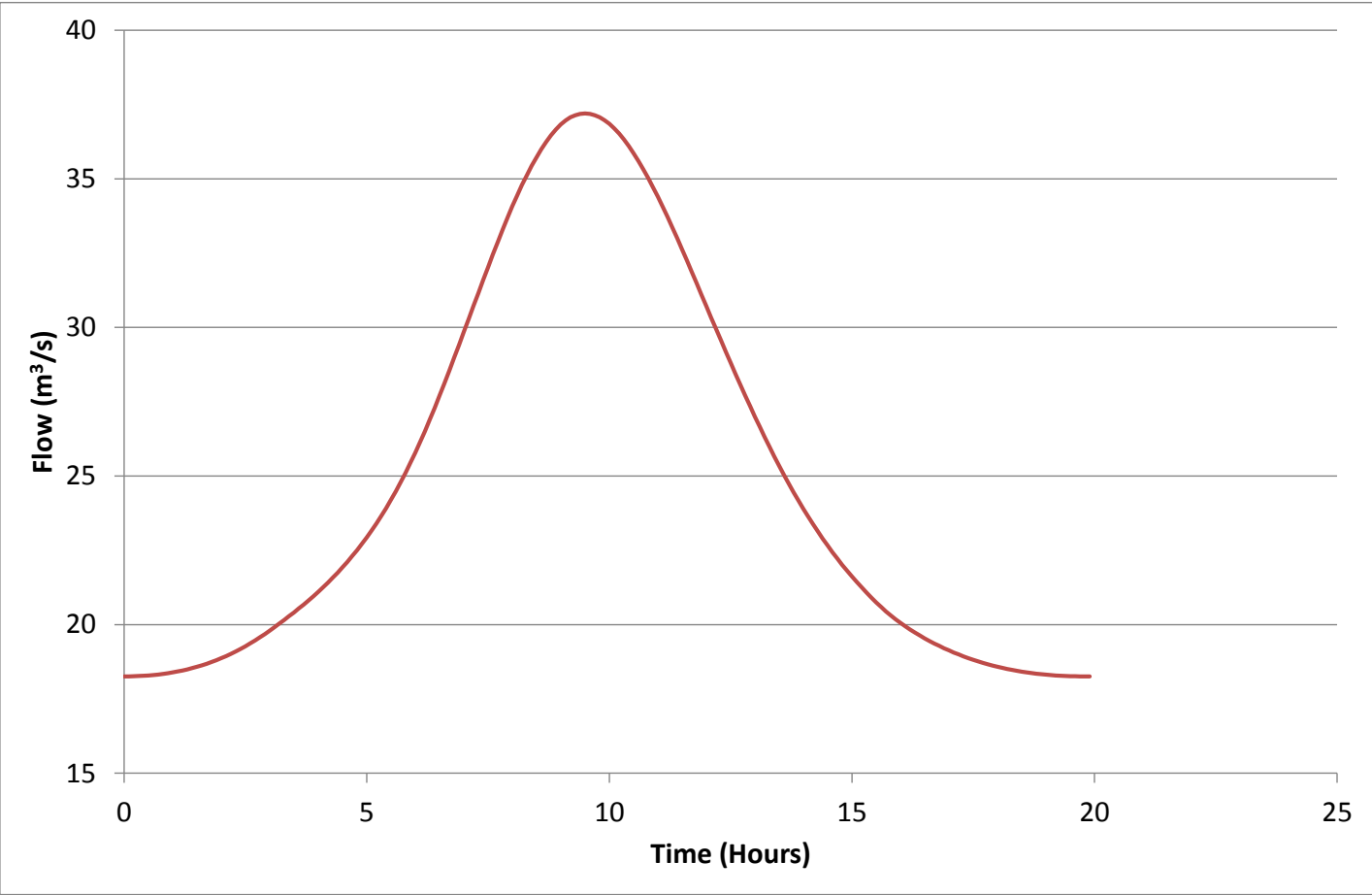


Figure C.23: Typical FSSR Rainfall-Runoff Hydrograph Finnihy Catchment



FSSR 16 Parameter	Finnihy and Lissaniska Catchments
M5 - 60 min (mm)	22.0
M5 - 2 day (mm)	122.3
M5 -25 day (mm)	428.8
Jenkinson's <i>r</i>	0.180
Catchment Wetness Index (CWI)	122
Critical Storm Duration, D (hours)	5.6
Time to Peak, Tp (hours)	2.8

Table C.10: Kenmare AFA Design Peak Flows

LOCATION	HEP	AREA	SAAR	BFI	Pivotal Site	QMED	95% Confidence Limit	QMED/ AREA ^{0.077}	Flood Growth Curve	Flood Growth Factor								Design Flows (m ³ /s)								Hydrograph
										50	20	10	5	2	1	0.5	0.1	50	20	10	5	2	1	0.5	0.1	
Kilowen	21_6311_1+	0.69	2270	0.49	22006	0.84	1.57	11	GLO	1.00	1.22	1.37	1.54	1.78	2.00	2.24	2.93	0.8	1.0	1.2	1.3	1.6	1.8	2.0	2.6	FSR Rainfall-Runoff
Lissaniska upstream Survey Extent	21_7313_1	1.00	2387	0.42	22006	1.69	3.17	17	GLO	1.00	1.22	1.37	1.54	1.78	2.00	2.24	2.93	1.7	2.1	2.4	2.7	3.1	3.5	4.0	5.3	FSR Rainfall-Runoff
Lissaniska upstream Kilowen	21_7313_3	2.54	2236	0.61	22006	2.22	4.17	11	GLO	1.00	1.22	1.37	1.54	1.78	2.00	2.24	2.93	2.2	2.7	3.1	3.4	4.0	4.4	5.0	6.5	FSR Rainfall-Runoff
Lissaniska downstream Killowen	21_6311_1	2.55	2236	0.61	22006	2.42	4.53	12	GLO	1.00	1.22	1.37	1.54	1.78	2.00	2.24	2.93	2.4	3.0	3.4	3.8	4.5	5.1	5.7	7.5	FSR Rainfall-Runoff
Lissaniska upstream Finnihy	21_6311_3	3.30	2207	0.58	22006	3.05	5.72	12	GLO	1.00	1.22	1.37	1.54	1.78	2.00	2.24	2.93	3.0	3.8	4.296	4.9	5.7	6.4	7.2	9.5	FSR Rainfall-Runoff
Finnihy downstream Kilmurray	21_2420_1	25.51	2859	0.50	22006	29.97	56.26	25	GLO	1.00	1.24	1.41	1.60	1.87	2.10	2.37	3.13	30.0	37.2	42.3	47.8	56.0	63.1	71.0	93.9	FSR Rainfall-Runoff
Finnihy upstream Gortamullin Stream	21_2420_3	26.24	2823	0.47	22006	31.39	58.91	25	GLO	1.00	1.24	1.41	1.60	1.87	2.10	2.37	3.13	31.1	38.6	44.0	49.7	58.2	65.5	73.8	97.6	FSR Rainfall-Runoff
Finnihy downstream Gortamullin Stream	21_2408_1	26.47	2823	0.47	22006	31.52	59.17	25	GLO	1.00	1.24	1.41	1.60	1.87	2.10	2.37	3.13	31.5	39.1	44.5	50.3	58.9	66.3	74.7	98.8	FSR Rainfall-Runoff
Finnihy upstream Lissaniska – excluding GortamullinWest	21_2408_4	27.50	2796	0.47	22006	32.96	61.85	26	GLO	1.00	1.24	1.41	1.60	1.87	2.10	2.37	3.13	33.0	40.9	46.6	52.6	61.6	69.3	78.1	103.3	FSR Rainfall-Runoff
Finnihy d/d Lissaniska – excluding GortamullinWest	21_2495_1	30.80	2733	0.44	22006	35.99	67.54	26	GLO	1.00	1.24	1.41	1.60	1.87	2.10	2.37	3.13	36.0	44.6	50.8	57.4	67.2	75.7	85.3	112.8	FSR Rainfall-Runoff
Finnihy downstream Survey Extent – excluding GortamullinWest	21_2495_4	31.55	2719	0.44	22006	37.15	69.73	26	GLO	1.00	1.24	1.41	1.60	1.87	2.10	2.37	3.13	37.2	46.1	52.5	59.3	69.4	78.1	88.0	116.4	FSR Rainfall-Runoff
Gortamullin East (flowing into Finnihy)	21_7822_2+	0.24	2824	0.47	22006	0.39	0.73	12	GLO	1.00	1.24	1.41	1.60	1.87	2.10	2.37	3.13	0.39	0.48	0.54	0.61	0.70	0.79	0.89	1.17	FSR Rainfall-Runoff

C.4 Wave Overtopping Discharges

Table C.11 below provided the peak wave overtopping discharge from the design scenario at each vulnerable section defined by the ICWWS. The * in the last column denotes the critical scenario for each target %AEP.

Table C.11: Wave Overtopping Discharges UoM21

Reach	Section	Easting	Northing	Defence Type	Effective Crest Level mODM)	Toe Level (mODM)	Length (m)	%AEP	Water Level (mODM)	Wave Height (m)	Wave Period(s)	Unit Discharge (m3/s/m)
Castletown Bearhaven	A	67773	45842	Concrete vertical wall	3.03	0.16	298	50	1.45	0.29	2.77	0.000000
									1.62	0.26	2.80	0.000000
									1.76	0.19	2.78	0.000000
									1.86	0.16	2.74	0.000000
									1.93	0.13	2.75	0.000000
									2.00	0.11	2.64	0.000000
								20	1.62	0.33	2.74	0.000001 *
									1.76	0.24	2.80	0.000000
									1.86	0.20	2.75	0.000000
									1.93	0.18	2.68	0.000000
									2.00	0.16	2.64	0.000000
									2.10	0.13	2.54	0.000000
								10	1.62	0.35	2.79	0.000001 *
									1.76	0.28	2.79	0.000000
									1.93	0.22	2.72	0.000000
									2.00	0.19	2.61	0.000000
									2.10	0.17	2.49	0.000000
									2.17	0.15	2.46	0.000000
								5	1.62	0.39	2.79	0.000001 *
									1.76	0.32	2.80	0.000000
									1.93	0.25	2.77	0.000000
									2.10	0.20	2.73	0.000000
									2.17	0.17	2.68	0.000000
									2.23	0.13	2.74	0.000000
								2	1.62	0.44	2.81	0.000007 *
									1.76	0.37	2.80	0.000004
									1.93	0.30	2.72	0.000000
									2.10	0.25	2.62	0.000000
									2.23	0.18	2.61	0.000000
									2.32	0.18	2.33	0.000000
								1	1.62	0.47	2.84	0.000013 *
									1.76	0.41	2.81	0.000010
									1.93	0.35	2.73	0.000007
									2.10	0.29	2.62	0.000005
									2.23	0.24	2.53	0.000003
									2.39	0.18	2.40	0.000000
								0.5	1.69	0.48	2.84	0.000029 *
									1.86	0.42	2.79	0.000024
									2.00	0.37	2.73	0.000020
									2.17	0.30	2.64	0.000012
									2.32	0.24	2.56	0.000007
									2.46	0.19	2.54	0.000004
								0.1	1.69	0.60	2.91	0.000175 *
									1.86	0.52	2.89	0.000133
									2.00	0.45	2.81	0.000098
									2.17	0.39	2.76	0.000099
									2.32	0.31	2.72	0.000056
									2.46	0.27	2.64	0.000073

Reach	Section	Easting	Northing	Defence Type	Effective Crest Level mODM)	Toe Level (mODM)	Length (m)	%AEP	Water Level (mODM)	Wave Height (m)	Wave Period(s)	Unit Discharge (m3/s/m)
Kenmare	A	90406	70200	Shingle slope leading to road/track with groynes	2.34	-0.90	209	50	1.75	0.61	3.07	0.000077
									1.82	0.58	3.12	0.000162
									1.89	0.52	3.18	0.000297
									1.98	0.44	3.24	0.000596
									2.05	0.39	3.28	0.001083
								20	2.12	0.34	3.31	0.001994 *
									1.75	0.70	3.15	0.000170
									1.89	0.61	3.23	0.000595
									1.98	0.53	3.29	0.001165
									2.05	0.47	3.32	0.002067
									2.12	0.42	3.34	0.003617
									2.22	0.35	3.37	0.008631 *
								10	1.82	0.72	3.17	0.000444
									1.98	0.61	3.27	0.001826
									2.05	0.55	3.31	0.003156
									2.12	0.49	3.34	0.005473
									2.22	0.42	3.37	0.012629
								5	2.28	0.36	3.38	0.019957 *
									1.82	0.78	3.19	0.000629
									1.98	0.68	3.29	0.002635
									2.12	0.56	3.35	0.007832
									2.22	0.49	3.38	0.017518
								2	2.28	0.43	3.40	0.027591
									2.35	0.34	3.40	0.041849 *
									1.82	0.87	3.24	0.001024
									1.98	0.77	3.33	0.004133
									2.12	0.65	3.39	0.011587
								1	2.28	0.52	3.43	0.038608
									2.35	0.46	3.44	0.065335
									2.43	0.40	3.45	Still water overtopping *
									1.89	0.88	3.29	0.002332
									2.05	0.78	3.36	0.009098
								0.5	2.22	0.65	3.41	0.031988
									2.35	0.54	3.44	0.080944
									2.43	0.47	3.46	Still water overtopping
									2.49	0.42	3.46	Still water overtopping *
									1.89	0.97	3.29	0.003200
								0.1	2.05	0.86	3.38	0.011953
									2.22	0.73	3.43	0.041069
									2.35	0.56	3.45	0.085678
									2.49	0.45	3.45	Still water overtopping
									2.56	0.43	3.45	Still water overtopping *
									1.98	1.07	3.36	0.011567
									2.12	0.98	3.43	0.032279
									2.28	0.84	3.47	0.092140
									2.43	0.71	3.50	Still water overtopping
									2.49	0.66	3.50	Still water overtopping
									2.56	0.60	3.50	Still water overtopping *

Reach	Section	Easting	Northing	Defence Type	Effective Crest Level mODM)	Toe Level (mODM)	Length (m)	%AEP	Water Level (mODM)	Wave Height (m)	Wave Period(s)	Unit Discharge (m3/s/m)	
Kenmare	B	90519	70129	Concrete quay wall leading to grassed crest	2.43	-0.26	213	50	1.75	0.26	2.53	0.000018	*
									1.82	0.21	2.54	0.000006	
									1.89	0.19	2.55	0.000006	
									1.98	0.15	2.56	0.000003	
									2.05	0.13	2.57	0.000003	
								20	2.12	0.11	2.57	0.000003	
									1.75	0.27	2.54	0.000025	
									1.89	0.22	2.55	0.000022	
									1.98	0.19	2.56	0.000022	
									2.05	0.16	2.57	0.000017	
									2.12	0.14	2.57	0.000021	
									2.22	0.11	2.58	0.000032	*
								10	1.82	0.31	2.53	0.000130	
									1.98	0.22	2.55	0.000063	
									2.05	0.20	2.55	0.000080	
									2.12	0.17	2.56	0.000077	
									2.22	0.14	2.56	0.000133	
								5	2.28	0.12	2.57	0.000202	*
									1.82	0.31	2.55	0.000130	
									1.98	0.25	2.56	0.000145	
									2.12	0.20	2.57	0.000199	
									2.22	0.16	2.57	0.000264	
								2	2.28	0.15	2.57	0.000541	
									2.35	0.12	2.57	0.000920	*
									1.82	0.36	2.56	0.000330	
									1.98	0.30	2.57	0.000417	
									2.12	0.25	2.57	0.000623	
								1	2.28	0.18	2.58	0.001096	
									2.35	0.16	2.57	0.002185	
									2.43	0.13	2.57	Still water overtopping	*
									1.89	0.34	2.75	0.000400	
									2.05	0.30	2.65	0.000764	
								0.5	2.22	0.24	2.60	0.001514	
									2.35	0.18	2.58	0.001819	
									2.43	0.15	2.57	Still water overtopping	
									2.49	0.13	2.57	Still water overtopping	*
									1.89	0.40	2.56	0.000948	
								0.1	2.05	0.35	2.57	0.001542	
									2.22	0.28	2.58	0.002614	
									2.35	0.21	2.58	0.004478	
									2.49	0.16	2.58	Still water overtopping	
									2.56	0.14	2.58	Still water overtopping	*
									1.98	0.41	2.82	0.001896	
									2.12	0.38	2.74	0.003519	
									2.28	0.32	2.66	0.006704	
									2.43	0.26	2.62	Still water overtopping	
									2.49	0.23	2.60	Still water overtopping	
									2.56	0.21	2.59	Still water overtopping	*

Reach	Section	Easting	Northing	Defence Type	Effective Crest Level mODM)	Toe Level (mODM)	Length (m)	%AEP	Water Level (mODM)	Wave Height (m)	Wave Period(s)	Unit Discharge (m3/s/m)
Kenmare	C	90519	70129	Shingle slope leading to grassed bank	Variable Min.= 2.45	-0.68	275 (truncated at southern end to remove high ground at Cromwell's Fort)	50	1.75	0.37	3.81	0.000011
									1.82	0.36	3.71	0.000019
									1.89	0.34	3.62	0.000028
									1.98	0.30	3.59	0.000056
									2.05	0.27	3.60	0.000109
									2.12	0.24	3.62	0.000218 *
								20	1.75	0.47	3.62	0.000024
									1.89	0.41	3.59	0.000070
									1.98	0.37	3.60	0.000140
									2.05	0.33	3.62	0.000263
									2.12	0.30	3.64	0.000505
									2.22	0.25	3.67	0.001267 *
								10	1.82	0.56	3.37	0.000069
									1.98	0.46	3.49	0.000273
									2.05	0.41	3.55	0.000479
									2.12	0.36	3.59	0.000868
									2.22	0.31	3.63	0.002026
									2.28	0.27	3.64	0.003290 *
								5	1.82	0.56	3.54	0.000103
									1.98	0.49	3.57	0.000410
									2.12	0.41	3.63	0.001308
									2.22	0.36	3.66	0.003025
									2.28	0.32	3.66	0.004704
									2.35	0.28	3.66	0.008854 *
								2	1.82	0.63	3.56	0.000182
									1.98	0.56	3.59	0.000705
									2.12	0.48	3.64	0.002127
									2.28	0.38	3.68	0.007450
									2.35	0.32	3.61	0.011148
									2.43	0.29	3.60	0.024471 *
								1	1.89	0.69	3.46	0.000462
									2.05	0.60	3.57	0.001822
									2.22	0.48	3.67	0.006716
									2.35	0.40	3.74	0.017770
									2.43	0.33	3.76	0.030275
									2.49	0.31	3.76	Still water overtopping *
								0.5	1.89	0.64	3.89	0.000743
									2.05	0.61	3.70	0.002258
									2.22	0.54	3.71	0.008846
									2.35	0.45	3.75	0.022701
									2.49	0.36	3.80	Still water overtopping
									2.68	0.40	2.67	0.00019
								0.1	1.94	1.07	2.75	0.00144
									2.12	0.99	2.76	0.00356 *
									2.30	0.88	2.74	0.00326
									2.45	0.79	2.72	0.00307
									2.61	0.67	2.70	0.00244
									2.68	0.58	2.68	0.00163

Appendix D. Future Peak Flows and Water Levels

Table D.1: Future Peak Flows

Location		MRFS Design Peak Flows (m³/s)								HEFS Design Peak Flows (m³/s)							
		HEP	50%AEP	20	10	5	2	1	0.5	0.1	50%AEP	20	10	5	2	1	0.5
Blue Hill South	21_7668_1+	1.1	1.4	1.6	1.8	2.1	2.4	2.7	3.6	1.2	1.5	1.7	2.0	2.3	2.6	3.0	3.9
Dromacoosane upstream	21_1091_1	1.2	1.5	1.8	2.0	2.4	2.7	3.0	4.0	1.3	1.7	1.9	2.2	2.6	2.9	3.3	4.3
Dromacoosane at Blue Hill Confluence	21_1091_3	1.5	1.9	2.2	2.5	3.0	3.4	3.8	5.1	1.7	2.1	2.4	2.7	3.2	3.6	4.1	5.5
Blue Hill South/Cappanaloha and Dromacoosane	21_7668_1	2.6	3.3	3.8	4.3	5.1	5.7	6.5	8.6	2.9	3.6	4.1	4.7	5.5	6.2	7.0	9.3
Dromacoosane downstream extent	21_7668_2	2.9	3.6	4.1	4.7	5.5	6.2	7.0	9.3	3.1	3.9	4.4	5.0	5.9	6.7	7.6	10.1
Kilnaruane	21_6264_3	1.2	1.5	1.7	1.9	2.2	2.5	2.8	3.8	1.3	1.6	1.8	2.1	2.4	2.7	3.1	4.1
Knocknaveagharea upstream	21_7060_1+	0.8	1.1	1.2	1.4	1.6	1.7	2.0	2.2	1.0	1.3	1.5	1.7	2.0	2.1	2.6	2.7
Bantry Main downstream Sheskin	21_7060_1	2.5	3.2	3.6	4.1	4.7	5.1	6.1	6.5	3.1	4.0	4.6	5.2	5.9	6.4	7.7	8.2
Bantry Main upstream School	21_7060_2	3.5	4.5	5.2	5.8	6.6	7.2	8.6	9.2	4.6	5.9	6.7	7.6	8.6	9.4	11.3	12.1
Bantry Main	21_7249_1	4.5	5.8	6.7	7.5	8.5	9.3	11.2	12.0	6.0	7.7	8.8	9.9	11.2	12.3	14.7	15.7
Bantry Main	21_7249_2	5.5	7.1	8.1	9.1	1.4	11.3	13.6	14.5	7.4	9.5	10.9	12.2	14.0	15.3	18.2	19.5
Bantry Main	21_7092_1	6.4	8.2	9.4	10.6	12.1	13.2	15.7	16.9	8.5	10.8	12.4	14.0	15.9	17.4	20.8	22.3
Bantry Main	21_7092_2	6.7	8.6	9.9	11.1	12.7	13.8	16.5	17.7	9.0	11.5	13.2	14.8	16.9	18.4	22.0	23.6
Bantry Main downstream Scart Road	21_7096_1	7.2	9.2	10.6	11.9	13.6	14.8	17.7	19.0	9.5	12.1	13.9	15.6	17.8	19.5	23.3	24.9
Bantry Main	21_7225_1	9.8	12.6	14.5	16.2	18.5	20.2	24.2	25.9	13.3	17.0	19.5	21.9	25.0	27.3	32.7	35.0
Bantry Main downstream Survey Extent	21_7225_2	10.4	13.3	15.2	17.1	19.5	21.3	25.5	27.3	14.0	18.0	20.6	23.1	26.4	28.9	34.5	36.9
Sheskin Stream	21_7249_1+	0.9	1.1	1.3	1.5	1.7	1.8	2.2	2.3	1.2	1.5	1.7	1.9	2.2	2.4	2.8	3.0
Carrignagat Stream	21_7092_1+	1.5	1.9	2.2	2.4	2.8	3.0	3.6	3.9	2.0	2.5	2.9	3.3	3.7	4.1	4.9	5.2
Dromleigh Stream	21_7096_1+	1.6	2.0	2.3	2.6	3.0	3.3	3.9	4.2	2.1	2.7	3.1	3.5	3.9	4.3	5.2	5.5
Reenrour Stream	21_7096_2+	2.1	2.8	3.2	3.5	4.0	4.4	5.3	5.7	2.8	3.6	4.1	4.6	5.3	5.8	6.9	7.4
Ardnageehy Stream	21_48_1+	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.5	0.5	0.7	0.7	0.8	1.0	1.1	1.2	1.6
Doneelagh	21_51_2	2.4	2.9	3.2	3.6	4.2	4.7	5.3	6.9	2.5	3.1	3.5	3.9	4.6	5.1	5.7	7.5
Ardnageehy	21_48_1	3.0	3.7	4.1	4.6	5.4	6.0	6.7	8.8	3.2	4.0	4.5	5.0	5.8	6.5	7.3	9.6
Doneelagh upstream Mealagh	21_2187_2	4.2	5.1	5.7	6.4	7.5	8.4	9.4	12.3	4.5	5.5	6.2	7.0	8.1	9.1	10.2	13.3
Mealagh at Inchiclogh - GAUGED	21_5827_3	105.0	128.2	144.7	162.3	188.5	211.1	236.7	310.2	113.8	138.8	156.8	175.9	204.2	228.7	256.4	336.0
Mealagh upstream Survey Extent	21_5826_1	107.7	131.4	148.4	166.4	193.3	216.5	242.7	318.0	116.7	142.3	160.7	180.3	209.4	234.5	262.9	344.5
Mealagh downstream Mealagh Tributary	21_6183_1	108.2	132.1	149.1	167.3	194.2	217.5	243.9	319.6	117.2	143.1	161.5	181.2	210.4	235.7	264.2	346.2
Mealagh	21_6412_1	114.0	139.1	157.1	176.2	204.7	229.2	257.0	336.7	123.5	150.7	170.2	190.9	221.7	248.3	278.4	364.8
Mealagh	21_6412_2	113.7	138.8	156.7	175.8	204.2	228.7	256.4	335.9	123.3	150.4	169.8	190.5	221.2	247.8	277.8	364.0
Mealagh downstream Milleencolla	21_6258_1	115.4	140.8	159.0	178.3	207.0	231.9	260.0	340.7	125.0	152.5	172.2	193.2	224.4	251.3	281.7	369.1
Milleagh downstream Survey Extent	21_6258_3	115.2	140.6	158.7	178.1	206.8	231.6	259.6	340.2	124.9	152.4	172.1	193.0	224.1	251.0	281.5	368.8
Raheen Beg	21_6183_1+	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.9	0.3	0.4	0.5	0.5	0.6	0.7	0.8	1.0
Milleencolla East Stream	21_6258_1+	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.7	0.6	0.7	0.8	0.9	1.1	1.2	1.4	1.8
Clashadoo	21_6225_1+	0.9	1.1	1.3	1.4	1.7	1.9	2.1	2.8	1.0	1.2	1.4	1.6	1.8	2.0	2.3	3.0
Ahanegavanagh upstream Survey Extent	21_5338_5	6.5	8.0	9.0	10.2	11.9	13.3	15.0	19.7	7.0	8.6	9.8	11.0	12.9	14.4	16.2	21.4
Ahanegavanagh upstream Clashadoo	21_5338_6	6.8	8.3	9.5	10.7	12.4	14.0	15.7	20.7	7.3	9.0	10.3	11.6	13.5	15.1	17.0	22.4
Ahanegavanagh downstream Clashadoo	21_6225_1	7.4	9.1	10.3	11.7	13.6	15.3	17.2	22.6	8.0	9.9	11.2	12.6	14.7	16.5	18.6	24.5
Ahanegavanagh downstream extent	21_6225_2	7.5	9.2	10.5	11.8	13.8	15.5	17.4	22.9	8.1	10.0	11.3	12.8	14.9	16.7	18.8	24.8
Four Mile South upstream Survey Extent	21_8046_2	2.9	3.6	4.1	4.7	5.5	6.2	7.0	9.3	3.1	3.9	4.5	5.1	5.9	6.7	7.6	10.0
Four Mile South	21_8046_3	3.1	3.8	4.4	5.0	5.8	6.6	7.4	9.8	3.3	4.2	4.8	5.4	6.3	7.1	8.0	10.7

Location	MRFS Design Peak Flows (m³/s)									HEFS Design Peak Flows (m³/s)							
	HEP	50%AEP	20	10	5	2	1	0.5	0.1	50%AEP	20	10	5	2	1	0.5	0.1
Four Mile North upstream Survey Extent	21_7736_3	17.0	21.2	24.2	27.4	32.2	36.3	40.9	54.3	18.4	23.0	26.2	29.7	34.9	39.3	44.3	58.8
Four Mile North	21_7736_5	17.3	21.6	24.6	27.9	32.7	36.9	41.6	55.1	18.7	23.4	26.7	30.2	35.4	39.9	45.1	59.7
Four Mile downstream Survey Extent	21_8044_2	20.4	25.5	29.1	32.9	38.6	43.5	49.1	65.1	22.1	27.6	31.5	35.6	41.8	47.2	53.2	70.5
Kilowen	21_6311_1+	1.0	1.3	1.4	1.6	1.8	2.1	2.3	3.0	1.1	1.4	1.5	1.7	2.0	2.2	2.5	3.3
Lissaniska upstream Survey Extent	21_7313_1	2.1	2.5	2.8	3.2	3.7	4.1	4.6	6.1	2.2	2.7	3.1	3.4	4.0	4.5	5.0	6.6
Lissaniska upstream Kilown	21_7313_3	2.7	3.2	3.7	4.1	4.8	5.3	6.0	7.8	2.9	3.5	4.0	4.4	5.2	5.8	6.5	8.5
Lissaniska downstream Killowen	21_6311_1	2.9	3.6	4.1	4.5	5.3	5.9	6.6	8.7	3.2	3.9	4.4	4.9	5.7	6.4	7.2	9.4
Kilowen upstream Finnihy	21_6311_3	3.8	4.7	5.3	5.9	6.8	7.6	8.6	11.2	4.3	5.2	5.9	6.6	7.7	8.6	9.6	12.6
Finnihy downstream Kilmurray	21_2420_1	36.0	44.6	50.8	57.4	67.2	75.7	85.2	112.7	39.0	48.3	55.1	62.2	72.8	82.0	92.3	122.1
Finnihy upstream Gortamullin Stream	21_2420_3	37.7	46.8	53.3	60.2	70.4	79.3	89.3	118.1	40.9	50.7	57.7	65.2	76.3	86.0	96.8	128.1
Finnihy downstream Gortamullin Stream	21_2408_1	38.1	47.3	53.9	60.8	71.2	80.2	90.3	119.5	41.3	51.3	58.4	66.0	77.2	86.9	97.9	129.5
Finnihy upstream Lissaniska - excluding Gortamullin West	21_2408_4	39.3	48.8	55.5	62.7	73.4	82.7	93.2	123.2	42.8	53.1	60.4	68.3	79.9	90.0	101.3	134.0
Finnihy d/d Lissaniska - excluding Gortamullin West	21_2495_1	44.7	55.4	63.1	71.3	83.5	94.0	105.9	140.0	48.8	60.5	69.0	77.9	91.2	102.7	115.7	152.9
Finnihy downstream Survey Extent - excluding Gortamullin West	21_2495_4	46.1	57.2	65.2	73.6	86.2	97.0	109.3	144.6	50.7	62.8	71.6	80.9	94.6	106.6	120.0	158.7

Table D.2: Future Total Tide Plus Sea Levels

Location	MRFS Total Tide Plus Surge Levels (mODM)								HEFS Total Tide Plus Surge Levels (mODM)							
	50%AEP	20	10	5	2	1	0.5	0.1	50%AEP	20	10	5	2	1	0.5	0.1
Kenmare	2.67	2.77	2.83	2.90	2.98	3.04	3.11	3.25	3.17	3.27	3.33	3.40	3.48	3.54	3.61	3.75
Castletown Bearhaven	2.54	2.64	2.71	2.77	2.86	2.93	3.00	3.15	3.04	3.14	3.21	3.27	3.36	3.43	3.50	3.65
Bantry	2.69	2.80	2.88	2.97	3.07	3.15	3.23	3.41	3.19	3.30	3.38	3.47	3.57	3.65	3.73	3.91
Durrus	2.64	2.75	2.83	2.91	3.01	3.09	3.17	3.34	3.14	3.25	3.33	3.41	3.51	3.59	3.67	3.84

