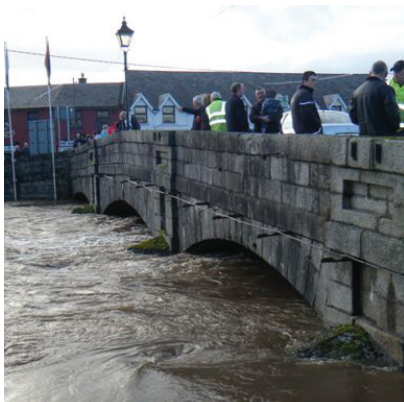
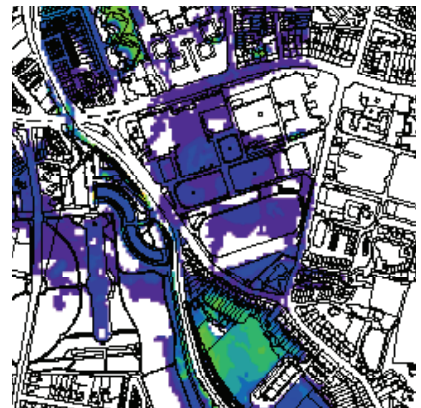
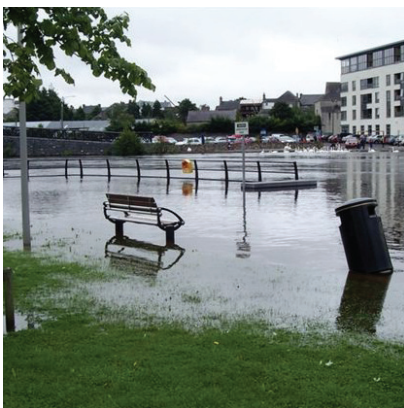
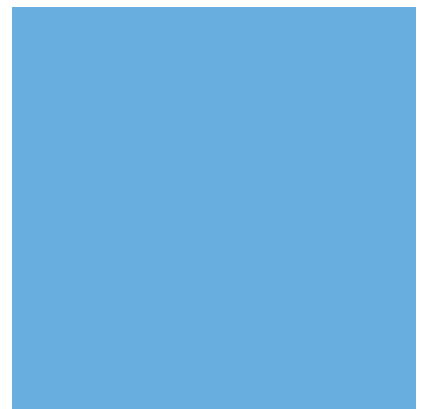


South Eastern CFRAM Study

HA11, 12 & 13 Inception Report

IBE0601Rp0007_F02/July12



South Eastern CFRAM Study

HA11, 12 and 13 Inception Report

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ABBREVIATIONS

AA	Appropriate Assessment
AEP	Annual Exceedance Probability
AFA	Area for Further Assessment
AMAX	Annual Maximum flood series
CFRAM	Catchment Flood Risk Assessment and Management
CC	Coefficient of Correlation
COD	Coefficient of Determination
COV	Coefficient of Variance
cSAC	Candidate Special Area of Conservation
DAHG	Department of Arts, Heritage and the Gaeltacht
DTM	Digital Terrain Model
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ESB	Electricity Supply Board
EU	European Union
EV1	Extreme Value Type 1 (distribution) (=Gumbel distribution)
FRA	Flood Risk Assessment
FRMP	Flood Risk Assessment and Management Plan
FRR	Flood Risk Review
FSU	Flood Studies Update
FSSR	Flood Studies Supplementary Report
GEV	Generalised Extreme Value (distribution)

GLO	General Logistic (distribution)
GIS	Geographical Information Systems
GSI	Geological Survey of Ireland
HA	Hydrometric Area
HEP	Hydrological Estimation Point
HPW	High Priority Watercourse
LA	Local Authority
LAP	Local Area Plan
LN2	2 Parameter Log Normal (distribution)
MAF	Mean Annual Flow
MPW	Medium Priority Watercourse
NDTM	National Digital Terrain Model
NHA	Natural Heritage Area
NIAH	National Inventory of Architectural Heritage
NPWS	National Parks and Wildlife Service
OD	Ordnance Datum
OPW	Office of Public Works
OSi	Ordnance Survey Ireland
PEE	Proportional Error Estimate
PFRA	Preliminary Flood Risk Assessment
Q_{med}	median of AMAX flood series
Q_{bar}	mean average of AMAX flood series
RBD	River Basin District

RBMP	River Basin Management Plan
RMSE	Root Mean Square Error
SAAR	Standard Average Annual Rainfall (mm)
SEA	Strategic Environmental Assessment
SERBD	South Eastern River Basin District
SAC	Special Area of Conservation
SEAI	Sustainable Energy Authority of Ireland
SC	Survey Contract
SI	Statutory Instrument
SPA	Special Protection Area
SuDS	Sustainable Urban Drainage
UoM	Unit of Management
WFD	Water Framework Directive
WNFC	Wexford Naturalists' Field Club
WP	Work Package
WWI	Waterways Ireland

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1 INTRODUCTION

The Office of Public Works (OPW) commissioned RPS to undertake the South Eastern Catchment Flood Risk Assessment and Management Study (South Eastern CFRAM Study) in July 2011. The South Eastern CFRAM Study was the third catchment flood risk management study to be commissioned in Ireland under the EC Directive on the Assessment and Management of Flood Risks 2007 (Reference 1) as implemented in Ireland by SI 122 of 2010 European Communities (Assessment and Management of Flood Risks) Regulations 2010 (Reference 2).

The South Eastern CFRAM Study covers an area of 9,315 km² and includes six Units of Management, Hydrometric Area (HA) 11 (Owenavorrhagh), HA12 (Slaney and Wexford Harbour), HA13 (Ballyteigue-Bannow), HA14 (Barrow), HA15 (Nore) and HA17 (Colligan-Mahon). HA16 (Suir) is covered by the Suir pilot CFRAM Study and covers an area of approximately 3,542 km². There is a high level of flood risk within the South Eastern CFRAM study area, with significant coastal and fluvial flooding events having occurred in the past. Table 1.1 lists the local authorities that intersect each unit of management.

Table 1.1: Local authorities

Unit of Management	Local Authorities
HA11 Owenavorrhagh	Wexford, Wicklow
HA12 Slaney and Wexford Harbour	Carlow, Kildare, Wexford, Wicklow
HA13 Ballyteigue-Bannow	Wexford
HA14 Barrow	Carlow, Kildare, Kilkenny, Laois, Offaly, Wexford, Wicklow
HA15 Nore	Carlow, Kilkenny, Laois, Offaly, North Tipperary, South Tipperary
HA16 Suir	Cork, Kilkenny, Laois, Limerick, North Tipperary, South Tipperary, Waterford City, Waterford County
HA17 Colligan-Mahon	Waterford City, Waterford County

HAs 11, 12 and 13 are covered together in this inception report. They have a combined area of 3,030 km² and include the majority of county Wexford as well as significant portions of southern Wicklow and eastern Carlow. Although it has been agreed that units of management 11, 12 and 13 will be grouped where appropriate to facilitate technical reporting, a separate Flood Risk Management Plan (FRMP) will be prepared for each.

HA11 covers an area of 395 km² and includes much of eastern Wexford. The main rivers in this area are the Owenavorrhagh, Blackwater, Inch, Bracken, Aughboy and Assaly rivers as well as the Cahore canal. The main town in the area is Gorey. HA11 is predominantly rural and agricultural in nature. Within HA11 there are three Areas for Further Assessment (AFA) (Gorey, Courtown and Blackwater)

under the South Eastern CFRAM Study as shown in Figure 1.1. All three of these AFAs have experienced flooding: Blackwater and Gorey are both subject to fluvial flood risk; Courtown is subject to coastal flood risk.

HA12 covers an area of 1,981 km² and includes significant portions of counties Wexford, Carlow and Wicklow. The principal river is the River Slaney. The Slaney rises in the Glen of Imaal near Lugnaquilla in the Wicklow Mountains. It flows in a westerly direction towards Stratford and then flows in a southerly direction through Baltinglass, Rathvilly and Tullow. It then continues in a south easterly direction through Bunclody and Enniscorthy and then southerly to Ferrycarrig where it turns east into Wexford Harbour and on into the sea. The total length of the river is 117 kilometres and it is tidal as far upstream as Enniscorthy. Upstream of Enniscorthy the main tributaries are the Derreen, Derry and Bann rivers which join the Slaney's left hand bank and the Douglas and Clody rivers which join the Slaney's right hand bank. Downstream of Enniscorthy the main tributaries are the Urrin and Boro rivers as well as the Sow River which enters the Slaney Estuary between Ferrycarrig and Wexford. The catchment of HA12 is predominantly rural and agricultural in nature. The main towns are Wexford, Enniscorthy and Baltinglass, and smaller towns include Tullow and Bunclody. There are seven AFAs (Baltinglass, Tullow including Tullowphelim, Bunclody, Enniscorthy & Environs, Wexford, North Slobs and South Slobs), within HA12 for assessment under the South Eastern CFRAM Study as shown in Figure 1.1. Four of these are at risk from fluvial flooding: Baltinglass; Tullow (including Tullowphelim); Bunclody; and Enniscorthy and Environs. The North Slobs and South Slobs AFAs are both at risk from tidal flooding. The Wexford AFA is subject to both tidal and coastal flooding.

HA13 covers an area of 654 km² and includes a significant portion of southern County Wexford. The main rivers in the area are the Bridgetown, Corock, Duncormick and Owenduff rivers. There are no particularly large towns in this area, the main settlements include Fethard-on-Sea and Duncannon. HA13 is predominantly rural and agricultural in nature. Within HA13 there is one AFA (Kilmore) for assessment under the South Eastern CFRAM Study, Kilmore AFA, as shown in Figure 1.1. There is no record of flooding in the area but it is however considered to be potentially at risk due to both tidal and fluvial flooding.

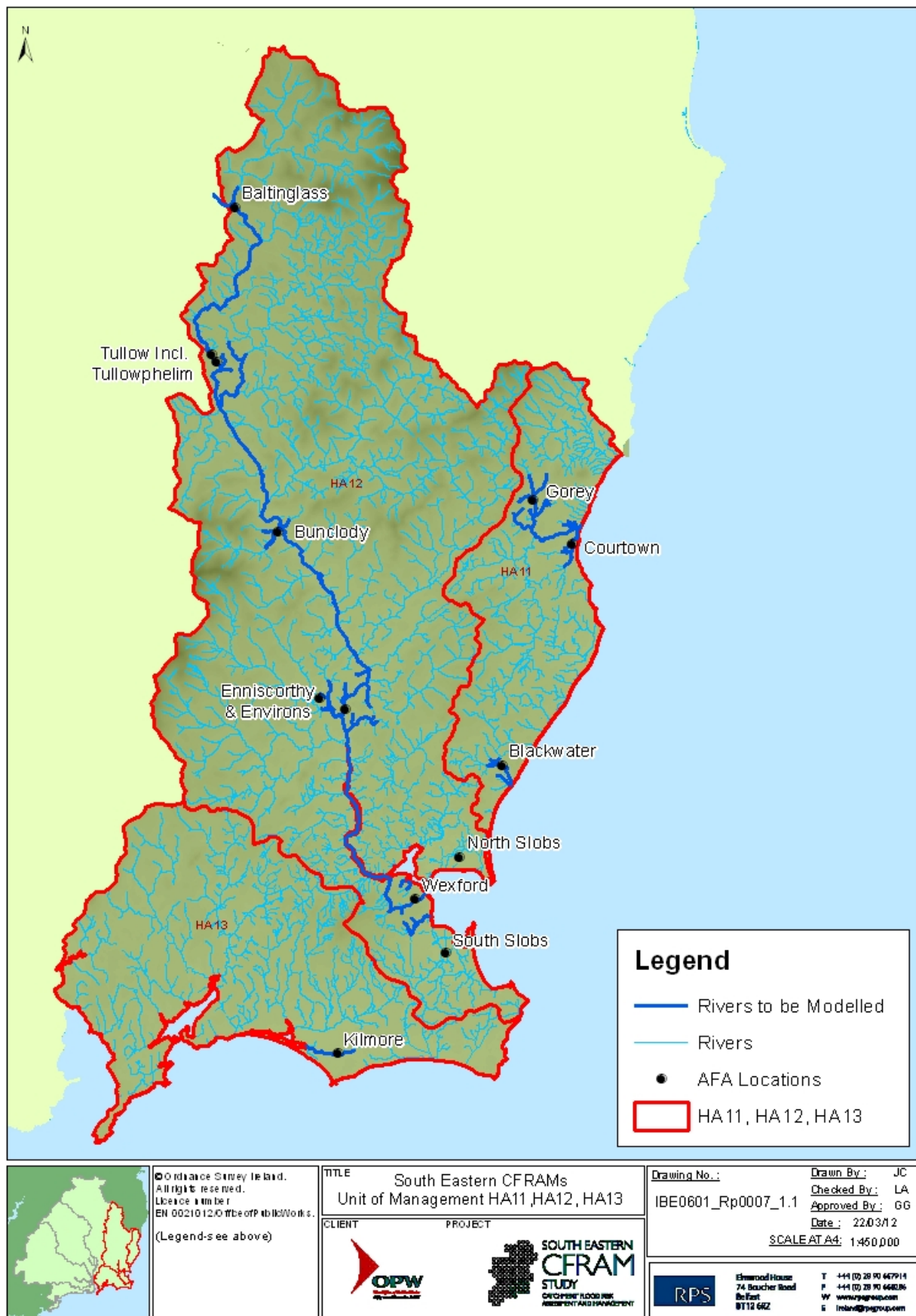


Figure 1.1: HA 11, 12 and 13 Extents and AFA Locations

1.1 OBJECTIVE OF THIS INCEPTION REPORT

The principal objective of this Inception Report is to provide detail on the relevant datasets identified for use in HA11, 12 and 13 as part of the South Eastern CFRAM Study, and provide an update on the collection and interpretation process to date for that data.

This document will also identify any issues that have been encountered in sourcing data and flag any that may affect the proposed methodologies or programme going forward.

The data requested, received or outstanding is detailed in the following section of this document, and progress with analysis of this data in current work packages is presented in Section 4.

1.2 APPROACH TO PROJECT DELIVERY

RPS has established a project specific team which includes a Project Management Board consisting of our nominated Project Director, Dr Alan Barr, assisted by the Project Manager, Grace Glasgow, and two Assistant Project Managers, Dr Malcolm Brian and Andrew Jackson. This senior management team are closely involved in all aspects of the study and will have responsibility for specific technical and geographic areas. All members of the RPS Project Board are based in the Belfast office of RPS as are many of the supporting technical staff, although the overall team includes staff from RPS offices in Dublin, Limerick, Cork and Galway as well as support from sub-consultants Compass Informatics and Hydrologic BV.

Within the overall RPS project team are a core group of staff who will remain involved in the project throughout its duration from initial data collection to reporting to ensure coherence and consistency in approach. Within this group we have identified a dedicated data manager, Richard Bingham, who is responsible for ensuring that all received data is logged and for maintaining a project specific inventory of datasets available to the project.

2 DATA COLLECTION

2.1 DATA COLLECTION PROCESS

RPS places a high importance on data collection throughout the lifetime of a project and considers sourcing, acquisition, quality checking and updating of information to be critical to the successful implementation of the CFRAM Studies.

The data collection process for the South Eastern CFRAM Study and Hydrometric Areas 11, 12 and 13 in particular started with a review of the lists of data sources and relevant reports identified in the “National Flood Risk Assessment and Management Programme, South Eastern River Basin District Catchment-based Flood Risk Assessment and Management (CFRAM) Study, Stage II Tender Documents: Project Brief” (Reference 3), hereinafter referred to as the South Eastern CFRAM Study Brief and the “National Flood Risk Assessment and Management Programme, Catchment-based Flood Risk Assessment and Management (CFRAM) Studies, Stage I Tender Documents: Project Brief” (Reference 4), hereinafter referred to as the Generic CFRAM Study Brief, followed by tailored requests to probable data holders including all steering and progress group members.

The formal data collection process for the South Eastern CFRAM Study was initiated by OPW providing RPS with a range of datasets in various formats, including data from various Local Authorities and other organisations at the end of July 2011. The datasets provided by OPW included:-

Social

- Primary Schools, Post Primary Schools, Third Level
- Fire Stations
- Garda Stations
- Civil Defence
- OPW Buildings
- Nursing Homes, Hospitals, Health Centres

Economic

- Geo-Directory (GeoDirectory Oct 2010)
- Infrastructure: ESB Power Stations, ESB HV Substations, Bord Gais Assets, Eircom Assets
- Road
- Rail
- Ports
- Airports

Environmental

- Architectural Heritage
- National Monuments
- National Heritage Area
- Proposed National Heritage Area
- Special Area of Conservation
- Special Protected Area
- Groundwater Drinking Water (EPA data)

- Pollution Sources (EPA data)

Hydrology

- Irish Coastal Protection Strategy Study: South East coast
- FSU data
- OPW Hydrometrics: Annual Maxima, Gaugings, Q 15min Data, Rating Equations, Staff Gauges Zero, WL 15min Data, Photographs
- EPA Water levels

Meteorology

- Rainfall logger (24hr storage). Daily gauges. (Met Éireann/Data files/Rainfall/Daily Rainfall)
- Rainfall logger (hourly). Synoptic Stations. (Met Éireann/Data files/Rainfall/Hourly Rainfall)
- Evaporation Data. Synoptic Stations (Met Éireann/Data files/Evaporation)
- Pot Evapotranspiration. Synoptic Stations (Met Éireann/Data files/Pot Evapotranspiration)
- Soil Moisture Defective. Synoptic Stations (Met Éireann/Data files/SMD)
- Air Pressure
- Temperature
- Wind Speed and Direction
- Soil temperature
- Rainfall Radar
- Met Éireann Spatial files

Geo-referenced Data

- Development and Local Area Plans
- Historical Flood data
- NDHM (5m resolution IfSAR)
- hDTM (20m resolution hydrologically corrected DTM) (EPA-20m hDTM/Disc 2-South Eastern RBD)
- OSi Maps
- LiDAR
- Aerial photography
- OPW Channels
- OPW Embankments
- OPW Benefiting Lands
- Lakes (Lakes/HA_11,12,13)
- River Centrelines

Other

- PFRA Access Database (110310_Final Database)
- floodmaps.ie Registered User log in details
- Contact list of Data Owners
- National Pluvial Screening Project for Ireland report
- PFRA Groundwater Flooding report
- PFRA Tables
- Defence Asset Database
- Operation Instructions for Flood Defences, Hydraulic Structures
- Existing Survey Data from existing studies
- Existing Studies Models and Reports
- Existing Low Flow/ Water Quality Studies Models and Reports

Following an initial review of the received data, further requests were made to the appropriate Local Authorities and other organisations via email and also at meetings, either at their offices or at the various project meetings. A summary of the range of data requests issued by RPS between July

2011 and January 2012 is provided below. In addition to requesting data from Progress and Steering Group members and other Stakeholder organisations RPS also undertook internet searches to obtain additional data in specific areas.

Immediately upon confirmation of appointment in July 2011, RPS received hydrometric data, levels and flows for all Environmental Protection Agency (EPA) gauging stations within the study area. Details of current rating equations and calibration measurements for these stations were also sought from EPA. No data was available for the two Electricity Supply Board (ESB) stations in South Eastern study area.

At the beginning of August 2011, RPS issued a request to Local Authorities seeking details of all culverted watercourses, storm sewer systems and discharges and any flood defence schemes in GIS or AutoCAD format. Requests were also submitted to Wexford County Council seeking information on their respective Planning and Development Boundaries and to OPW for missing OSI vector mapping tiles. Data was received from Wexford and Wicklow County Councils.

In mid August, requests were made to GSI for soil and groundwater datasets to inform the MIKE-NAM model parameters decision trees and derive model input parameters. These were received that same month. The actual datasets requested were:

- Groundwater Vulnerability;
- Soil Permeability;
- Well Drained / Poorly Drained Soils;
- Aquifer Type.

At the start of September, a request was submitted to OPW seeking:

- Re-supply of the National Digital Height Model data as some of the original information was for the wrong area. These were received that same month.;
- Details of the Gauging stations, this information was received;
- Feasibility study reports or design reports / drawings that OPW held for any of the schemes listed in the tender documents.

At the beginning of October RPS made a number of data requests to OPW in relation to the following items:

- Orthophotography, which was received;
- PFRA Flood extents for the Wexford area, which were received.

Further requests were made to EPA and Met Éireann during September in relation to data gaps within gauging station data previously received. The data was received.

In the middle of October, RPS issued requests to EPS Ireland (consultants managing rain gauges on behalf of some Local Authorities) and Teagasc for any rainfall data they held. The data was received from Teagasc.

At the end of October a request was submitted, and data received, from JBA Consulting for GIS layers relating to the survey contract for Hydrometric areas 12, 14 and 15. Also at this time RPS requested and received 2,500, 5,000 and 1,000 OSi vector mapping datasets and additional missing Orthophotography data from OPW.

In early November, RPS requested, and received, information on the Electrical infrastructure data across Ireland from ESB. RPS also made a further request to OPW for missing OSi Vector mapping tiles that had been omitted from the previous resupply at the end of October, these were received. RPS also issued a request to all of the Local Authorities asking them to review the list of previously supplied rainfall gauging stations within their administrative areas and advise RPS regarding:

1. Whether they were aware of additional stations to those listed; and
2. If so, to provide:
 - a. Station name;
 - b. Location (coordinates);
 - c. Type – daily / hourly;
 - d. All available data.

Data was received from Wexford County Council.

During November RPS requested additional Development and Planning information from Wexford County Council, some data was received.

A request was also issued to Met Éireann for missing rainfall data for the meteorological stations in the study area that had been identified through a review of the previously supplied data, this data was received.

At the beginning of December, RPS sent a final data request to each Local Authority seeking any outstanding information on the following topics that they were aware of or held:

Flood Relief/Risk Management Measures

- Previous reports or studies concerning flood hazard or risk or possible flood relief measures;

- Information on current flood risk and water management measures or practices;
- Information on other flood-related matters undertaken under other national programmes or other EU directives.

Historic Flood Data

- Information on historic flooding;
- Maps of flood extents;
- Flood levels;
- Flood depths;
- Causes or mechanisms of flooding;
- Resulting damage.

Hydrometric Data

- Information on recorded water levels and tidal data, flows, flow gaugings and ratings (stage-discharge relationships).

Meteorological Data

- Information on rainfall, air pressure, wind speed and direction, temperature and evapo-transpiration.

Land-use Data

- Information on current and past land use.

Soil and Geological Data

- Data on soil classifications, sub-soils, geology and aquifers.

Planning and Development Information

- Information concerning existing development and possible future development;
- Local area plans, town plans, master plans.

Defence and Coastal Protection Asset Data

- Information in relation to the location, type, ownership, design and/or actual performance standard, and condition of these assets.

Existing Survey / Geotechnical Data

- Topographical, channel, structural or geotechnical survey data collected for previous flood relief studies or other construction projects e.g. main drainage or sewer projects.

Environmental Data

- Information, reports, studies, zoning or assessments of environmental and archaeological status, issues, constraints and impacts.

Other Receptor Data

- Data on flood risk receptors, including types and locations such as property types, utility and transport infrastructure, national monuments and protected structures, hospitals, schools etc.

Urban Drainage

- Culverted Watercourse - extents / locations / inlets and outlets;
- Diverted Watercourses;
- Outfalls;
- Storm Water Infrastructure Records.

Other

- Aerial photography of flooding.

This request was implemented by forwarding to each Local Authority a tailored document which stated the study data requirements and also the data currently held by RPS for their area. In this request, Local Authorities were asked to either forward any other relevant data they held in relation to each of the data requirement headings or confirm that they had no further information. This was classified as being the final data collection cut-off date for Local Authority data, however as RPS go through the various stages of the South Eastern CFRAM study, further data needs may be identified and therefore the information will be requested and obtained.

At the beginning of January a request was made to the National Roads Authority for their most recent version of their Road Network dataset. This data was received. A request was also made to OPW to obtain the WFD Gauged Catchment Outlines for Hydrological Areas HA11, 12, 13, 14, 15, and 17. This data was received.

Finally in late January a request was issued to a number of Agencies such as DAHG – NPWS; Irish Peatland Conservation Council; Department of Agriculture, Food and Marine; Bat Conservation Ireland; Waterways Ireland; WNFC C/o Wexford Wildfowl Reserve; SEAI; The Heritage Council; DAHG; Inland Fisheries Ireland; and Port of Waterford. RPS also issued requests to Carlow County Council, Wexford County Council and also OPW to obtain complete Flood Scheme reports.

In all cases every request for information was logged into the Data Request Register and followed up with further emails and phone calls as appropriate.

2.2 DATA MANAGEMENT AND REGISTRATION

When data is received by RPS, it is transferred from the medium supplied into a temporary Incoming Data Folder. Any spatial data that is not provided in ESRI ArcMap format is converted using a piece of Safe Software called FME (Feature Manipulation Engine). A File Geodatabase is then created and the translated feature classes are imported into it, where they are named appropriately using the convention of (Owner, Dataset Name, Date received), for example, WexfordCoCo_Enniscorthy_ZoningLAP_111011, and the correct spatial reference is attached. These datasets are then imported to ArcMap to verify the positional accuracy against OSi background mapping.

All spatial and non-spatial information details are recorded into the Incoming Data Register. This register records the date of receipt, issuing organisation, supplier contact, data owner, filename as received, renamed filename, category, work package, description, original data format, new data format, type, medium, metadata, hyperlink, hydrological area, data requirement. Once receipt has been recorded and the data has been re-processed as necessary, the spatial and non-spatial datasets are moved to the appropriate folder location on our dedicated data server i.e. spatial data is moved to the folder '6.0 Spatial data', non-spatial is moved to the folder '8.2 Data Collection'. Data which is specific to a particular work package is moved into the relevant work package folder, for example, hydrometric data is moved to the '8.5 Hydrology WP' folder.

2.3 DATA REVIEW

2.3.1 Flood Relief / Risk Management Measures

Following a number of data requests as outlined in Section 2.1 RPS has received details of a number of existing flood relief and management measures within HA11, 12 and 13.

Carlow County Council

- Tullow - Drawings\Catchment Characteristics
- Tullow - Drawings\Drawings
- Tullow - Drawings - Lidar - 3m DTM
- Tullow - Drawings - Lidar - BareEarth
- Tullow - Drawings - Lidar - Contours

- Tullow - Drawings - Lidar - ESRI
- Tullow - Drawings - Prefeasibility
- OPW_Tullow_FloodReliefStudy_111205\Final Reports
- Tullow - Historic Flood Data - Photos
- Tullow - Survey Data - Property Survey
- Tullow - Survey Data - Rathvilly
- Tullow - Survey Data - Rathvilly - From_BKS
- Tullow - Survey Data - Rathvilly - Rathvilly_Drawings
- Tullow - Survey Data - Rathvilly - Rathvilly_Photos
- Tullow - Survey Data - Rathvilly -XS_Data_from_BKS_Rathvilly
- Tullow - Survey Data - Tullow - CCC
- Tullow - Survey Data - Tullow - From_BKS
- Tullow - Survey Data - Tullow - From_BKS - S photos190804
- Tullow - Survey Data - Tullow - From_BKS - XS Photos_041004
- Tullow - Survey Data - Tullow - LIDAR XS-LOB and ROB
- Tullow - Survey Data - Tullow - Tullow_Drawings
- Tullow - Survey Data - Tullow - Tullow_Photos - XS photos_040819
- Tullow - Survey Data - Tullow - Tullow_photos_041004
- Tullow - Survey Data - Tullow - XS - HECRAS
- Tullow - Survey Data - Tullow - XSandDetails_Data_Fron_BKS_Tullow
- Tullow EIS October 2008 Volume 1
- Tullow EIS October 2008 Volume 2
- Constraints study report Vol 1
- Constraints study report Vol 2
- Environmental Assessment of Options Vol1 – Main report
- Environmental Assessment of Options Vol2 – Appendices
- Environmental Assessment of Options Vol3 – Appendices
- Hydrology / Hydraulics Report for the Flood Feasibility study
- TULLOW FLOOD RELIEF SCHEME FEASIBILITY STUDY PRELIMINARY OPTIONS REPORT

Wexford County Council

- OPW_Enniscorthy_FloodReliefStudy_111205\Drawings
- OPW_Enniscorthy_FloodReliefStudy_111205\EIS Report
- OPW_Enniscorthy_FloodReliefStudy_111205\EIS Report\Interim Photomontages
- OPW_Enniscorthy_FloodReliefStudy_111205\Historic Flood Photographs
- OPW_Enniscorthy_FloodReliefStudy_111205\Reports\Final Report on Design (Rev. D)
- OPW_Enniscorthy_FloodReliefStudy_111205\Reports\Public Display - Preferred Option Report
- OPW_Enniscorthy_FloodReliefStudy_111205\Survey Data\combSectDS, combSectUS
- OPW_Enniscorthy_FloodReliefStudy_111205\Survey Data\flood plain sections DS , US
- OPW_Enniscorthy_FloodReliefStudy_111205\Survey Data\Property Survey Data

Wicklow County Council:

- OPW minor works allocation list 2011;
- OPW coastal and non-coastal approved projects list 2010;
- OPW list of funding allocations coastal and non-coastal 2009

All scheme and feasibility reports relevant to HA11, 12 or 13 received by RPS were reviewed to identify relevant information for the purposes of the South Eastern CFRAM Study. A summary of the various reports reviewed is provided in Table 2.1, which summarises; the area the report covers, the river associated with the report, the name of the report, who compiled the report, when it was produced and a brief summary of any recommendations contained within each report.

Table 2.1: Summary of reviewed reports

Flood Relief Study	River Name	Report Name	Author	Date	Recommendations
Courtown		No report			Information from the county manager indicating that the Courtown Flood Alleviation Scheme has been completed in the Water Services Flood Alleviation Programme 2009-2011.
Gorey		No report			Bridge improvements, channel cleaning and regrading. In the OPW 2010 minor works allocation.
Old Town Lane, Castlebridge		No report			Replacement of existing 600mm pipes with 1200mm pipes terminating in a pumping chamber under the roadway.
Enniscorthy	Slaney	Feasibility Report on the Enniscorthy Flooding Problem	OPW	December 2008 Doc No. 1427/RP/001/D	On both technical and economic grounds, Scheme D is the most viable alleviation scheme for Enniscorthy. While recognising many issues that will need addressing, the Environmental Impact Study sees that it can be built in an acceptable manner. The scheme can be constructed in three (or four) years (see Section 8.2). Scheme D is for Full Excavation Measures Combined with Defence Walls, Local Alleviation Measures and a Diversion.
Enniscorthy	Slaney	River Slaney (Enniscorthy) Drainage Scheme Environmental Impact Statement	Royal Haskoning	February 2009 Ref: 9M9540/R/EIS. Final/Exet	Report recommends Option D - Flood Walls, Local Alleviation Measures and Dredging.
Enniscorthy	Slaney	Additional information	Various		Additional information including drawings, historical flood photographs as well as survey data.
Tullow	Slaney	Tullow Pre-Feasibility Flood Relief Study - Final Report	OPW	Doc No:1426/RP/001 /C September 2003 Final	It appears that a flood relief scheme would be technically viable based on a combination of flood defence walls, localised works to remove / reduce restrictions to flow and channel / floodplain works downstream to reduce downstream water levels. It is concluded that a flood relief scheme for Tullow is potentially viable based on technical, environmental and economic criteria. A clear economic benefit has been demonstrated. 5 options noted however none mentioned as preferred as the report is only to test the potential economic viability of a scheme for Tullow.

Flood Relief Study	River Name	Report Name	Author	Date	Recommendations
Tullow	Slaney	Constraints Study Report. Proposed River Slaney Flood Relief Scheme	Malone O'Regan	August 2004	Constraints relating to Socio economic/human beings, infrastructure and utilities, landscape and visual, ecology and archaeology were all considered within the report. These sections identify a large number of constraints of varying significance within the study area and also with the river channel downstream of the study area. These will require further assessment in Stage II depending on the chosen option. Appendices contain reports undertaken by specialist consultants in each specific area.
Tullow	Slaney	Interim Report on Hydrology and Hydraulics	OPW	09 March 2005	This phase of the study shows that flooding in the town of Tullow occurs because floodwaters from the river, along the stretch from upstream of the weir to the islands downstream of the bridge, flood out over the riverbanks and follow separate flow paths through the town (i.e. through the Supermarket car-park on the left bank, and along Thomas Traynor Street on the right bank). For the 100-year flood, four hydraulic features have been identified as creating significant backwater effects up along this stretch of river. The Design Options that will be assessed should consider increasing the hydraulic efficiency of the river, primarily by addressing these four features, and thereafter by looking at possibly increasing conveyance downstream of the islands through bank works. If, once full channel optimisation has been achieved, it is found that flood defence structures are still required, these will then be addressed.
Tullow	Slaney	Preliminary Options Report on Tullow Flood Relief Scheme Feasibility Report	OPW	15 April 2005	Identifies three possible schemes, 4-a Do nothing, 4-b Flood defences (walls/embankments) and 4-c Flood level lowering through: Realignment of bend near Walseley Village, deepening of channel through town, lowering of Corcoran's Weir and re-grading of channel upstream of Corcoran's Weir, plus flood defences. Channel works alone cannot completely remove the need for walls or embankments in Tullow town. 4-b involves construction of walls and embankments and these are the sole means of protecting against the 100-year flood. Scheme 4-c however aims to reduce the height of such walls (which may have environmental or health and safety implications) by inclusion of a number of channel works. The 3 options are to be evaluated (a) on environmental grounds, through and "Environmental Assessment of Viable Options" and (b) on economic grounds, through a thorough Cost-Benefit Analysis (CBA). Based on these two evaluations, an optimum scheme, should one exist, will be

Flood Relief Study	River Name	Report Name	Author	Date	Recommendations
					recommended in the Preliminary Draft Final Report.
Tullow	Slaney	Environmental Assessment of Options. Proposed River Slaney Flood Relief Scheme	Malone O'Regan	24 June 2005	The purpose of this report is to objectively describe the actual and potential environmental impacts arising from implementation of any of the flood relief options and suggest mitigation measures as a means of reducing or offsetting and actual or potential negative impacts that may arise. Option 4b (Flood defences) has less impacts when compared to 4b alternative and 4c. Should this progress to EIS stage there would be further information required including: Option 4b - Photomontages depicting visual impacts. Option 4b alternative - Geophysical survey of the riverbed at Tullow Bridge and photomontages depicting visual impacts. Option 4c - In addition to the above, complete survey of Corcoran's Weir, Lands downstream of Town Bridge. Geophysical and diver based survey of the riverbed and riverbanks affected. Freshwater pearl mussel and lamprey survey of affected stretches of the river. Salmon survey. Photomontages depicting landscape and visual impacts at Mount Wolseley Village bend. Appendices contain reports from specialist consultants.
Tullow	Slaney	Tullow Flood Relief Scheme Feasibility Study, Draft Final Report	OPW	25 April 2006	The report shows that scheme B - flood defences (walls / embankments) is the preferred option to be implemented for Tullow.
Tullow	Slaney	EIS, Slaney Flood Relief Scheme, Tullow, Co. Carlow	Malone O'Regan	15 October 2008	The EIS provides information on Human Beings - Socio Economic, Human Beings - Recreation Amenity and Tourism, Material Assets - Land Use and Planning, Material Assets - Infrastructure and Utilities, Landscape and Visual, Aquatic Flora and Fauna, Terrestrial Flora and Fauna, Cultural Heritage, noise and Vibration, Air quality and climate, Water Quality, River Regime, Sediment, Soils and Geology. Mitigation measures are indicated for: Aquatic Flora and Fauna, Terrestrial Flora and Fauna, Cultural Heritage. Other minor recommendations are made referring to the construction of the scheme within the report.
Tullow	Slaney	Additional information			Information on survey data, drawings and historical flooding provided.

Flood Relief Study	River Name	Report Name	Author	Date	Recommendations
Baltinglass	Slaney				OPW approved minor flood mitigation works in 2011 for Baltinglass. Improvements include flap valves in the town centre and to provide an earth embankment/bund to provide barrier against flood waters.
Wexford Harbour		No report			OPW have approved funding of €90,000 for several critical sections of the existing erosion/flood defences around Wexford harbour to be strengthened and raised in order to avoid/mitigate future flooding.

2.3.2 Historical Flood Data

Information on historical flood events was sought from a variety of sources including OPW and Local Authority records, internet searches and other general enquiries. In total, 17 historical events were identified that had led to flooding within AFAs situated in Hydrometric Areas 11, 12 and 13 during the period 1924 to 2011 as detailed in Table 4.8. A summary of the information available for each of these events is presented in Section 4.3 and 4.4.

2.3.3 Baseline Mapping

RPS has obtained complete baseline mapping coverage of the entire South Eastern CFRAM study area. The mapping which has been supplied by OPW includes the following datasets:

- SERBD Digicity10000 Raster;
- SERBD Digitowns 10000 Raster;
- SERBD OS MAP 5000 Raster;
- SERBD OS MAP 5000 Vector;
- SERBD OS MAPS 1000 Vector;
- SERBD OS MAPS 1000 Raster;
- SERBD OS MAPS 50000 Raster;
- SERBD Six Inch Tiles;
- Orthophotography (Raster);
- SERBD OS Map 2500 Vector.

Due to the limited quality of the 5000 and 1000 raster mapping when printed at the scales required for this study, the equivalent vector mapping had to be processed using Feature Manipulation Engine Software to convert it from AutoCAD to ArcMap format. During the conversion process it was discovered that complete spatial coverage had not been included in the original OPW data supply. Consequently, additional 2500 vector mapping was requested. Again this information was also provided in AutoCAD format which had to be converted into ArcMap shapefile format for use within this study.

2.3.4 Hydrometric Data

Details of the hydrometric data available for Hydrometric Areas 11, 12 and 13, and the analysis of this data are presented in Section 4.1. In summary, 49 hydrometric stations (11 OPW and 38 other) were

identified as being, or having been, operational within Hydrometric Areas 11, 12 and 13. However, of these only 23 had data available for use and only nine are located along watercourses to be modelled as part of the South Eastern CFRAM Study and will consequently be used to inform the hydrological analysis and derivation of return period flows

2.3.5 Meteorological Data

Meteorological data provided by Met Éireann through OPW at the project outset was subject to a gap analysis and additional data was acquired directly by RPS as required. Requests were also issued to Local Authorities for any additional rainfall data they might possess over and above that available from the Met Éireann gauges. Further discussion of the actual rainfall data obtained is presented in Section 4.2.

2.3.6 Land Use Data

Following various data requests, land use data obtained includes CORINE land cover data, GSI data and development data. The development plan and GSI datasets received are outlined in Sections 2.3.7 and 2.3.9.

The CORINE datasets obtained are as follows:

- EPA_Corine_2000rev;
- EPA_CorineChangesOnly_2006;
- EPA_Corine_2006_complete.

Having viewed the European Environment Agency (EEA) website (<http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-clc2000-seamless-vector-database-3>) it was identified that the current European version is 'CORINE 15' which was updated in August 2011. A query was issued to EPA Ireland to ascertain if the updated European CORINE 15 dataset had any impact on the Irish CORINE dataset, to which they responded that they were not aware of any updates made to the Irish CORINE data and that the CORINE 2006 dataset supplied is the latest version of the dataset available for Ireland.

Carlow County Council also provided RPS with the Land use data listed below:-

- Aquifers.MAP
- Bedrock Geology.MAP
- Carlow_Soils.MAP
- Ground Water Vulnerability GSI.MAP
- Carlow_FIPS.MAP

2.3.7 Planning and Development Information

Accurate and current development zoning information is essential to the correct delineation of AFA extents and will also be important when considering options and developing future scenarios. At present we have the following development zoning datasets;

Carlow County Council

- Carlow LAP Landuse Zonings
- Carlow_FIPS.MAP
- LAP Boundaries.MAP
- LAP Landuse Zonings.MAP
- Parcels.MAP

The current Carlow County Council Development Plan covers the period 2009 to 2015 and so the above development zoning information will not be updated during the lifetime of the study.

Wexford County Council

- Bunclody_Zoning.MAP
- Clonroche_zoning.MAP
- Enniscorthy_Zoning.MAP
- Ferns_Zoning.MAP
- Gorey_Zoning.MAP
- Taghmon_zoning.MAP
- Wexford_Zoning.MAP
- Kilmore and Courtown.MAP
- Blackwater Zoning.MAP
- Rosslare Strand Zoning. Zip

The current Wexford County Council Development Plan covers the period 2007 to 2013 so the above development zoning information may be updated for the next County Development Plan for the period 2014 - 2020.

Wicklow County Council:

- CDP2010-2016 - Employment-Tourism-Health;
- Wicklow CoCo Land Zoning;
- Wicklow CoCo LAP-TP Boundaries.

The current Wicklow County Council Development Plan covers the period 2010 to 2016 and so the above development zoning information will not be updated during the lifetime of the study.

2.3.8 Environmental Data

RPS has identified a preliminary list of datasets and sources as indicated in Table 2.2 which are relevant to the Strategic Environmental Assessment and Appropriate Assessment. However this list is subject to revision pending the outcome of the scoping exercise which is ongoing.

Table 2.2: Preliminary List of Environmental Datasets

SEA Issue Area	Data	Availability
Biodiversity, Flora and Fauna	National Parks and Wildlife database (e.g. protected habitats and species including SAC/SPA/NHA).	www.npws.ie RPS has access
Biodiversity, Flora and Fauna	Relevant Freshwater Pearl Mussel Sub-basin management plans (if relevant).	www.npws.ie RPS has access
Biodiversity / Flora and Fauna	Invasive species, threatened species, protected species.	www.biodiversity.ie Free to download
Biodiversity / Flora and Fauna	Waterways Ireland ecological, invertebrate, kingfisher, Japanese Knotweed, otter and lamprey surveys	RPS has received relevant WWI data
Water/Biodiversity/Flora and Fauna	Inland Fisheries Ireland - South Eastern Area Species present, counts etc., Fisheries assessments if available.	www.fisheriesireland.ie On request
Water / Material Assets	Waterways Ireland databases;	www.waterwaysireland.ie Free to download but not as GIS
Cultural Heritage/ Biodiversity / Flora and Fauna	Cultural Heritage e.g. Brú na Bóinne UNESCO World Heritage Site Natural Heritage e.g. local biodiversity action plans	www.heritagecouncil.ie Free to download
Cultural Heritage	Record of Monuments and Places;	www.archaeology.ie RPS has access
Cultural Heritage	National Inventory of Architectural Heritage (NIAH)	www.buildingsofireland.ie Free to download
Cultural Heritage	Waterways Ireland heritage information (including Barrow Line and Barrow navigation)	RPS has received relevant WWI data
Material Assets	Coillte forestry database (FIPS)	www.coillte.ie Will request
Soils / Geology	Geological Survey of Ireland (GSI) mapping, including groundwater maps; groundwater vulnerability, protection schemes; soils classification.	www.gsi.ie RPS has access
Soils	Teagasc soil information;	www.teagasc.ie RPS has access
Material Assets / Land Use	Corine and Landcover Land Use Databases;	RPS has access
Water	Information gathered during the implementation of the Water Framework Directive;	RPS has access

SEA Issue Area	Data	Availability
Population	Central Statistics Office database, including census data. Prelim 2011 data available but full dataset expected in March 2012	www.cso.ie RPS has access to 2006. Will request 2011 when it becomes available.
Material Assets / Landuse	Department of Agriculture, Food and the Marine databases e.g. fertilizer usage.	Will request.
All aspects	Relevant County Development Plans Detailed flora and fauna field surveys, habitat mapping, water quality measurements, tree protection orders, landscape character areas, seascapes, protected views, areas of high amenity, development plan boundaries and zonings digitally;	Will be requested from environmental, heritage officers during scoping consultation
All aspects	Other Local Authority datasets;	Will be requested from environmental, heritage officers during scoping consultation
All aspects	Regional Authority datasets;	Will be requested during scoping consultation
All environmental aspects	EPA databases (e.g. groundwater and surface water quality, air quality, etc.); EPA 2008 State of Environment Report and updated report, if available; and EPA ENVision (Environmental Mapping / Geographical Information System).	www.epa.ie Free to download
All environmental aspects	EPA Additional datasets e.g. contaminated land, brownfield sites etc	www.epa.ie Not available for download but will request.
General / mapping	3 Rivers Data: DTM, historical mapping etc.	RPS has access
General / mapping	Aerial photography OSI vector mapping	RPS has access

It is also important to note that many of the environmental dataset are not static over time and thus early acquisition of all data is not necessarily desirable, rather such data is much better requested only when it is required. Consequently, RPS will maintain contact with the relevant data owners as the project develops to ensure that data requests are appropriately timed to ensure that the most up to date information is used to inform the study.

2.3.9 Soil and Geological Data

Following requests to GSI for soil and sub-soil information to inform the selection of appropriate parameters for the MIKE-NAM modelling activities, RPS have obtained the following datasets:

- Bedrock and SG Aquifers Union;

- Soils – Wet and Dry;
- Sub soil Permeability;
- Vulnerability.

Initial review of this data indicates that it will be sufficient for the intended purpose. However this data will be reviewed in detail in the hydrology report

2.3.10 Defence and Coastal Protection Asset Data

Requests to Local Authorities and OPW for details of any information held on existing flood defence and coastal protection assets has provided limited information for assets within Hydrometric Areas 11, 12 and 13. The limited information obtained to date will be supplemented as further assets are identified and relevant geometric data collected through subsequent survey contracts. Information on the current condition of all assets will be obtained during the follow up asset condition survey.

2.4 DATA OUTSTANDING

RPS has made one final request for missing information / data from each of the Local Authorities. The requests were made at the beginning of December 2011 via email and each Local Authority was forwarded a tailored document outlining study data requirements and also the information / data that has been received to date from them or from OPW which covers their administrative areas. Within the document under each of the requirement headings, Local Authorities have been requested to either provide any additional information they feel appropriate for the South Eastern CFRAM Study or confirm that they have no further information. Also detailed in this document is information that has previously been requested but not yet provided. The cut-off point for data collection activities was February 2012, i.e. the date of preparation of the first draft of this report. A breakdown of requirements where information has not been received from each local authority is detailed below:

Carlow County Council

- Flood Relief/Risk Management Measures;
- Hydrometric Data;
- Meteorological Data;
- Defence and Coastal Protection Asset Data;
- Existing Survey / Geotechnical Data
- Environmental
- Other Receptor Data
- Aerial Photography of flooding

Wexford County Council

- Hydrometric Data;
- Defence and Coastal Protection Asset Data;
- Existing Survey / Geotechnical Data
- Environmental Data
- Aerial Photography of flooding

Wicklow County Council

- Hydrometric Data;
- Meteorological Data
- Existing Survey / Geotechnical Data;
- Other Receptor Data;
- Aerial Photography of flooding.

2.5 DATA GAPS

At present RPS has not confirmed any significant data gaps that will impact on the completion of the South Eastern CFRAM Study however this statement is made without having received any survey information or having fully established how much of the remaining data requested from the Local Authorities, outlined in the preceding section, is not available. RPS expect that as the final scope of the study is refined as the study progresses through the next phases additional data needs will be identified, which will be addressed in so far as is possible through on-going data collection exercises in a similar manner to the initial data collection phase reported here. Thus it is not possible at this point in time to categorically state that there are no data gaps which will impact in some way on the completion of the South Eastern CFRAM Study.

RPS has been implementing data quality and validity checks on information that has been obtained throughout the data collection process. The findings of these checks have been briefly detailed in Table 2.3 below.

Table 2.3: Summary of Data Quality and Validity Checks

Section Reference	Section Heading	Comment
2.3.1	Flood Relief / Risk Management Measures	Historical Flood data has been reviewed by a member of RPS staff to ascertain its fitness for purpose. The outcome of the review has been detailed in Section 2.3.1 of this report.

Section Reference	Section Heading	Comment
2.3.2	Historical Flood Data	Historical Flood data has been reviewed by a member of RPS staff to ascertain its fitness for purpose. The outcome of the review has been detailed in Section 2.3.2 of this report.
2.3.3	Baseline Mapping	Originally only Raster mapping was provided which was not fit for purpose as it was not of sufficient clarity for the production of detailed maps, therefore Vector mapping was requested and received which is adequate for printing detailed maps. Also complete coverage of HA11, 12 and 13 was not supplied initially however full coverage has now been obtained following further data requests as described in Section 2.3.3.
2.3.4	Hydrometric Data	Hydrometric Data has been reviewed by a member of RPS staff to ascertain its fitness for purpose. The outcome of the review has been detailed in Section 4. Preliminary Hydrological Assessment and Method Statement of this report.
2.3.5	Meteorological Data	Meteorological Data has been reviewed by a member of RPS staff to ascertain its fitness for purpose. The outcome of the review has been detailed in Section 5. Detailed Methodology Review of this report.
2.3.6	Land Use Data	RPS originally received old versions of Land Use datasets which were not fit for purpose. RPS therefore requested and obtained the most recent version of the Land Use datasets as outlined in section 2.3.6 of this report.
2.3.7	Planning and Development Information	Some of the Planning and Development datasets received were not the latest revision of the County's Development Plans and therefore a request was made to obtain their most recent datasets, which depict the zoning areas required by RPS. This is further detailed in 2.3.7
2.3.8	Environmental Data	This information has not been fully assessed for fitness for purpose, as the information is not required at this early stage of the project.
2.3.9	Soil and Geological Data	Initial review of this data indicates that it will be sufficient for the intended purpose.

Section Reference	Section Heading	Comment
2.3.10	Defence and Coastal Protection Asset Data	RPS have obtained a very limited amount of information on Defence data, however further analysis of defence information shall be undertaken during the asset condition surveys. Further information on Defence Surveys is outlined in Section 3.2 Flood Defence Assets.

2.6 CONCLUSION

In conclusion RPS has made every attempt to identify and obtain data that is valid and of good quality for use within the South Eastern CFRAM Study. Requests have been issued and tracked in order to try and obtain as much relevant information as possible. The complete process of requesting and obtaining information has been recorded and logged within the various Request and Incoming Data registers. Reports and Spatial data have been reviewed to ensure they relate to the South Eastern CFRAM study area and that they provide beneficial information for the project. During this process RPS identified a few datasets which were not fit for purpose for the project as they were out of date consequently RPS sourced and acquired the most up-to-date versions of such datasets.

RPS has received a limited amount of information in relation to defence assets from the Local Authorities, however this should not have a significant impact on the South Eastern CFRAM study as this information shall be collected and recorded during subsequent planned onsite surveys.

3 SURVEYS

3.1 CHANNEL AND CROSS-SECTION SURVEYS

On behalf of OPW, JBA Consulting has prepared documentation to procure a survey contract for HA12. This pre-contract survey contract (known nationally as SC4) encompasses the full channel cross-sections, details of hydraulic structures and geometric survey of defences for HA12, 14 and 15. The contract was advertised through e-tenders and OJEU on 4 November 2011 with tenders returned in December. JBA completed tender evaluation and a preferred bidder was identified. The OPW issued a letter of intent on 15 February 2012 with surveys expected to start on site in April/May 2012.

Following completion of the Flood Risk Review and subsequent delineation of all watercourses within AFAs to optimise the quantity of rivers to be surveyed, RPS proposed a substantial reduction in the length of the rivers specified in SC4. Further to this, RPS identified that the quantity of cross sections removed from SC4 was equivalent to that proposed for the survey contract covering HAs 11, 13 & 17. RPS therefore proposed to OPW that these two contracts could be merged, thus offering a time and cost saving and additionally providing CCS with a contract of the magnitude of which they originally tendered. This proposal was accepted by OPW and subsequently CCS were awarded a contract covering the whole of the South Eastern CFRAM Study area.

3.2 FLOOD DEFENCE ASSETS

The identification of flood defence assets is a requirement of both the HA12 pre-contract survey contract and the RPS contract for HA11 and HA13 and thus at present RPS have not established a definitive list of flood defence assets. However the locations of the flood defence assets identified by JBA Consulting during survey scoping site visits and advised by the OPW in the tender documentation are indicated in Figure 3.1 and listed in Table 3.1. In addition to the defence structures indicated in Figure 3.1 RPS is aware of the existence of a significant additional length of embankments at the South Slobs for which geometric and condition information will be required.

Table 3.1: Flood Defence Assets Identified in HA11, HA12 and HA13 Survey Spec.

Name	River Reach	Flood Defence Type	Total Length (m)
South Slobs	Wexford	Embankment	790
North Slobs	Wexford	Embankment	4100
Kilmannock	Campile River Inlet	Embankment	2150
Kilmore	Ballyteigue_Kilmore Inlet Trib	Embankment	17,317
Baltinglass	Slaney River	Wall	110
Bunclody	Clody River	Wall	240
Crossfarnoge or Forlorn Point	Ballyteigue_Kilmore Harbour	Sea Wall	190
Crossfarnoge or Forlorn Point	Ballyteigue_Kilmore Harbour	Sea Wall	70

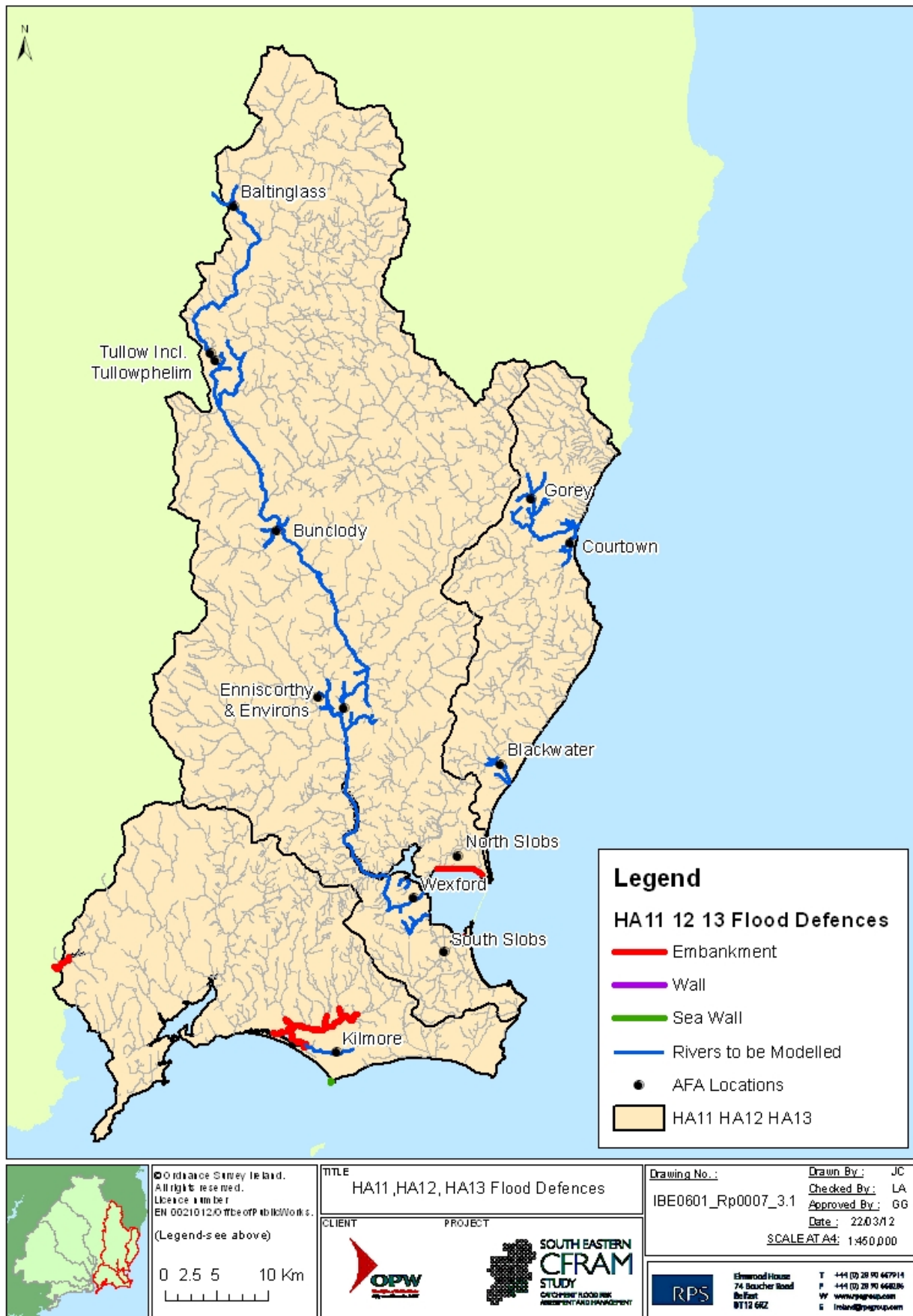


Figure 3.1: Locations of Identified Flood Defence Assets in HA11, HA12 and HA13

3.3 FLOODPLAIN SURVEY

The tender documents indicated that OPW would supply the results of a flood plain survey based on LiDAR techniques by December 2011. RPS has provided input in to the required coverage of this survey based on our initial assessment of AFA locations and extents however delivery of this information has been delayed and therefore it is not possible to make any comment on the adequacy of the information received for use in later stages of the South Eastern CFRAM Study.

3.4 PROPERTY SURVEY

The Generic CFRAM Study Brief requires property surveys to be undertaken to confirm, locations, type, use, floor area etc of properties identified as potentially being at risk consequently we will not be undertaking this work until draft flood hazard maps are available.

4 PRELIMINARY HYDROLOGICAL ASSESSMENT AND METHOD STATEMENT

4.1 HYDROMETRIC DATA

4.1.1 Hydrometric data – HA11, 12 and 13

The OPW provided RPS with hydrometric station data from the OPW Hydrometric Section database. This consisted of all available data for all OPW stations within the South Eastern RBD including Annual Maximum (AMAX) Series data for those stations included in the OPW's Flood Studies Update (FSU). The OPW operate 11 river hydrometric stations within HA11, 12 and 13. One station is inactive and has no data available. Therefore ten OPW hydrometric stations are available for use within the study. These are listed in Table 4.1.

Table 4.1: OPW Hydrometric Stations with available data within HA 11, 12 and 13

Station Number	Station Name	River/Lake	Records Length
11001	Boleany	Owenavorrigh	Mar 1972 - Mar 2011
12001	Scarawalsh	Slaney	Sept 1955 - Mar 2011
12005	Tulow Town Br. U/S	Slaney	Oct 2002 - Mar 2011
12006	Tulowbeg	Slaney	Mar 2005 - Jan 2011
12007	St. John's Br.	Urrin	Apr 2003 - Feb 2010
12008	Rafter Br. D/S	Slaney	Feb 2003 - Jan 2009
12009	Rafter Br. U/S	Slaney	Feb 2003 - Dec 2010
13070	Lady's Island	Lady's Island Lake	Nov 1998 - Dec 2010
13071	Tacumshin Lake	Lake Tacumshin	Nov 1998 - Mar 2011
13081	Cull Bank	Ballyteige Lagoon	Sept 2007 - Dec 2010

An additional 38 hydrometric stations are located within HA 11, 12 and 13 that are owned by Local Authorities (operated by EPA). Hydrometric data is only available for 13 of these and has been acquired by RPS. These are listed in Table 4.2. The data provided consisted of flow and level data and rating curves where available.

Table 4.2: Local Authority (EPA) Hydrometric Stations with Available Data in HA11, 12 and 13

Station Number	Station Name	River/Lake	Data Available	Records Length
12013	Rathvilly	Slaney	Water Level and Flow	Dec 1975 - May 2011
12014	Pallis Br.	Bann	Water Level and Flow	Dec 1975 - Jul 2000
12015	Ferns	Bann	Water Level and Flow	Oct 1977 - Jun 2007
12016	Dunanore	Boro	Water Level and Flow	Jun 1978 - Jun 2011
12030	Knicken Ford	Knicken	Water Level and Flow	Sept 1988 - Sept 1998
12036	Managan	Urrin	Water Level Only	Nov 2006 – May 2011
12037	Castleruddery	Slaney	Water Level and Flow	Sept 1995 - Aug 2011
12038	Woodlands	Sow	Water Level Only	Aug 2009 - Jun 2011
12039	Pallis New	Bann	Water Level Only	Nov 2006 - Apr 2011
12040	Finoge Br.	Unnamed Watercourse	Water Level Only	Aug 2007 - May 2011
13001	Goff's Br.	Mulmontry	Water Level and Flow	Jun 1976 - Aug 2011
13002	Foulk's Mill	Corock	Water Level and Flow	Jan 1977 - Feb 2010
13003	Mullinderry	Owenduff	Water Level and Flow	Jun 1976 - May 2011

The remaining 25 Local Authority (EPA) hydrometric stations have no continuous monitoring data available. 24 of these stations are staff gauge only, and therefore only spot measurements were taken at these sites in the past and usually for one-off projects related to control of water pollution.

Therefore in total, 23 hydrometric stations (10 OPW / 13 Local Authority (EPA)) located in HA11, 12 and 13 have data available for use within this Study.

Each of the 23 stations with data available has a monitoring station fitted with a staff gauge and an automatic water level recorder. The automatic water level recorder can either be an autographic recorder or a digital datalogger. An autographic recorder is a simple float operated device that records water level on to a paper chart. These charts are then digitised to convert the data to a digital format. In recent years data loggers have replaced the recorder technology and are now installed at almost all stations where continuous water levels are recorded. The digital data from these loggers can be entered directly into a computer, overcoming the need to digitise water level records. The production of continuous flow data for a gauging station is derived from the water level data and it requires: continuous recording of water levels and; development of a station calibration. The station calibration is developed by plotting the results of flow measurements (spot gaugings) which have been carried out at various water levels and developing a stage-discharge relationship (also known as a rating curve) between water level and river flow. 11 of the 23 hydrometric gauges have flow data available that has

been derived from continuous water level data using this methodology. The other 12 hydrometric sites have only water level data available.

As part of the FSU, selected hydrometric stations throughout the country were reviewed and analysed to generate a database of hydrometric data (using data up to 2004). Where applicable, OPW have provided a summary of this FSU generated station data, which includes any changes in rating classification, Highest Gauged Flow (HGF), Q_{med} and MAF (Mean Annual Flow) estimates and the period of AMAX record analysed under FSU (including AMAX 2009). An FSU generated rating classification was also assigned to these stations. Of the 23 stations listed in Table 4.1 and 4.2, five were included in the FSU review and had a classification assigned as shown in Table 4.3. A definition of the rating quality classification is provided below the table.

Table 4.3: Final Station Rating Quality Classification

Station Number	Station Name	Final Station Rating Quality Classification
11001	BOLEANY	B
12001	SCARAWALSH	A2
12014	PALLIS BR.	C
12016	DUNANORE	C
13002	FOULK'S MILL	B

A1 sites – Confirmed ratings good for flood flows well above Q_{med} with the highest gauged flow greater than $1.3 \times Q_{med}$ and/or with a good confidence of extrapolation up to 2 times Q_{med} , bankfull or, using suitable survey data, including flows across the flood plain.

A2 sites – ratings confirmed to measure Q_{med} and up to around 1.3 times the flow above Q_{med} . Would have at least one gauging to confirm and have a good confidence in the extrapolation.

B sites – Flows can be determined up to Q_{med} with confidence. Some high flow gaugings must be around the Q_{med} value. Suitable for flows up to Q_{med} . These were sites where the flows and the rating was well defined up to Q_{med} i.e. the highest gauged flow was at least equal to or very close to Q_{med} , say at least $0.95 Q_{med}$ and no significant change in channel geometry was known to occur at or about the corresponding stage.

C sites – possible for extrapolation up to Q_{med} . These are sites where there was a well defined rating up to say at least $0.8 \times Q_{med}$. Not useable for the FSU

Figure 4.1 shows all 49 hydrometric stations within HA 11, 12 and 13. The 23 for which data is available are coloured green (water level and flow data), yellow (water level data only). Those which have additional data from the FSU work, including AMAX series are also highlighted. All 23 stations with data available will be used in the hydrological analysis as appropriate:

- Stations along modelled watercourses with water level and flow data, gaugings and ratings will be used for hydrological and hydraulic model calibration, historical flood analysis and growth curve derivation.
- Stations along modelled watercourses with water level data only are also useful in calibration exercises. Recorded water levels are useful in comparing hydraulic model outputs with observed flood events. AMAX series of water levels and derived AEPs can also be useful in hydraulic model calibration of water levels for various design return periods.
- Stations with water level and flow data within the wider HA 11, 12 and 13 areas are used in historical flood analysis and growth curve derivation.
- Stations which have already been included in the FSU are of benefit to the Study since AMAX series of flows have previously been derived, and quality ratings have been assigned. A range of hydrometric data analyses would have been undertaken at these stations (up until 2004). These stations will also be used in the Study with care taken to ensure all available data, including post 2004 is used.

In addition to the 23 stations within HA's 11, 12 and 13, additional stations outside of the area will be used where appropriate to supplement the data from within the catchment. Stations from outside the catchment will be used for the following purposes:

- Stations within the Eastern and South-Eastern CFRAM Study areas with a sufficient quality of data will be used to form a study specific pooling group from which additional gauge years will be used to provide a sufficient amount of gauge years for pooled flood frequency analysis and growth curve development.
- Where small to medium sized catchments (<100km²) are ungauged Pivotal Sites from outside HA's 11, 12 and 13 may be used to transfer data in order to modify regression equation estimates of the index flood (Q_{med}) where the Pivotal Site is found to be sufficiently hydrologically similar as per FSU Work Package 2.3.
- Gauge review data share with Suir CFRAM Study.

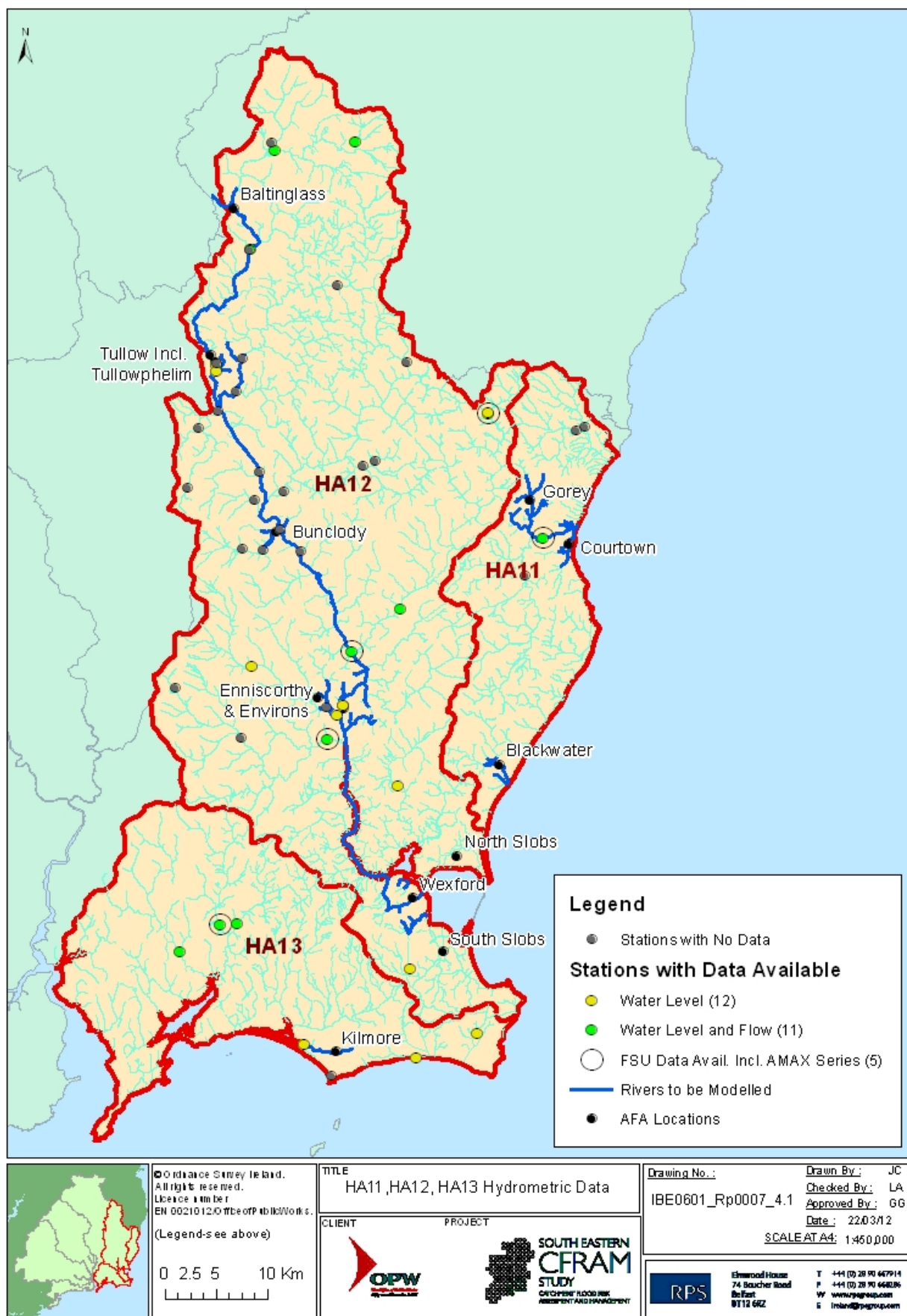


Figure 4.1: Hydrometric Stations in HA 11, 12 and 13

4.1.1.1 Hydrometric Stations along modelled watercourses

There are nine hydrometric stations along the rivers to be modelled as Medium or High Priority Watercourses (MPW or HPW). These are shown on Figure 4.2. Three of these stations have water level and flow data, whilst six have level data only. Two of these stations were included in the FSU which is also indicated on Figure 4.2.

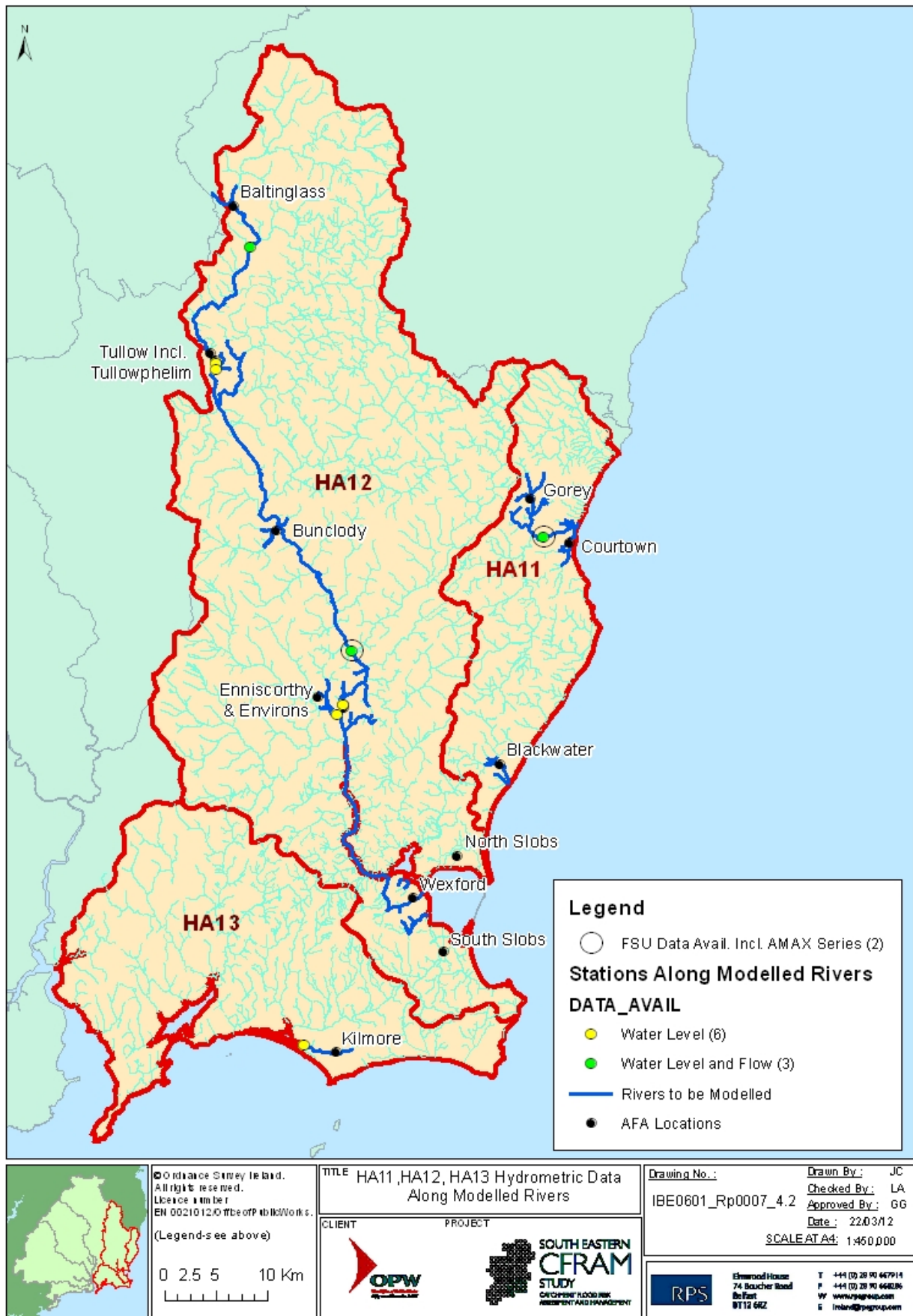


Figure 4.2: Hydrometric Stations along Modelled Watercourses (HPW / MPW)

4.1.1.2 Rating Reviews – South Eastern CFRAM Study

As a follow on from the recommendations of Work Package 2.1 of the FSU (Reference 5), a task was included in the South Eastern CFRAM Study brief to undertake further rating review of a subset of hydrometric stations. This entails using hydraulic modelling techniques to extrapolate rating curves where high flow gaugings are lacking to construct a theoretical rating curve that provides a relationship between stage and discharge for flood flows. Three hydrometric stations have been specified for this analysis within HA 11, 12 and 13 and are shown in Figure 4.3. The current rating quality classification assigned under the FSU for each station (if available) is stated in

Table 4.4.

Table 4.4: Existing Rating Quality Classification for Rating Review Stations in HA 11, 12 and 13

Station Number	Station Name	Final Station Rating Quality Classification
11001	BOLEANY	A1
12001	SCARAWALSH	A2
12015	FERNS	NOT REVIEWED UNDER FSU

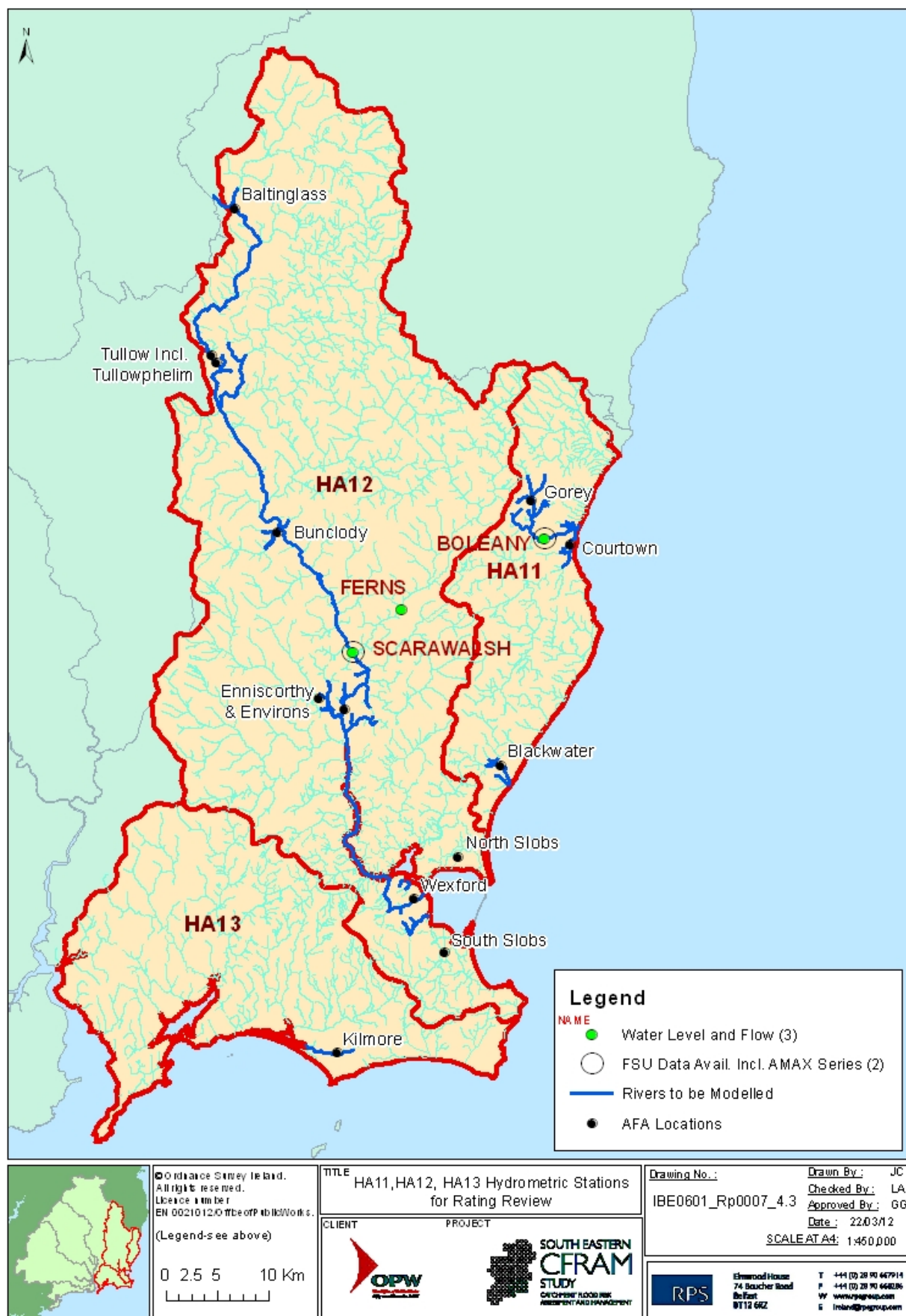


Figure 4.3: Hydrometric Stations used for rating review in HA11, 12 and 13

Summary of Hydrometric Data

Table 4.5 summaries the number of hydrometric stations with data available within HA11, 12 and 13 overall, and those located on modelled watercourses only. Three of these stations require CFRAM Study rating review, all of which have water level and flow data available.

Table 4.5: Number Summary – HA 11, 12 and 13 Stations with Data Available

Data Available	HA11, 12 and 13	HPW/MPWs	CFRAM Rating Review
Water Level and Flow	11	3	3
Water Level Only	12	6	0
Total	23	9	3

Table 4.6 provides a more detailed summary of the type of data for each of the 23 usable Hydrometric Stations within HA 11, 12 and 13 that has been collected for the South Eastern CFRAM Study. The nine stations that are located on the watercourses to be modelled are highlighted in blue.

Hydrometric Station Data Status Tables for HA 11, 12 and 13 are provided in Appendix A.

Table 4.6: Summary of Hydrometric Data Provision within HA 11, 12 and 13

NUMBER	NAME	BODY RESPONSIBLE	STATUS	DATA AVAILABLE	Record Length (dates)	Rating Info Provided	Gaugings Provided	AMAX Series Provided	FSU Generated Data Provided	Located on HPW/MP W	CFRAM RATING REVIEW
11001	Boleany	Office of Public Works	Active	Water Level and Flow	Mar 1972 - Mar 2011	N	Y	Y	Y	Y	Y
12001	Scarawalsh	Office of Public Works	Active	Water Level and Flow	Sept 1955 - Mar 2011	N	Y	Y	Y	Y	Y
12005	Tullow Town Br. U/S	Office of Public Works	Active	Water Level Only	Oct 2002 - Mar 2011	N	Y	N	N	Y	N
12006	Tullowbeg	Office of Public Works	Active	Water Level Only	Mar 2005 - Jan 2011	N	N	N	N	Y	N
12007	St. John's Br.	Office of Public Works	Active	Water Level Only	Apr 2003 - Feb 2010	N	N	N	N	Y	N
12008	Rafter Br. D/S	Office of Public Works	Active	Water Level Only	Feb 2003 - Jan 2009	N	N	N	N	Y	N
12009	Rafter Br. U/S	Office of Public Works	Active	Water Level Only	Feb 2003 - Dec 2010	N	N	N	N	Y	N
12013	Rathvilly	Carlow County Council	Active	Water Level and Flow	Dec 1975 - May 2011	Y	Y	Y	Y	Y	N
12014	Pallis Br.	Wexford County Council	Inactive	Water Level and Flow	Dec 1975 - Jul 2000	Y	N	Y	Y	N	N
12015	Ferns	Wexford County Council	Active	Water Level and Flow	Oct 1977 - Jun 2007	Y	N	N	N	N	Y
12016	Dunanore	Wexford County Council	Active	Water Level and Flow	Jun 1978 - Jun 2011	N	N	Y	Y	N	N

NUMBER	NAME	BODY RESPONSIBLE	STATUS	DATA AVAILABLE	Record Length (dates)	Rating Info Provided	Gaugings Provided	AMAX Series Provided	FSU Generated Data Provided	Located on HPW/MP W	CFRAM RATING REVIEW
12030	Knickeen Ford	Wicklow County Council	Inactive	Water Level and Flow	Sept 1988 - Sept 1998	Y	Y	N	N	N	N
12036	Managan	Wexford County Council	Active	Water Level Only	Nov 2006 – May 2011	N	N	N	N	N	N
12037	Castleruddery	Wicklow County Council	Inactive	Water Level and Flow	Sept 1995 - Aug 2011	Y	Y	N	N	N	N
12038	Woodlands	Wexford County Council	Active	Water Level Only	Aug 2009 - Jun 2011	N	N	N	N	N	N
12039	Pallis New	Wexford County Council	Active	Water Level Only	Nov 2006 - Apr 2011	N	N	N	N	N	N
12040	Finoge Br.	Wexford County Council	Active	Water Level Only	Aug 2007 - May 2011	N	N	N	N	N	N
13001	Goff's Br.	Wexford County Council	Active	Water Level and Flow	Jun 1976 - Aug 2011	Y	Y	N	N	N	N
13002	Foulk's Mill	Wexford County Council	Active	Water Level and Flow	Jan 1977 - Feb 2010	Y	N	Y	Y	N	N
13003	Mullinderry	Wexford County Council	Active	Water Level and Flow	Jun 1976 - May 2011	Y	N	N	N	N	N
13070	Lady's Island	Office of Public Works	Active	Water Level Only	Nov 1998 - Dec 2010	N	N	N	N	N	N
13071	Tacumshin Lake	Office of Public Works	Active	Water Level Only	Nov 1998 - Mar 2011	N	N	N	N	N	N

NUMBER	NAME	BODY RESPONSIBLE	STATUS	DATA AVAILABLE	Record Length (dates)	Rating Info Provided	Gaugings Provided	AMAX Series Provided	FSU Generated Data Provided	Located on HPW/MP W	CFRAM RATING REVIEW
13081	Cull Bank	Office of Public Works	Active	Water Level Only	Sept 2007 - Dec 2010	N	N	Y (No flow data)	Y	Y	N

4.2 METEOROLOGICAL DATA

Meteorological data was provided by Met Éireann through the OPW at the project outset. A gap analysis was undertaken and additional data acquired from Met Éireann directly by RPS. Additional rainfall data was also requested from Local Authorities if available. Further development of the hydrological analysis method required rainfall radar data at Dublin Airport (refer to Section 5.1.3 for detail). Radar data was requested and received from Met Éireann.

4.2.1 Daily Rainfall Data

Daily rainfall data was received from Met Éireann for a total 837 rainfall gauges both within and beyond the South Eastern CFRAM Study Area. Additional information was also provided by Wexford County Council for one further station (Mayglass) giving a total of 838 daily rainfall gauges that are available for the Study. Table 4.7 summarises the number of available daily rainfall stations for the Study.

Table 4.7: Number of Available Daily Rainfall Stations

Station Location	Provided By:		Total
	Met Éireann	Local Authorities	
Within South Eastern CFRAM Study Area Only	323	1	324
Within South Eastern CFRAM Buffer Area Only	514	0	514
Within South Eastern CFRAM Study Area plus Buffer	837	1	838

324 of the daily rainfall stations are located within the South Eastern CFRAM Study Area. An additional 514 are located beyond the Study area boundary as shown in Table 4.7 and Figure 4.4. These additional stations have been included to provide a wide enough rainfall station network for determining the rainfall event input at Hydrological Estimation Points (refer to Section 5.3).

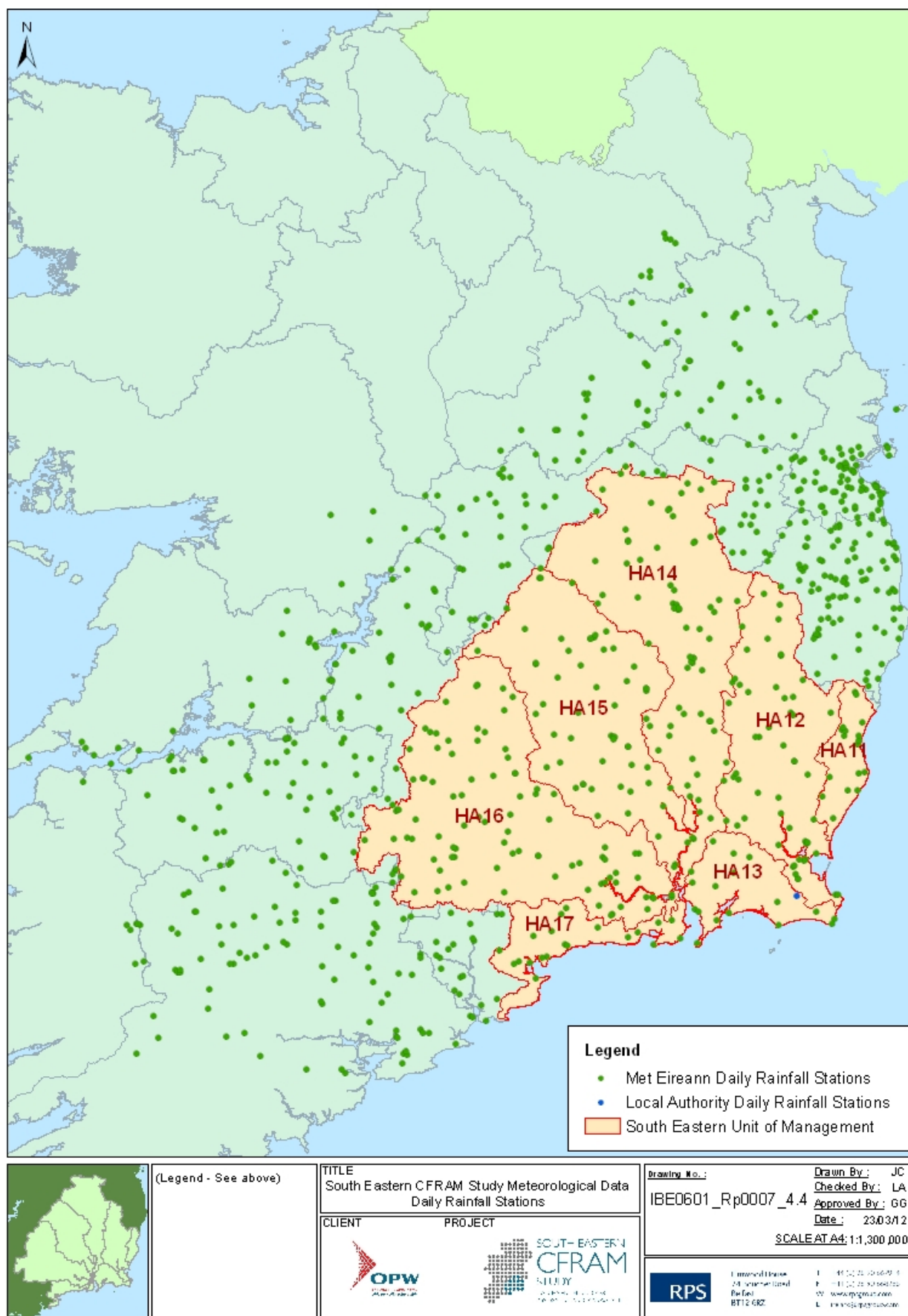


Figure 4.4: Location of Daily Rainfall Gauges

Within HA 11, 12 and 13 there are 88 Met Éireann daily rainfall gauges and 1 Local Authority gauge. A 20 – 30km buffer will also be applied to this area and the surrounding rainfall gauges within the buffer zone will be included in rainfall spatial analysis. This will be decided on a case by case basis depending on the spatial analysis requirements towards the boundary of the Study area.

A data status table has been compiled for all daily rainfall stations as shown in Appendix B. This table shows the time line over which daily rainfall data is provided for each station.

4.2.2 Hourly Rainfall Data

Data for hourly rainfall stations was also provided by Met Éireann. A total of 15 hourly rainfall gauges were provided. Their location is shown in Figure 4.5. Johnstown Castle and Rosslare are located within HA12. Information on the length of the records for each hourly rainfall gauge is provided in Appendix B.



Figure 4.5: Hourly Rainfall Gauges

4.2.3 Rainfall Radar Data

A data collection meeting held at the beginning of the Eastern CFRAM Study (between RPS, HydroLogic, OPW and Met Éireann) identified an opportunity for exploring the use and benefits of rainfall radar data in hydrological analysis. Pending the outcome of trials within the Eastern CFRAM Study area this analysis approach may be rolled out to the South Eastern CFRAM Study area in which case additional rainfall radar data will be requested including:

- Hourly precipitation accumulation (PAC) data of the Dublin and Shannon radar on a 1 x 1 km grid (from 1997)
- 15 minute Pseudo-CAPPI (PCR) data of the Dublin and Shannon radar (from 1997)
- Plan Position Indicator (PPI) data of the Dublin and Shannon radar (from 1997)

If following the trials on the use of the rainfall radar data it is decided not to use it then hydrological input data for rainfall run-off modelling will be taken from the rainfall gauge stations only.

4.3 HISTORICAL FLOOD EVENTS – SOURCES OF INFORMATION

The following sources of information were consulted as part of the historical flood data assessment: -

Office of Public Works (OPW) National Flood Hazard Mapping

The OPW National Flood Hazard Mapping website <http://www.floodmaps.ie> contains information on flood events that occurred within Units of Management HA11, 12 and 13. The information available includes Local Authority flood records, OPW Flood Event Reports, press articles and consultants flood study reports.

The information can be searched for and downloaded in a number of ways (e.g. by location, by date, by catchment name and river name). To ensure all available information was downloaded for review, the website was searched firstly by catchment name, and each catchment was in turn searched according to river name. In the case of HA11, there are three catchments – the Clonough, Owenavorrhagh and Coastal (Kilmuckridge) catchment. In total, there are nine rivers in these three catchments. A search was carried out for each river or stream within each catchment in HA11. Similarly for HA12, there are seven catchments – the Coastal (Carnsore Point), Coastal (Kilmuckridge), Coastal (Wexford), Corock, Slaney, Sow and Stream (Duncormick) catchment. These seven catchments include a total of 37 rivers/streams, each of which were searched for flood events. The same approach was applied to HA13 where there are seven catchments – the Coastal (Ballymadder Point), Coastal (Carnsore Point), Coastal (Hook Head), Coastal (Wexford), Corock, Owenduff and Stream (Duncormick) Catchment. These seven catchments include a total of 11 rivers/streams.

Internet Search Engines

In some instances, it was considered it may be useful to supplement the information gathered from the OPW National Flood Hazard Mapping website. This was especially the case for more recent flood events such as the November 2009 event. There were some reports available for these events on the OPW website (primarily from Local Authorities); however there was a lack of press reports when compared to floods which had occurred pre-2005.

A wider search for information on the more recent flood events was carried out for each AFA in HA11, 12 and 13 using internet search engines. While a number of results were yielded, these were generally news reports, photos or press articles which contained details of affected areas and damage done, but contained no details on flows, flood extents, estimated annual exceedance probabilities (AEPs), etc.

4.3.1 Hydrometric Data

In conjunction with the researched historical data as described above, hydrometric data from the OPW Hydro-Data website (<http://www.opw.ie/hydro>) was consulted, where available. This website includes data such as recorded water levels and corresponding flow rates, quoted in some cases as mean daily flows. The data was used to verify and supplement the historical data, such as dates of floods, river levels and flows.

In the case of HA13, there are no hydrometric stations located in/near the Kilmore AFA (the only AFA in HA13). For AFAs within HA12 reference was made to the active hydrometric stations for the River Slaney at Enniscorthy and Rathvilly, while within HA11, the active hydrometric station on the Owenavorrhagh River at Boleany was referenced.

4.3.2 Historical Flood Events

4.3.2.1 Summary of Historical Flood Events

Based on a review of the information outlined above, the historical flood events which occurred in the various AFAs in HA11, 12 and 13 are summarised in Table 4.8 below:

Table 4.8: Summary of Historical Flood Events for each AFA

Event	HA11			HA12						HA13
	Courtown	Gorey	Blackwater	Baltinglass	Buncloody	Enniscorthy and Environs	Tullow (incl Tullowphelim)	Wexford	South Slob	
Recurring/Undated									✓	No results found
Oct-11				✓						
Nov-09		✓				✓		✓		
Aug-08		✓								
Oct-04						✓	✓	✓		
Nov-02		✓	✓			✓	✓			
Dec-01								✓		
Nov-00		✓		✓	✓	✓	✓	✓	✓	
Sep-99							✓			
Aug-97			✓			✓		✓	✓	
Jun-96							✓			
Jan-96								✓	✓	
Aug-86	✓	✓				✓				
Dec-78					✓	✓				
Nov-65	✓	✓		✓	✓	✓	✓			
Nov-54						✓				
Mar-47						✓				
Nov-24						✓				

These flood events are discussed in the following sections, with additional details summarised in Table 4.10, such as dates, flows, estimated annual exceedance probability (AEP) and flood mechanisms.

It should be noted that the review of historical data failed to yield any information on a flood event for the North Slob AFA. Flood events which occurred in the surrounding areas were analysed; however, no details were found relating to the North Slob AFA or immediately surrounding areas.

Furthermore, the review indicated that regular flooding occurs in the South Slob AFA due to high tides and insufficient surface water drainage. A County Council Report outlines how The Drinagh Slob Road is particularly affected with one house flooding however no additional information is provided.

4.3.2.2 Flood Event of October 2011

Two websites (www.rte.ie and www.irishtimes.com) were found during the internet search which indicated that flooding occurred in the Baltinglass area on 26th October 2011 after exceptional rainfall. Treacherous conditions were reported on the N81 Dublin to Baltinglass route and also between Baltinglass and Tallaght.

4.3.2.3 Flood Event of September 2010

Maps provided by the local authority (Wicklow County Council) through the flood risk review process indicated significant flooding at Baltinglass on the 6th September 2010. Flooding affected properties on Main Street and Church Lane while up to 11 residential properties were flooded in the Parkmore area of the town.

4.3.2.4 Flood Event of November 2009

Information sourced from www.enniscorthyecho.ie, and www.wexfordecho.ie during the internet search indicated that flooding occurred in Enniscorthy, Wexford and Gorey in late November 2009 following heavy and prolonged rainfall. The levels in the River Slaney were reported to be extremely high; however no confirmation is available of the river overflowing.

In Wexford, homes in Newlands, Carriglawn and Sycamore Close were affected by the floods. The floods also caused the collapse of a boundary wall on the Newlands and Coolcotts Link Road which backs onto four properties.

In Enniscorthy, property in the area avoided serious damage as the expected levels of water failed to materialise. Minor damage was caused however and the cost of this flooding was estimated to be in the region of €100,000.

In the Gorey area, the rail line between Wicklow and Gorey closed due to the instability of an embankment south of Arklow, and a landslide south of Wicklow. Flooding also occurred of the Gorey/Ballycanew Road in Wexford.

4.3.2.5 Flood Event of August 2008

Information was found on www.enniscorthyguardian.ie during the internet search which indicated that a flood event occurred in early August 2008 in Gorey as a result of heavy rainfall. A section of Gorey's Town Park near the playground was under water following heavy rains throughout the week. The Flower Pub was also flooded as stormwater backed up through the drains.

4.3.2.6 Flood Event of October 2004

The historical data indicated that flooding occurred in Enniscorthy, Wexford and Tullow on 28th and 29th October. Photos were found on www.floodmaps.ie providing information on the event.

In Wexford, flooding was caused by a combination of high tides and strong winds, which resulted in overtopping of the quay wall and railway embankment in a number of locations. Water levels in Wexford Harbour exceeded the previous maximum recorded levels and rose above the level of the main street. An OPW report entitled “Report on October 2004 Flooding in County Wexford” indicated that the maximum flood levels were in the region of 2.1mOD. Flooding occurred of the Quays, Main Street and connecting streets with further flooding of Redmond Road and the Square causing significant damage to properties in those areas. The lower parts of the town and the harbour bridge were blocked off to traffic for several hours and severe storm damage was caused to the Ferrybank Sea Wall, which protects the Borough Council's Caravan Park, and Swimming Pool lands. It was reported in the minutes of a County Council Meeting that rainfall had an insignificant role in the flooding.

In Enniscorthy, the River Slaney burst its banks causing flooding of the N11 in the town. Riverside roads were also closed for a period late on Friday and both quays were blocked to traffic. Many businesses too were affected by the flooding. A mean daily flood level of 8.3mOD (Malin) and a corresponding daily mean flow of $1738\text{m}^3/\text{s}$ was recorded for the River Slaney at Enniscorthy Hydrometric Station on 29th October (as per <http://www.opw.ie/hydro>). However, it was noted on the OPW website that this flood level and flow data is above the prescribed data range and must only be used with caution. As it was reported that rainfall played an insignificant part in the flood event in Wexford, it is likely that high tides caused the River Slaney to back up and overflow in Enniscorthy; therefore the estimated flow of $1738\text{m}^3/\text{s}$ for the corresponding flood level may not have occurred.

In Tullow, the River Slaney reached a high level, the extent of which can be seen in photographic format. However, no details could be found relating to any damage caused.

4.3.2.7 Flood Event of November 2002

Information was found for a flood event which occurred in Enniscorthy, Gorey, Blackwater and Tullow on 21st November following a series of rainfall events. Press articles from the Irish Times, Irish Independent and Evening Herald were found on www.floodmaps.ie detailing this event.

In Tullow, Ouragh Road and Thomas Traynor Street were flooded to shallow depths. It is believed that this flooding was caused by high water levels backing up through the surface water drainage system, rather than from the River Slaney breaking its banks.

The flooding was more extensive in Enniscorthy, with Irish Street, Island Road, Slaney Place, Abbey Square, Riverview Court, Shannon Quay and Templeshannon all affected. Flooding also occurred of the main Gorey to Enniscorthy Road. Flood levels at various locations around Enniscorthy are available on the OPW Report entitled "Pre Feasability Report - Enniscorthy Flooding Appendices". A mean daily flood level of 2.17mOD (Malin) and a corresponding daily mean flow of $204\text{m}^3/\text{s}$ was recorded for the River Slaney at Enniscorthy Hydrometric Station on 21st November (as per

<http://www.opw.ie/hydro>). However, it was mentioned on the OPW website that the reliability of this flow data is unknown and it should therefore be treated with caution.

It was reported that over 38 mm of rain fell in a 12-hour period causing considerable damage to properties and businesses in the village of Blackwater.

A similar scenario was present in Gorey with a number of businesses and homes affected by the floods.

4.3.2.8 Flood Event of December 2001

In Wexford, at the beginning of December, flooding occurred in the Barntown area following a period of heavy rainfall. Although details on the rainfall are not available, photos were found on www.floodmaps.ie depicting the extent of the flooding. The gardens of three properties were flooded, as was a garage causing damage to equipment. Structural damage was also caused to the grounds of the local church and the N25 was reduced to one lane for a distance of up to 200 metres.

4.3.2.9 Flood Event of November 2000

Information was found on www.floodmaps.ie for a flood event that occurred in Baltinglass, Bunclody, Enniscorthy, Wexford, South Slobbs/Rosslare Port, Tullow and Gorey in November 2000. The sources of information included photos, OPW reports, Carlow County Council reports, Wexford County Council reports and press articles from the Nationalist & Leinster Times, Irish Times, Irish Independent, Irish Examiner, Enniscorthy Echo and the Evening Herald. The flooding was caused by excessive rainfall on the 5th and 6th November, which varied in intensity from 40mm to 100mm over a 24 hour period.

Baltinglass was badly hit by the flood with the town centre closing to traffic throughout the day and many businesses were under significant depth of flood water (reported as several feet of water).

Major disruptions occurred in Bunclody with flooding of houses, commercial premises and roads in the area. One residence and grounds at Chapel Road was badly flooded and water had to be pumped out by the local fire brigade. The Bunclody to Enniscorthy Road was impassable as was the N80 at Ryland Road.

In Enniscorthy, the River Slaney burst its banks causing widespread flooding. Island Road and adjoining premises were flooded to a depth of 1.2m. The North and South Quays were flooded to a depth of 2m as well as the Templeshannon area which was also flooded. The new bridge was flooded to a depth of 0.6m and the N11 was impassable at Enniscorthy Quays. Rail services were affected with the Dublin - Rosslare line closing due to a mud slide near Enniscorthy. Two men became trapped in a 4x4 vehicle near The Riverside Park Hotel. The strong gales also had an effect with more than 750 homes left without power. The OPW Report entitled "Tullow Pre-Feasibility Flood Relief Study" reported an AEP of approximately 2.9%. Flood levels at various locations in Enniscorthy are available on OPW Report entitled "Pre Feasibility Report - Enniscorthy Flooding Appendices" and also the

OPW Report "Flooding event of 5-7 Nov 2000 - Wexford". A mean daily flood level of 4mOD (Malin) and a corresponding daily mean flow of $555\text{m}^3/\text{s}$ was recorded for the River Slaney at Enniscorthy Hydrometric Station on 6th November (as per <http://www.opw.ie/hydro>). However, it was mentioned on the OPW website that the reliability of this flow data is unknown and it should therefore be treated with caution.

The November 2000 flood event also affected Wexford, however, no further details are available.

22mm of rain fell in Rosslare in a 12-hour period causing the Rosslare and Waterford rail line to close due to a mudslide and collapsed wall.

In Tullow, The Bridge House was flooded with over 1.2 metres of water and severely damaged. Many other businesses and homes were similarly affected with fire services having to rescue many residents from their homes. The worst affected areas were the Castledermot Road (submerged in 1-1.2 metres of water), Tullowbeg and Ballymurphy. The Slaney Quik Pick was also flooded. It was reported that 25 No. residential properties and 10 No. commercial properties were flooded and that members of the travelling community parked in the town's car park were also affected by the floods.

In Gorey, the Owenavorrage River burst its banks flooding a garden centre and three houses at Essex Bridge. There was also flooding of two houses at Killina Bridge, a road and slatted shed at Corbally Bridge and extensive flooding of lands at Boira. Various roads at Castlebridge were also flooded due to the Tidal River overflowing. The OPW Report entitled "Wexford Flooding Nov 2000" reported an AEP of less than 5% for the flood event. A peak flood level of 9.36mOD (Malin) and a corresponding peak flow of $70.8\text{m}^3/\text{s}$ were recorded at Boleany Hydrometric Station on 5th November, as per <http://www.opw.ie/hydro>. The Boleany Hydrometric Station is located approximately 3 miles south east of Gorey.

4.3.2.10 Flood Event of September 1999

An article from the Nationalist & Leinster Times, downloaded from www.floodmaps.ie, reported that high winds and the heaviest rains since Hurricane Charlie of August 1986 caused the River Slaney to burst its banks at Tullow in late September 1999. Residents and businesses were forced to sandbag their front doors to prevent any damage occurring. No further details were available.

4.3.2.11 Flood Event of August 1997

Information was found for a flood event which occurred in Enniscorthy, Wexford, Rosslare and Blackwater Village in early August 1997. Details of the event were obtained from press articles in the Irish Times, Irish Independent, Munster Express and the Examiner (Cork), as well as photos and a Wexford County Council memo (dated 7th February 2001), downloaded from www.floodmaps.ie.

In Wexford, flooding occurred in the Redmond's Square area, and the Rosslare-Dublin train service was disrupted when the rail line became submerged.

Approximately 33mm of rainfall was recorded at Met Éireann's station in Rosslare for a 12-hour period. Train services were also disrupted between Rosslare and Enniscorthy and damage was caused to a ferry carrying 1,300 passengers, which attempted to dock in Rosslare.

The River Blackwater burst its banks at Blackwater Village blocking the centre of the village and damaging a large amount of property. Three pubs, a supermarket and restaurant were all flooded following 36 hours of constant rain.

In Enniscorthy, a daily mean flow of $63.9\text{m}^3/\text{s}$ was recorded for the River Slaney at Enniscorthy Hydrometric Station on 4th August (as per <http://www.opw.ie/hydro>). However, it was mentioned on the OPW website that the reliability of this flow data is unknown and it should therefore be treated with caution.

4.3.2.12 Flood Event of June 1996

Heavy rainfall caused flooding in Tullow on 1st June 1996. Photographs available on www.floodmaps.ie showed flooding in the vicinity of the bridge and at the Bridge House Pub.

4.3.2.13 Flood Event of January 1996

Wexford and Rosslare endured floods on 10th January 1996 following heavy rainfall and strong gales. Details on the event were available in a letter from Wexford Borough Council (dated 14th February 2006) downloaded from www.floodmaps.ie.

In Wexford, the flooding was caused by a combination of high tide, wind and surcharged storm drainage. The storm water discharge was therefore prevented from entering the sea and flooded several low lying streets in the town. The Old Quay front was also overtopped for a time.

Extensive erosion occurred at Rosslare Strand as a result of the inclement weather conditions.

4.3.2.14 Flood Event of August 1986

Information from OPW and Wexford County Council sources, was found on www.floodmaps.ie, for a flood event which occurred in Enniscorthy, Courtown and Gorey in August 1986. The flooding was caused following heavy and prolonged rainfall.

The August 1986 storm event, more commonly referred to as Hurricane Charlie, caused Island Road to flood in Enniscorthy. A mean daily flood level of 1.97mOD (Malin) and a corresponding daily mean flow of $139\text{m}^3/\text{s}$ was recorded at Enniscorthy Hydrometric Station on 26th August (as per <http://www.opw.ie/hydro>). However, as with the November 2000 flood event, it was mentioned on the OPW website that the reliability of this flow data is unknown and it should therefore be treated with caution.

Around the Courtown area, the roadway at Boleany Bridge was flooded for a few hours and lands upstream of the bridge and downstream of the outfall at Courtown were also affected. The stretch between Boleany and Courtown was also affected by bank slips and erosion resulting in the river altering its course.

In Gorey, structural damage was carried out to a wall on Esmonde Street following the storm. A peak flood level of 9.62mOD (Malin) and a corresponding peak flow of 121m³/s were recorded at Boleany Hydrometric Station on 27th August, as per <http://www.opw.ie/hydro>.

4.3.2.15 Flood Event of December 1978

The historical data indicated that flooding occurred in Bunclody and Enniscorthy at the end of December 1978 following three days of heavy rain and strong winds. Details were available in an Enniscorthy Echo press article, downloaded from www.floodmaps.ie.

In Enniscorthy, a licenced premises at Templeshannon was flooded to a depth to a significant depth (reported as several feet) and the fire brigade spent three hours pumping the premises. A residence at 17 Aidan Villas was also extensively damaged causing the family to evacuate. Further flooding occurred of the main Enniscorthy/Bunclody road.

The River Slaney burst its banks in Bunclody resulting in over 300mm of water blocking the main Enniscorthy/Bunclody Road.

4.3.2.16 Flood Event of November 1965

The review of information indicated that a flood event occurred in Baltinglass, Bunclody, Enniscorthy, Tullow, Courtown and Gorey in November 1965 following three days of persistent rainfall. Information on the event was available from various press articles, including those published in the Enniscorthy Echo, Wicklow People, Wexford People, Leinster Leader, Cork Examiner, Irish Independent, and also from Wexford County Council and OPW information on www.floodmaps.ie.

In Baltinglass, a number of businesses were flooded but no additional details were provided.

The River Slaney overflowed as far as Ryland Road in Bunclody resulting in the road being covered to a depth of 3 metres in places. Homes along this street were flooded with water up to lower window level in some instances. River waters almost completely covered cars and lorries in the car park of Colliers Bros., adjacent to their garage on Ryland Road. Pupils of St. Mary's Convent School were collected by a lorry due to fears of a bridge being swept away.

In the early morning of Thursday 18th November, flood waters rose in the Slaney and the town of Enniscorthy experienced its worst ever flooding in living memory with damage amounting to thousands of pounds caused by the floodwaters. From anecdotal accounts, the '65 flood was worsened by debris partially blocking arches of Enniscorthy Bridge. Flooding was particularly heavy in the areas of Island

Road, Templeshannon, and Abbey Square and rising to a height of over 2.7 metres in some parts. The Railway Bridge over the Slaney was severely damaged and at one stage it was feared that the Road Bridge over the Slaney might be in danger of collapse. Such was the extent of the flooding that three rowing boats were brought in from Wexford for rescue purposes. Places of note that were affected by the floods included the E.S.B. station, the Co-operative Stores, Enniscorthy Gas Company and the railway station. The Garda Barracks and Co. Council Machinery Yard were also severely flooded to a depth of over 1 metre in some places. Buttles Barley Fed Bacon Factory was also affected where two sows and seven pigs were lost. The OPW Report entitled "Feasibility Report on the Enniscorthy Flooding Problem" reported that the flood event yielded an AEP of approximately 1%.

In Tullow, the River Slaney burst its banks resulting in one butcher losing about 20 pigs and several cattle. Approximately 60 properties were flooded to depths in excess of 1.5m. Garages, The Slaney Hotel and some shops also had to be evacuated. An OPW Report entitled "Tullow Pre-Feasibility Flood Relief Study" reported an estimated AEP of less than 2% and possibly 1% or less.

The Owenavorrigh River was about four times its normal width at Courtown. The wooden bridge connecting Courtown Harbour with Courtown Golf Links via "The Burrow Road" was washed away in the floods and a whole section of the sand dunes were also swept away at this point.

In Gorey, over 100mm of rain fell over the course of two days, which is roughly the average rainfall for the month of November. Gorey was completely cut off from Dublin resulting in no newspaper deliveries or mail deliveries. Public transport services into the town were also running behind schedule due to the snow and floods. Slates were stripped from houses and many trees were uprooted. A number of TV aerials were also damaged.

The gales also caused considerable damage to the Kilmore District. At Kilmore Quay, fishing boats got a severe battering and part of the end of the breakwater wall was also washed away. A new cattle shed at Killag was washed away also.

4.3.2.17 Flood Event of November 1954

Press articles were found in the Wexford People and Enniscorthy Echo which reported that the River Slaney burst its banks in Enniscorthy following the torrential rain and storm conditions on 8th November. Premises at Templeshannon Quay, Abbey Quay and Island Road were all flooded. At Island Road, Doherty's garage and shop were flooded to a depth of approximately 300mm. 1-1.2 metres of water lay on the road of Templeshannon Quay and floodwaters poured into the E.S.B. station at Abbey Quay, the premises of Enniscorthy Gas Co. and the Co. Council Machinery Yard. The extent of the flooding at Island Road, the Railway Bridge, Templeshannon and Shannon Quay can be seen in a series of photographs.

4.3.2.18 Flood Event of March 1947

The OPW Report entitled "Feasibility Report on the Enniscorthy Flooding Problem" contains a photograph that depicts the extent of the flooding of Island Street in Enniscorthy during March 1947. Information from The Enniscorthy Echo press article indicates that flooding was caused by a severe snowfall that fell and when it began to thaw, the run off caused a swollen river that burst its banks. Flooding occurred along the residential parts of Island Road and the commercial businesses on Templeshannon Quay.

4.3.2.19 Flood Event of November 1924

Similar to the November 1924 flood event, the OPW Report entitled "Feasibility Report on the Enniscorthy Flooding Problem" contains a photograph outlining the extent of the flooding in Enniscorthy in late November 1924. The photograph is of the town downstream of Enniscorthy Bridge and shows similar flood levels to those recorded for the November 2000 flood event. The same report estimates an AEP of between 2% and 3.33% for the flood event.

4.4 PRELIMINARY ASSESSMENT OF PAST FLOODS AND FLOODING MECHANISMS

A preliminary assessment of a number of major historical flood events which occurred within HA11, 12 and 13 has been carried out. The assessment mainly focused on the examination of flood generation mechanism for each event and estimation of its frequency of occurrence.

4.4.1 Past Flooding History and Selection of Flood Events

River catchments within HA11, 12 and HA13 have experienced a number of major flood events in the past, most notably in November 1965, August 1986, March 1995, November 1997, November 2000, November 2002, August 2008, November 2009 and January 2010. The November 1965, August 1986, November 2000 and November 2002 flood events were the worst among these. The August 1986 flood event was locally known as Hurricane Charlie.

The historic flood data collected from various sources were reviewed and reported in Section 4.3. Based on the historical review of the severity of all flood events and subject to the availability of continuous and AMAX records, a number of major flood events were selected to examine further their causes/mechanisms, behaviour and their frequency of occurrences. AMAX time series and/or continuous flow records are available for a number of gauging stations located on the watercourses to be modelled within HA11 and HA12 as shown below.

Table 4.9: Gauges with AMAX series available

	Station Number	Station Name	Watercourse	Catchment	AMAX Series Provided	Continuous Flow Record Available
HA11	11001	Boleany	Owenavorrhagh	Owenavorrhagh	Y	Y
HA12	12001	Scarawalsh	Slaney	Slaney	Y	Y
	12002	Enniscorthy	Slaney	Slaney	Y	Y
	12013	Rathvilly	Slaney	Slaney	Y	Y
HA13	No records for the modelled rivers are available					

These have been used to conduct flood event analysis within HA11, 12 and 13. (Note that none of the watercourses to be modelled within HA13 are gauged). Table 4.10 presents the selected events on the affected AFA basis.

4.4.2 Flood Mechanisms in HA11, 12 and 13

Flooding is a natural process and can happen at any time in a wide variety of locations. Flooding can come from rivers and the sea, directly from rainfall on the ground surface and from rising groundwater, surcharging sewers and drainage systems.

The various types of flooding can be categorised as follows:

Fluvial flooding: This type of flooding occurs when the capacity of the river channel is exceeded or the channel is blocked or restricted, and excess water spills out from the channel onto adjacent low-lying areas. Fluvial flooding is generally caused by short duration high-intensity or prolonged rainfall in the catchment.

Pluvial flooding: This type of flooding is defined as flooding from rainfall-generated overland flow, before the runoff enters any watercourse or sewer. This mainly occurs when intense rainfall, often of short duration, that is unable to soak into the ground or enter drainage systems, can run quickly off land and result in local flooding. It can also result when the drainage system is overwhelmed by heavy rainfall, becomes blocked or is of inadequate capacity.

Groundwater flooding: Groundwater flooding occurs when water levels in the ground rise above surface elevation following prolonged and heavy rainfall. It is most likely to occur in low-lying areas underlain by permeable rocks. Groundwater flooding may take weeks or months to dissipate because groundwater flow is much slower than surface flow and water levels thus take much longer to fall.

Tidal and coastal flooding: This type of flooding occurs during exceptionally high tides or during storm events when low pressure systems result in storm surges on the coast lines and estuaries. Wind action causes increased wave heights which also contribute to coastal flooding.

Combined fluvial and tidal flooding: This type of flooding occurs from the joint effect of both fluvial and tidal flood events.

Snowmelt: There is historical evidence that this type of flooding may be a factor on the upper reaches of the Slaney Catchment. Flooding occurs when snow and ice on higher ground begins to thaw and creates run-off. Usually accelerated by rainfall and can compound pluvial / fluvial flooding.

In HA11, 12 and 13, most flooding events are of the 'fluvial' category.

4.4.3 Flood Event Behaviour and Their Frequency

The behaviour of the selected flood events were examined by plotting their associated flow hydrographs. The shape of the hydrograph, its response time and flood duration have been examined for each of the selected events. The shape of the hydrograph is obviously dependent on the catchment physical and meteorological characteristics and in particular, the catchment area, slope, catchment soil type and the antecedent wet condition, drainage density and the catchment storage behaviour and the rainfall type. In small, steep catchments, local intense rainfall can result in the rapid onset of deep and fast-flowing flooding with little warning. Such 'flash' flooding, which may last a few hours can give a very peaky shape hydrograph. In a larger catchment like the Slaney River, flash flood in the upper steeper tributary catchments can have lesser effects on the downstream part of the catchment, due to the attenuation effect. Flooding at the coastal downstream reaches of river catchments like Slaney, Owenavorrhagh and Blackwater can arise from the joint occurrences of fluvial and tidal flood events. The frequency of selected flood events within HA11 and 12 have been analysed by fitting the AMAX time series for the associated gauging sites. The AMAX time series were fitted to three flood-like distributions, namely, the GEV, EV1 and 2-parameter Lognormal (LN2) distributions.

No AMAX records for any modelled rivers within HA13 are available, flood event analysis could not be carried out.

As an example of flood event analysis within HA11 a hydrograph plot of the November 2000 flood event on the Owenavorrhagh River as recorded at Hydrometric Station 11001 (Boleany) is shown on Figure 4.6..

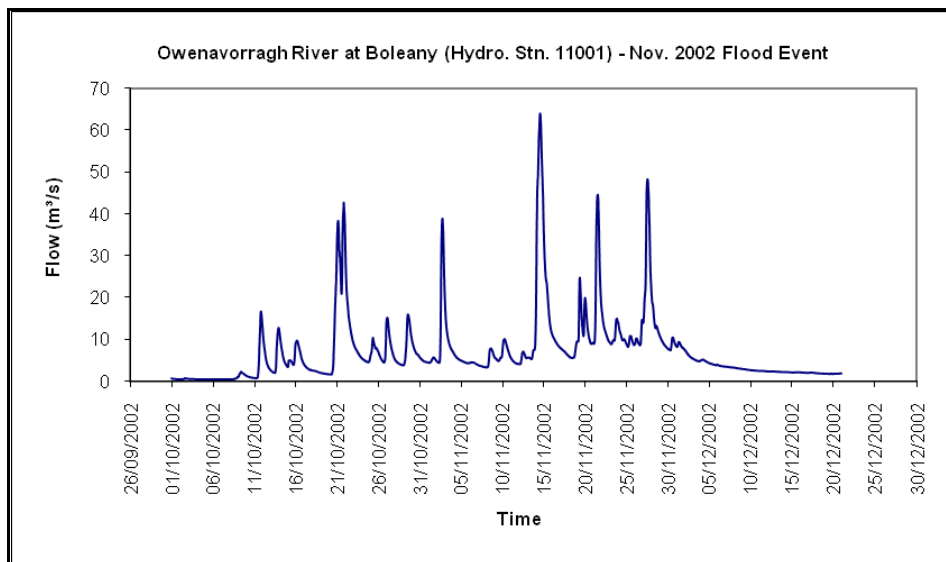


Figure 4.6: Observed flood hydrograph during the November 2002 flood event at the Boleany Hydrometric Station of Owenavorrh River (11001).

Figure 4.6 shows observed AMAX flow records for River Owenavorrh at Boleany for the period of 1972 to 2009

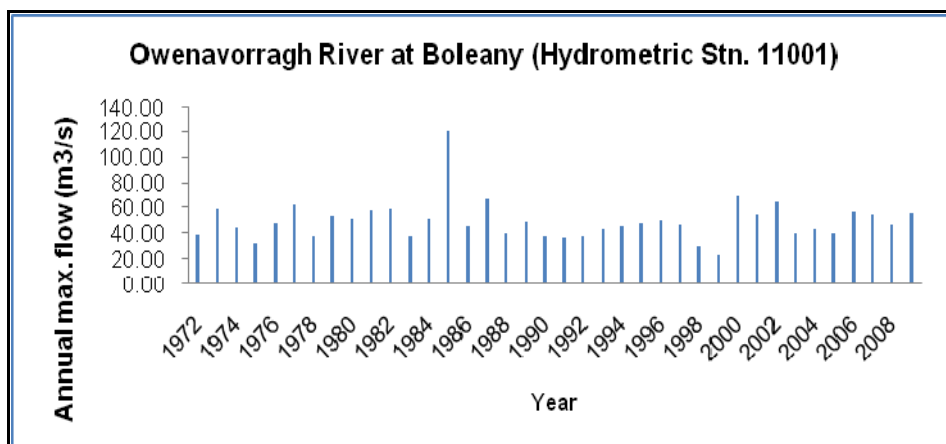


Figure 4.7: Observed Annual Maximum Flows for Owenavorrh River at Boleany (1972 – 2009).

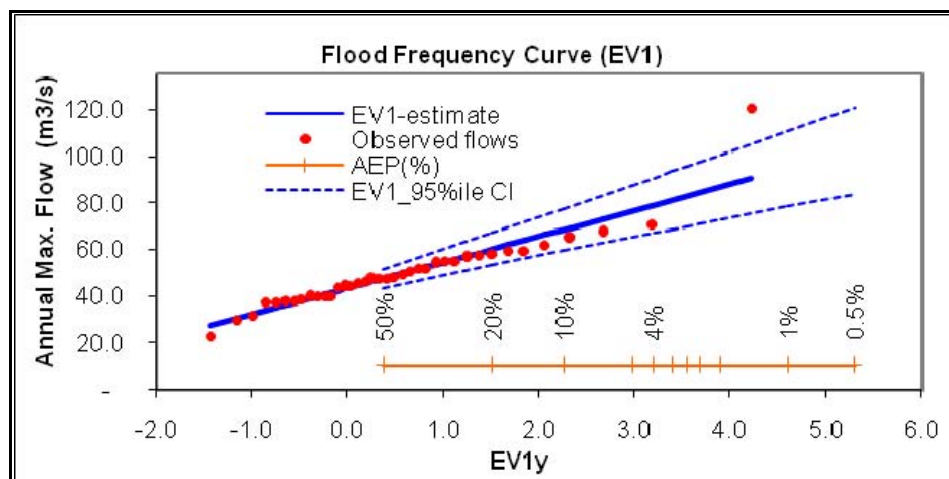


Figure 4.8: Fitted EV1 frequency Curve to the observed annual maximum records for Owenavorrhagh River at Boleany (Hydro.Stn.11001).

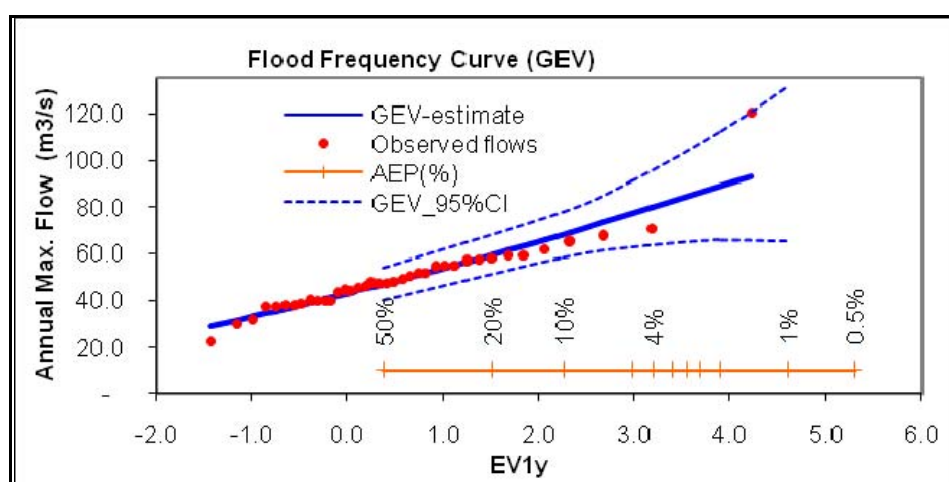


Figure 4.9: Fitted GEV frequency curve to the observed annual maximum records for Owenavorrhagh River at Boleany (Hydro.Stn.11001)

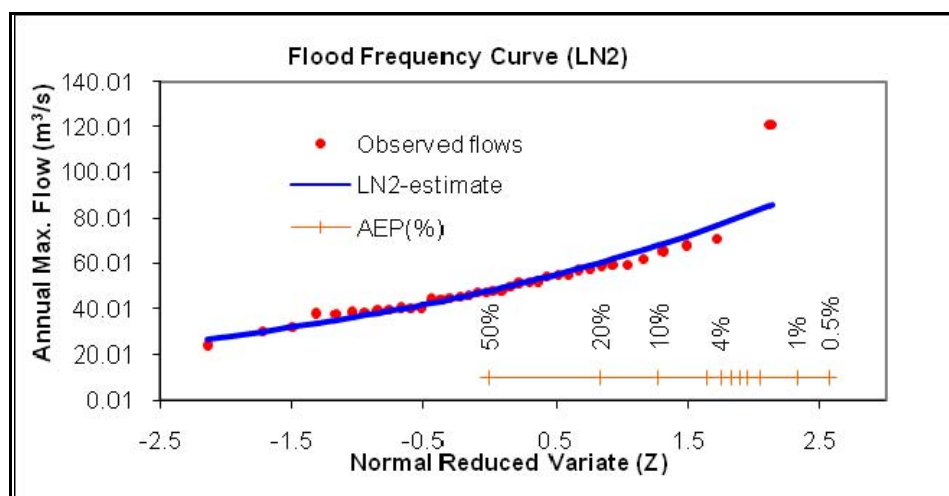


Figure 4.10: Longnormal (2-parameter) frequency curve to the observed annual maximum records for Owenavorrhagh River at Boleany (Hydro.Stn.11001)

Figures 4.8, 4.9 and 4.10 show the fitted EV1, GEV and 2-parameter Lognormal distributions to these records respectively. It can be seen from these figures that GEV distribution provides slightly better fit to the observed annual maximum records. Based on this, the estimated AEP of the observed flood flow of $64.84\text{m}^3/\text{s}$ during the November 2002 flood event (14/11/2002) is approximately 10%.

As an example of flood event analysis within HA12, **Figure 4.11** shows a hydrograph plot of the November 2000 flood event on the Slaney River as recorded at Hydrometric Station 12002 (Enniscorthy).

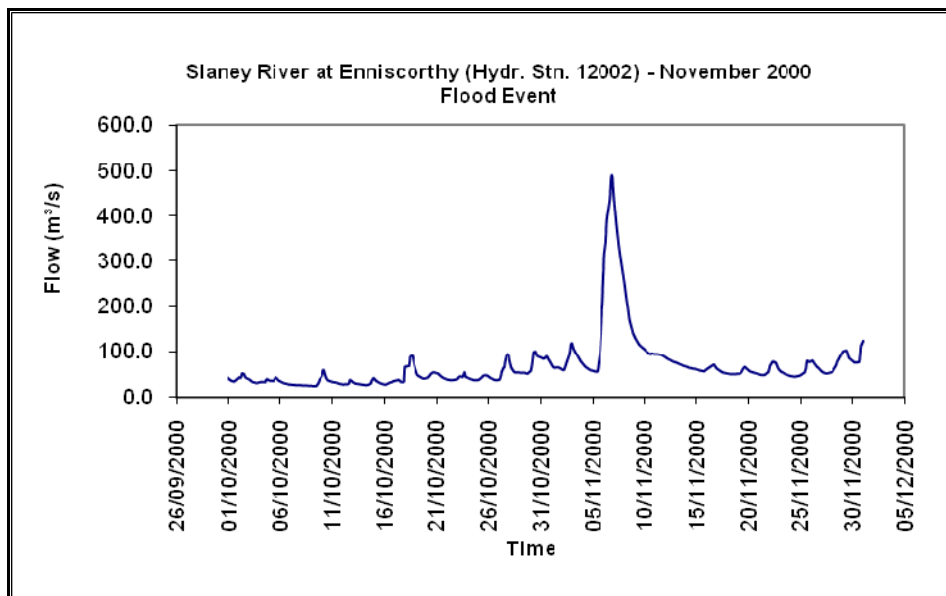


Figure 4.11: Observed flood hydrograph during the November 2000 flood event at the Enniscorthy Hydrometric Station of Slaney River (12002).

Figure 4.12 shows observed AMAX flow records for Slaney River at Enniscorthy for the period of 1979 to 2009.

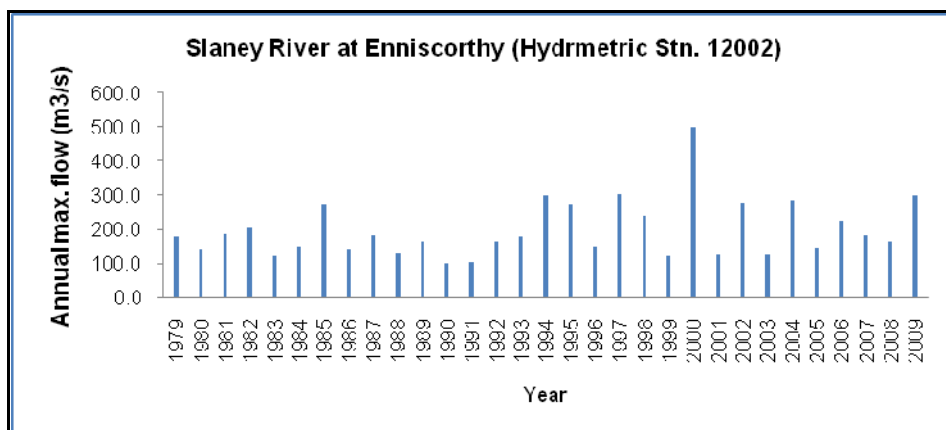


Figure 4.12: Observed Annual Maximum Flows for Slaney River at Enniscorthy (1979 – 2009).

Figures 4.13, 4.14 and 4.15 show the fitted EV1, GEV and 2-parameter Lognormal distributions to these records respectively.

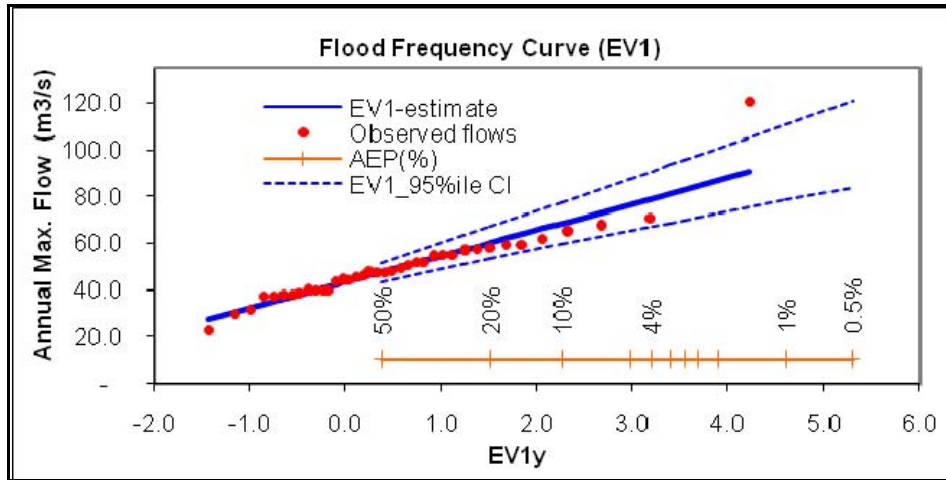


Figure 4.13: Fitted EV1 frequency Curve to the observed annual maximum records for Slaney River at Enniscorthy (Hydro.Stn.12002).

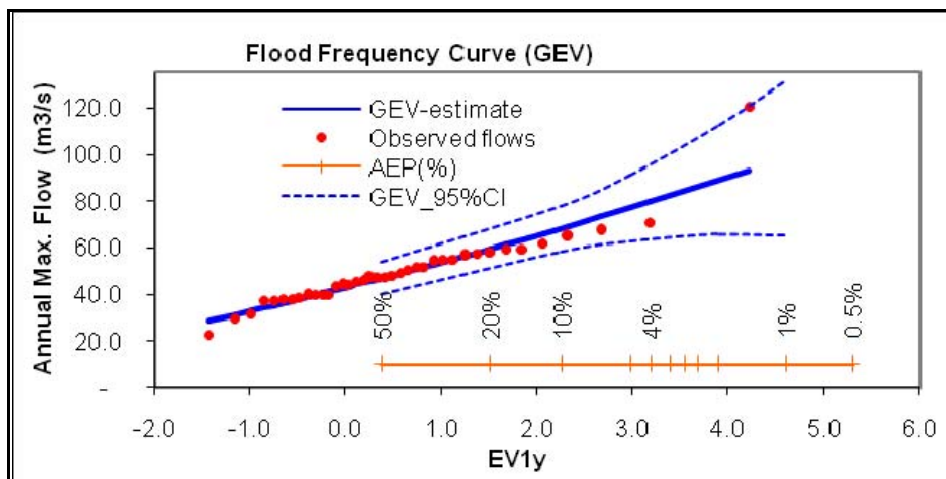


Figure 4.14: Fitted GEV frequency curve to the observed annual maximum records for Slaney River at Enniscorthy (Hydro.Stn.12002)

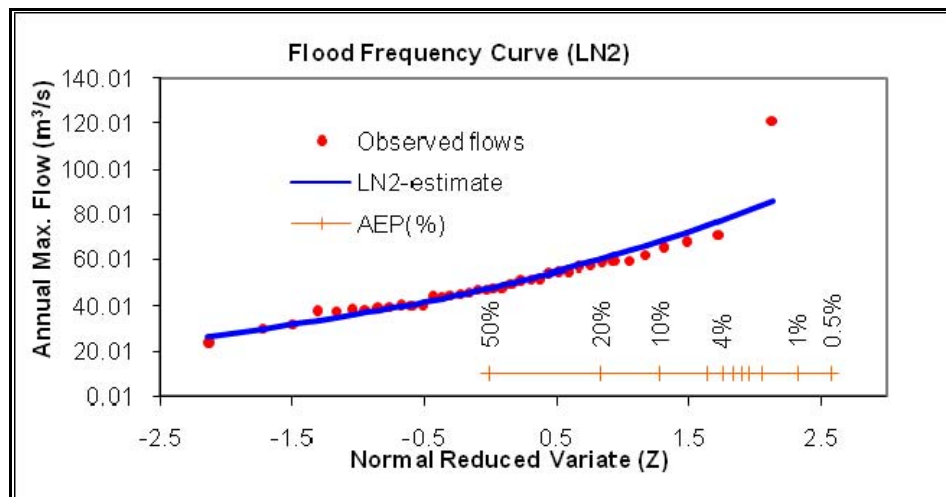


Figure 4.15: Longnormal (2-parameter) frequency curve to the observed annual maximum records for Slaney River at Enniscorthy (Hydro.Stn.12002)

It can be seen from these figures that GEV distribution again provides slightly better fit to the observed AMAX records. Based on this, the estimated AEP of the observed flood flow of 498.90 m³/s during the November 2000 flood event (06/11/200) is approximately 1.33% (1 in 75 years return period).

Table 4.9 summarises the flood mechanism, hydrograph shape and estimated frequency of all selected flood events. It can be seen from this table that the majority of the flood events are of 'fluvial' type. It can be seen from this table that the majority of the flood events are of 'fluvial' type. The historical review in Section 4.3 identified most severe flood events (in terms of frequency and damage caused) in the river catchments within HA11, HA12 and HA13 hydrometric areas were the November 1965, August 2008 and November 2000 flood events. Most parts of these catchment areas were affected during these events and the causes of flooding were the prolonged intense rainfall (fluvial). The estimated approximate AEP of the November 1965 flood event recorded at Station 12001 (Scarawalsh) on the Slaney River is approximately 1%.

The historical review of flood information and hydrometric data has been used to select flood events that will be used in calibration of the hydraulic models of MPWs and HPWs. This is discussed in Section 5.2.2, Hydraulic Model Calibration.

Table 4.10: Significant flood events, their generation mechanisms and frequency in HA11, 12 and 13

HA	AFA/HPW	Nearest Gauging Stations		Major flood events				
		Stn. No.	Location	Date	Peak flow (m ³ /s)	Rank	Approx. AEP (%)	Flood mechanisms
HA11	Gorey and Courtown	11001	Owenavorragh River at Boleany	27/08/1986	120.70	38 (highest)	≈ 1%	Fluvial and tidal: Intense rainfall and gale force. Fast response catchment, time to peak is approximately 15-20 hours. Flood duration was 2 days. Slightly slower recession.
				19/01/1988	67.40	36	20 – 10%	Fluvial: Heavy and prolonged rainfall. Flood duration was 3 days.
				05/11/2000	70.80	37	10 – 6.67%	Fluvial: Heavy and prolonged rainfall. Flood duration was 3 days.
				14/11/2002	64.84	35	20 – 10%	Fluvial: Heavy and prolonged rainfall. Fast response catchment, time to peak is approximately 15-20 hours. Flood duration was 2-3 days.
				30/12/2009	56.56	29	50 – 20%	Fluvial: Heavy and prolonged rainfall. Flood duration was approximately 4 days.
	Blackwater HPW	No gauge	No gauge	Aug. 1997	No records	-	-	Fluvial: Heavy and prolonged rainfall.
Nov. 2002				No records	-	-	Fluvial: Heavy and prolonged rainfall.	
		12001	Slaney River at Scarawalsh	18/11/1965	388.40	55 (highest)	≈ 1%	Fluvial: Intense rainfall. Fast response catchment, time to peak 1-2 days. Flood duration was approx. 5 days. Slightly slower recession.

HA	AFA/HPW	Nearest Gauging Stations		Major flood events				
		Stn. No.	Location	Date	Peak flow (m ³ /s)	Rank	Approx. AEP (%)	Flood mechanisms
HA12	Enniscorthy and environs			26/08/1986	218.70	49	20 - 10%	Fluvial: Intense rainfall and gale force. Flood duration was approx. 4 days.
				10/03/1995	221.20	51	20 - 10%	Fluvial: Heavy and prolonged rainfall. Flood duration was approx. 4 days.
				18/11/1997	208.70	47	20 – 10%	Fluvial: Heavy and prolonged rainfall. Flood duration was approx. 14 days.
				06/11/2000	287.20	54	2.5 – 2%	Fluvial: Intense rainfall. Flood duration was approx. 4 days.
				28/11/2002	187.70	41	50 – 20%	Fluvial: Heavy and prolonged rainfall. Flood duration was approx. 21 days.
				29/10/2004	208.10	46	20 – 10%	Fluvial: Intense rainfall. Flood duration was approx. 6 days.
				16/01/2010	217.0	48	20 – 10%	Fluvial: Heavy and prolonged rainfall. Flood duration was approx. 10 days.
				Nov. 1965	No records	-	-	Fluvial: Intense rainfall.
		12002	Slaney River at Enniscorthy	27/08/1986	271.60	25	20 – 10%	Fluvial: Intense rainfall and gale force. Flood duration was approx. 4 days.
				10/03/1995	298.60	28	10%	Fluvial: Heavy and prolonged rainfall. Flood duration was approx. 5 days.
				18/11/1997	305.10	30	10 – 6.67%	Fluvial: Heavy and prolonged rainfall. Flood duration was approx. 15 days.
				06/11/2000	498.90	31	1.43 – 1.33%	Fluvial: Intense rainfall. Flood duration was approx. 5 days.
				28/11/2002	277.90	26	20 – 10%	Fluvial: Heavy and prolonged rainfall. Flood duration was approx. 21 days.
				30/10/2004	286.40	27	20 – 10%	Fluvial: Prolonged intense rainfall. Flood duration was approx. 10 days.

HA	AFA/HPW	Nearest Gauging Stations		Major flood events				
		Stn. No.	Location	Date	Peak flow (m ³ /s)	Rank	Approx. AEP (%)	Flood mechanisms
	Baltinglass and Tullow			16/01/2010	301.20	29	10%	Fluvial: Heavy and prolonged rainfall.
				Nov. 1965	No records	-	No records	Fluvial: Intense rainfall.
		12013	Slaney River at Rathvilly	18/11/1997	61.60	34	10 – 6.67%	Fluvial: Intense rainfall.
				06/11/2000	72.30	35 (highest)	1.1 – 1%	Fluvial: Intense rainfall
				27/11/2002	55.20	28	20 – 10%	Fluvial: Heavy and prolonged rainfall. Fast response catchment. Flood duration was approx. 10 days.
	Wexford	12064	Slaney River at Ferrycarrig Brudge	17/08/2008	47.10	24	50 – 20%	Fluvial: Heavy and prolonged rainfall. Flood duration was 9 days
				26/10/2011	No record	-	-	Fluvial: intense rainfall
				Jan. 1996	No record	-	-	Fluvial and tidal
				Aug. 1997	No record	-	-	Fluvial and tidal
				Nov. 2000	No record	-	-	Fluvial and tidal
Kilmore	13081	Ballyteige lagoon at Cull Bank	Nov. 2002	No record	-	-	Fluvial and tidal	
			Oct. 2004	No record	-	-	Fluvial and tidal	
			Nov. 2009	No record	-	-	Fluvial and tidal	
			Nov. 1965	No record	-	-	Fluvial and tidal	
			Nov. 1982	No record	-	-	Fluvial and tidal	
			Nov. 2000	No record	-	-	Fluvial and tidal	
			Nov. 2002	No record	-	-	Fluvial and tidal	
			Nov. 2009	No record	-	-	Fluvial and tidal	

5 HYDROLOGICAL ANALYSIS METHOD STATEMENT

5.1 ANALYSIS OF HYDROMETRIC AND METEOROLOGICAL DATA

5.1.1 Gauging Station Rating Review

A rating review of three hydrometric stations in HA11 and 12 is being undertaken. The stations were identified in the South Eastern Project Brief document as stations 11001 – Boleany, 12011 – Scarawalsh and 12015 - Ferns. The rating review task involves:

- visiting the site (at high flows where practical);
- liaising with OPW or EPA (as appropriate) to request available information on each station. This included the staff gauge zero datum history, the history of the station, annual maximum series data, spot gaugings and a rating report;
- procuring a channel and floodplain survey for an adequate reach of the river upstream and downstream of the gauging station location;
- constructing a hydraulic model based on the surveyed sections, using MIKE FLOOD software;
- calibrating the model (by adjusting weir / bridge coefficients and Manning's roughness values) using the existing station rating up to the reliable limit (usually the highest gauged flow or Q_{med});
- using the calibrated model to simulate fluvial discharges up to and exceeding the estimated 1 in 1000 year flow for the site.

The above process results in a modelled stage-discharge relationship for upper range of the hydrometric gauging station ratings. It reduces the uncertainty associated with previous rating equations which were based on simple extrapolation beyond the maximum gauged flow over the period of record for the station.

Past experience has shown that this is a critical exercise in terms of improving confidence and providing a site specific understanding of limitations at certain stations due to, for example, changes in the rating curve with time at "soft" engineered stations, bypass flow, blockages or over levée flood situations.

5.1.2 Hydrometric Data

Refer to discussion of preliminary data analysis in Section 4.3.2.2.

5.1.3 Rainfall Data Analysis

Rainfall data analysis is required to provide the necessary rainfall input to hydrological models (refer to Sections 5.4 and 5.6.1) where required. An ongoing trial looking at the potential benefits of using rainfall radar data (calibrated to daily and hourly rainfall gauges described in Section 4.2) to provide

rainfall input to hydrological models is currently ongoing as part of the overall Eastern CFRAM Study. If the trial outcomes conclude that there is a benefit to using rainfall radar data, then its use may be rolled out to the South Eastern Study Area. If this is the case, rainfall radar data analysis will be undertaken to provide rainfall input to rainfall runoff hydrological models as part of the overall hydrology methodology. A detailed description of rainfall radar data analysis is provided in Appendix C.

However if the radar data analysis trial of the Dublin radar data for the Eastern CFRAM Study project area shows significant problems and inconsistencies that are difficult to correct and calibrate in order to generate the hourly data rainfall series for each of the HEPs; rainfall data analysis will be undertaken using data from daily and hourly rainfall gauges to provide the necessary rainfall input to hydrological models. GIS elevation-based spatial-temporal interpolation techniques will be used to enhance the standard Thiessen polygons methodology to generate spatially-weighted rainfall time series as inputs to the hydrological models, refer to Sections 5.4 and 5.6.1.

5.2 MODEL CONCEPTUALISATION

5.2.1 HA 11, 12 and 13 Hydraulic Models

To facilitate hydrological assessment and hydraulic modelling, nine hydraulic models have been conceptualised for HA 11, 12 and 13 as shown in Figure 5.1. Hydrological estimation will be undertaken to provide inputs for each hydraulic model. The number and boundaries of the models have been largely chosen due to modelling practicalities such as having one 2D mesh per model and therefore one AFA per model and where possible such that gauge stations separate models and therefore can be used to directly calibrate flow estimations on both models. The large number of HEPs will allow good variation in the rarity / frequency conditions up and down the catchments and at each HEP comparison of different hydrology estimations will be undertaken for robustness (from rainfall runoff methods to statistical analysis methods such as outlined in FSU WP 2.2 & 2.3). Where appropriate the guidance within FSU WP 3.4, paragraph 4.3.3 will be followed:

‘One way to meet the aspiration for treating large river models in small units is to carry out multiple runs with different inflow conditions, each run being intended to simulate the required design conditions in a different part of the model’

In selecting the nine models the degree of interdependence has been a secondary consideration. This is acknowledged within WP 3.4 as being less important where an FSU approach is being used *‘because there is no direct link between design peak flow and event duration’* (FSU WP 3.4, paragraph 4.3.1).

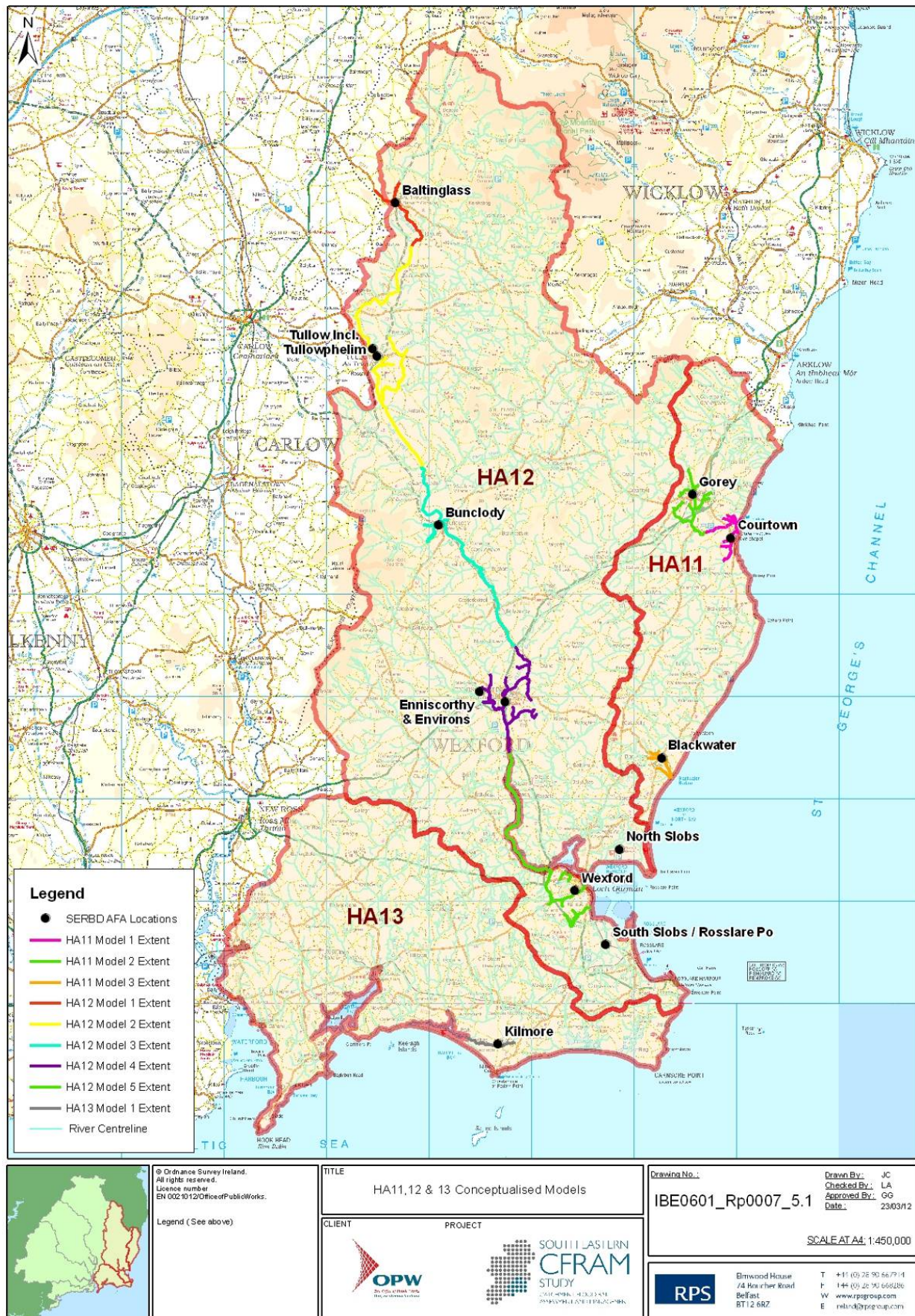


Figure 5.1: HA11, 12 and 13 Conceptualised Models

5.2.2 Catchment Boundary Review

Catchment boundaries for each HEP have been derived from the OPW national dataset containing the ungauged catchment outlines produced as part of the FSU for points every 500m along watercourses. Each catchment boundary will be reviewed against orthophotography and the NDHM (National Digital Height Model) using GIS based tools. Any amendments to catchment boundaries will be reported at the hydrology reporting stage.

5.2.3 Hydraulic Model Calibration

Based on the review of historical flood events (Section 4.3) and preliminary assessment of flood mechanisms using available hydrometric data to determine AEPs (Section 4.3.2.2), the following flood events have been selected for model calibration and verification purposes (refer to Table 5.1).

Table 5.1: Selected Flood Events for Hydraulic Model Calibration and Verification

Hydrometric Stations	Selected Flood events for hydraulic model calibration and verification	
	Date	Peak flow (m3/s)
11001	27/08/1986	120.70
	19/01/1988	67.40
	05/11/2000	70.80
	14/11/2002	64.84
	30/12/2009	56.56
12001	26/08/1986	218.70
	18/11/1997	208.70
	06/11/2000	287.20
	28/11/2002	187.70
	16/01/2010	217.0
12002	27/08/1986	271.60
	18/11/1997	305.10
	06/11/2002	277.90
	30/10/2004	286.40
12005	-	No flow records available
12006	-	No flow records available
12007	-	No flow records available
12008	-	No flow records available
12012	-	No flow records available
12013	27/11/2002	55.20
	17/08/2008	47.10
	29/11/2009	42.50
12021	-	No flow records available
12023	-	No flow records available
12026	-	No flow records available
12027	-	No flow records available

Hydrometric Stations	Selected Flood events for hydraulic model calibration and verification	
12031	-	No flow records available
12033	-	No flow records available
12035	-	No flow records available
12060	-	No flow records available
12061	-	No flow records available
12062	-	No flow records available
12064	-	No flow records available
12066	-	No flow records available
13081	-	No flow records available

The fluvial hydraulic models will be calibrated and verified against these past flood events. The models will be verified to vertical accuracies of not less than 0.2m and 0.4m for HPWs and MPWs respectively. Calibration and verification of the models will involve adjusting a number of parameters in various combinations during a series of additional simulations, in an attempt to achieve modelled levels closer to the recorded levels. The parameters investigated included channel and structure roughness coefficients, link weir roughness coefficients, tidal boundaries and floodplain resistance.

Rating curve analysis, including hydraulic modelling of the hydrometric stations to reduce uncertainty in extrapolated values will also be used where appropriate to verify the magnitude of observed events.

The results of this historical flood analysis will also be compared with design flood levels and extents to ensure that there is consistency between observed and design events, particularly with reference to the events' estimated AEPs. This desk based historical data analysis along with the information gathered during our site visits will help the modellers to understand the hydrologic and hydraulic behaviour of the river catchment including flood generation mechanism, causes of flooding and constraints (i.e. to establish the source pathway-receptor model).

A review of all previous studies and reports relating to the study area will also be undertaken with relevant data again being used to support the calibration and verification process.

In the case of HA13 none of the watercourses to be modelled are gauged and there are no quantitative flood records (i.e. flood levels) available. RPS will continue to liaise with Wexford County Council to ensure that any available quantitative historical flood information (e.g. flood wrack levels) are obtained.

In the absence of quantitative data, calibration of the hydraulic model will involve a 'reality check' with photographs, historic information and anecdotal accounts of flooding to ensure that the model is representative of the catchment. Should any flood level information become available, the models will be verified to vertical accuracies of not less than 0.2m and 0.4m for HPWs and MPWs respectively. A review of all previous studies and reports relating to the study area will be undertaken with relevant data being used to support the calibration and verification process.

The results of the historical flood analysis will be compared with design flood levels and extents to ensure that there is consistency between observed and design events, particularly with reference to the events' estimated AEPs (where available). This desk based historical data analysis along with the information gathered during our site visits will help the modellers to understand the hydrologic and hydraulic behaviour of the river catchment including flood generation mechanism, causes of flooding and constraints (i.e. to establish the source pathway-receptor model).

Calibration and verification of the models will involve adjusting a number of parameters in various combinations during a series of additional simulations, in an attempt to achieve modelled levels closer to the recorded levels or other available information. The parameters investigated include channel and structure roughness coefficients, link weir roughness coefficients, tidal boundaries and floodplain resistance.

5.3 HYDROLOGICAL ESTIMATION POINTS

Hydrological Estimation Points (HEPs) are located along each modelled watercourse to denote points where hydrological analysis is required for the estimation of design flows that will be used as hydraulic model input. They also serve as check points at gauging station locations, so that the design AEP event is properly derived, particularly in AFAs.

Based on model conceptualisation, and following finalisation of the AFA designations (post PFRA consultation and Flood Risk Review), a GIS exercise is being undertaken to identify HEPs in HA11, 12 and 13. These are identified according to the following categories.

5.3.1 HEP Categories

5.3.1.1 HEP at Upstream Limit of Model

The upstream extent of each model requires an HEP at which design flows and hydrographs will be derived primarily from a rainfall runoff model; or flow estimation methods as appropriate (for example in small catchments). Upstream model limits will always be at 1km² contributing catchment areas or more.

5.3.1.2 HEP where Tributaries enter Modelled Channel

Moving downstream along the modelled reach, an HEP is located where tributaries with catchment areas greater than 5km² enter the channel. The Generic CFRAM Study Brief required these HEPs at tributaries where it was considered that more than 10% of the main channel flow was contributed. However, this application led to an abundance of HEPs at tributary confluences in the upper reaches of catchments, and under representation in the lower reaches. This was discussed with the OPW Suir CFRAM Study team (who were identifying HEPs in the Suir Catchment at the same time) and it was considered that including all tributaries with catchments greater than 5km² would ensure a more appropriate distribution of HEPs at tributary confluences throughout the catchment. On High Priority

Watercourses (HPWs) it will often be appropriate to include flows from catchments which are much smaller than 5km² and where this is the case the inclusion of tributaries will be considered on an individual basis.

5.3.1.3 HEP at gauging stations on Modelled Channel

At gauging stations along the modelled reaches (for which data is available), a HEP is located. These HEPs serve as check points throughout the modelled catchment, so that flow estimates can be calibrated on a catchment basis ensuring appropriate discharges are modelled for each design event.

5.3.1.4 Intermediate/Reporting HEPs

Intermediate/Reporting HEPs have both hydraulic input (top-up) and reporting functions as described below:

- Hydrology estimations at HEPs in the middle of the catchment will be undertaken to ensure that the total contributing catchment at that point in the model can be checked to ensure that the sum of the model inputs are consistent with the total catchment up to that point in the model. Where necessary the models may need to be 'topped up' at these HEPs to ensure all of the contributing catchment is considered.
- HEPs along main channel ensuring there are no reaches greater than 5km without a HEP – this is a requirement of the Generic CFRAM Study Brief. HEPs will serve as reporting points where calibrated peak flows for each design event at the end of the hydraulic analysis task will be reported as a CFRAM Study deliverable.
- HEPs immediately upstream and downstream of AFAs and in the centre of each AFA. This is a requirement of the Generic CFRAM Study Brief. At these HEPs, calibrated peak flows for each design event will be reported at the end of the hydraulic analysis task as a CFRAM Study deliverable.

5.3.1.5 HEP at Downstream Limit of the Model

The downstream extent of each model requires an HEP such that the total contributing catchment can be estimated in order to check that the sum of the model inputs are consistent with hydrology estimations for the whole catchment. These will act as upstream limit HEPs where a further model is connected downstream. Where a gauging station HEP forms the boundary between two models this will act as the upstream and downstream HEP for the respective models.

5.3.2 Catchment Boundaries

As part of the OPW FSU programme, physical catchment descriptors and catchment boundaries were delineated at 500m node points along all watercourses in Ireland (based on 50k mapping), with associated GIS point and polygon shapefiles produced. Each node point has a corresponding NODE

ID. This dataset has been used as the basis for HEP and catchment boundary identification, with adjustments made as necessary.

Where HEPs have corresponding FSU NODE_IDs, the catchment is extracted from the FSU Ungauged Catchment Boundary GIS polygon dataset. This is reviewed by checking mapping, DTM; and LiDAR data where available. Where local knowledge or site walkover information indicates a deviation from the boundary shown, it will be revised accordingly.

Several HEPs do not have a FSU NODE_ID (particularly those at the upstream limit of models) and as such will require catchment delineation. This will be done on GIS using mapping, DTM and LiDAR when available. Again, local knowledge and information gained from site walkover will feed into the process. Urban catchments are particularly relevant in this respect, as catchment boundaries can be affected by drainage infrastructure and engineering interventions such as pumping from one catchment to another in high flows.

5.4 ESTIMATION OF DESIGN FLOW PARAMETERS

5.4.1 Design Flow Estimation

Design flow estimation will be undertaken using the process illustrated by the schematic Figure 5.2. It indicates a two-phased hydrology process. Phase 1 involves initial design flow estimation by two main routes depending on the type of HEP being analysed. These routes are:

- Rainfall run off modelling using NAM to provide peak flow and design hydrograph input to the hydraulic model or;
- Peak flow estimation providing point / lateral flow inputs to the hydraulic model.

When these hydrographs and flows are derived, they will be simulated in the hydraulic model and the outputs compared with observed flows at HEP gauging station check points for the AEP being considered. This brings the process into Phase 2 which is an integrated process between hydrology and hydraulics, iteratively adjusting hydrological inputs until calibration with the HEP gauging station check points is achieved.

In the case of HA13, observed data is not available and catchment sizes for each hydraulic model are very small, consequently the hydrology estimation process must be tailored appropriately. For instance it is unlikely that rainfall runoff modelling will be of benefit due to small catchment size and the absence of observed hydrometric data to achieve calibration. Rather ungauged index flow estimation methods for small catchments, namely the Institute of Hydrology's Report No. 124 (IH) No. 124 (Reference 9) is more applicable, coupled with the relevant growth curve to estimate peak flows for various design AEPs. As such, Phase 1 as indicated on Figure 5.2 will focus on these methods as opposed to rainfall runoff modelling. Therefore boxes 3, 7, 8 and 9 will not apply to HA13.

In Phase 2 of the hydrology process for HA13, the absence of observed data at gauging stations means that catchment flow calibration is not possible. Instead, the focus will be on comparative methods and sensitivity analysis during hydraulic model simulation of the initial flow estimates from Phase 1 until results are achieved that are deemed realistic.

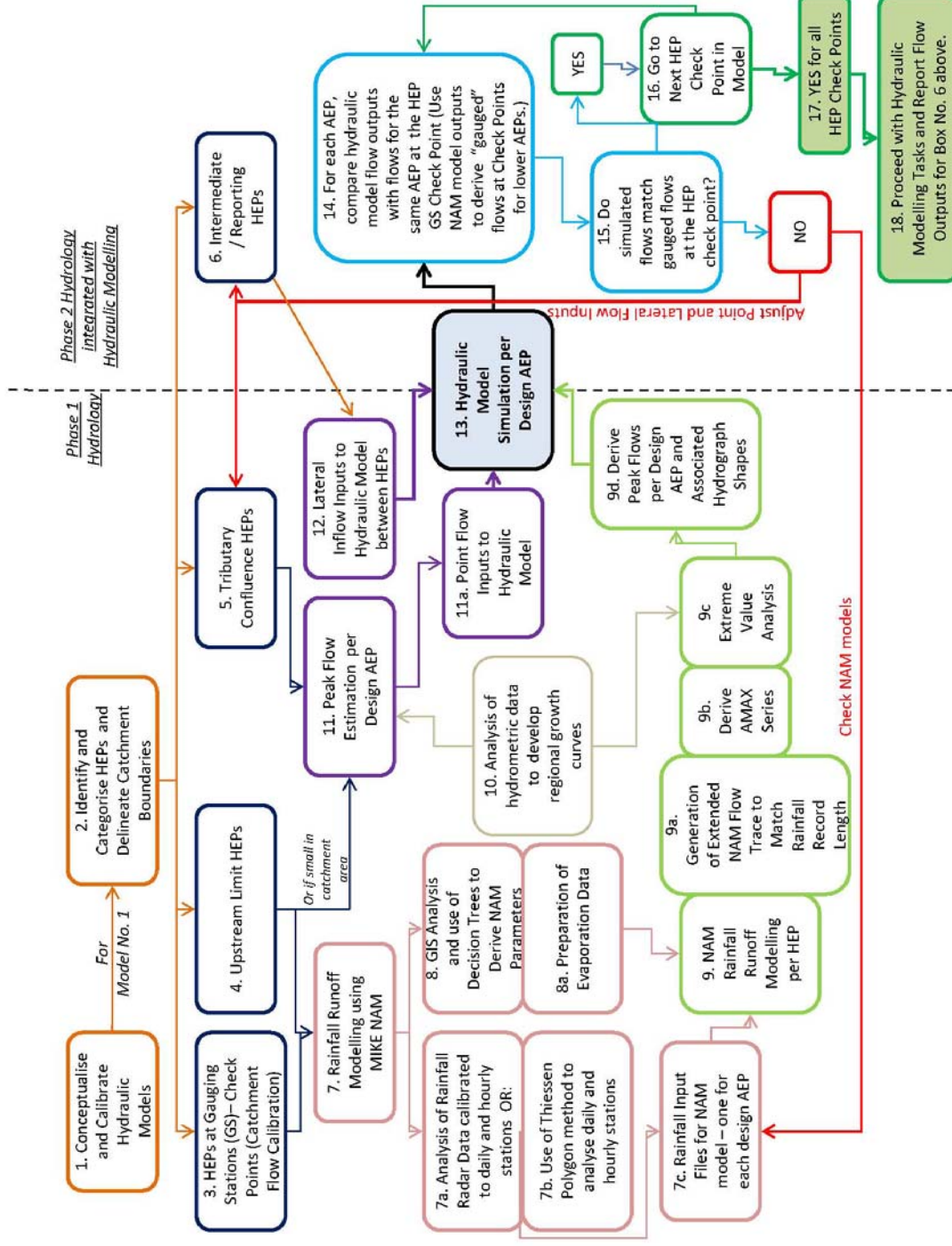


Figure 5.2: Two Phased Hydrology Analysis Process Chart

Boxes 1 and 2 shown in Figure 5.2 relate to Hydraulic Model Conceptualisation/Calibration and defining HEP/Catchment Boundaries as previously described in Sections 5.2 and 5.3. Boxes 3, 4, 5 and 6 relate to the HEP categories as described in Section 5.3.1. The remaining boxes outline the hydrology estimation tasks according to HEP type as undertaken for each hydraulic model, and for each design AEP. The subsequent sections of this chapter describe these tasks and refer back to the box numbers in Figure 5.2 for clarity. Appendix D contains a table indicating the datasets that will be used in completing each task on the process chart according to Box Number.

5.4.2 Phase 1: Derivation of Growth Curves for HA11, 12 and 13 – (Box 10)

In accordance with the FSU method, each of the HEPs should have a separate growth curve. Or as a minimum, a growth curve should be developed at each of the hydrometric stations (gauged or ungauged) on a river network. However this is likely to result in an abundance of growth curves with unrealistic changes to growth factors along modelled reaches. In these circumstances, by examining the catchment characteristics associated with each of the HEP nodes/gauging stations a number of strategic locations or nodes will be identified/selected for which growth curves would be developed on a more regional basis. Alternatively the estimated growth curves at each of the nodes will be grouped into a lesser number of representative growth curves on a zoned basis. Growth curves will be developed using the FSU proposed 'Region-of-Influence' approach. Suitability of a suite of flood like distributions will be examined such as GEV, EV1, GLO and LN2. All relevant calculations will be carried out using a FORTRAN language based Program which was developed by NUI Galway as part of the FSU Work Package 2.2 "Frequency Analysis" (Reference 10).

A review of the available records within the Eastern and South Eastern CFRAM areas showed that there are sufficient records (AMAX) to form a recommended minimum pooling group size of 450 station-years from these records. However, a region can be formed by pooling records from all across Ireland.

- HA11 – has AMAX records of 38 station-years
- HA12 – has AMAX record of 121 station years
- HA13 – has no AMAX records

Therefore for estimation of growth curves at each of the hydrometric gauging locations, pooling of AMAX records from other gauged catchments with similar physiographic and climatological characteristics located in the neighbouring hydrometric areas would be required.

In addition, hydrometric station review outputs from the Suir CFRAM Study will be incorporated to pooling group analysis as deemed appropriate based on the confidence associated with any revised stage discharge relationships and AMAX series.

5.4.3 Phase 1: Calculation of Design Flows at HEPs

In general Figure 5.2 outlines the hydrology estimation methods depending on the type of HEP. Derived peak flows and hydrographs at these HEPs will then be input to the hydraulic model for the design event AEP being considered. Upstream Limit inflows will generally be input to the model as hydrographs or as point flows for small catchments. Flows from tributary confluences will generally be input as point flows, unless the tributary is of a significant catchment area, in which case a hydrograph will be derived for model input. Lateral inflows will also be used to facilitate inclusion of flow inputs between tributaries where necessary. In addition, incoming flow between tributaries will be accounted for in the catchment flow calibration process whereby tributary flow inputs are iteratively adjusted to achieve a match with observed flow at hydrometric stations. The subsequent sections describe the hydrology estimation methods per HEP type.

5.4.3.1 Upstream Limit HEPs (Box 4, 7, 8, 9,11)

The choice of hydrology estimation method for Upstream Limit HEPs largely depends on the contributing catchment area. Rainfall runoff modelling using all available rainfall data and GIS catchment parameters is the preferred method for providing design peak flow and hydrograph input to the upstream limit of each model. This is as outlined in **Boxes, 7, 8 and 9**. Rainfall runoff modelling will be undertaken using MIKE NAM software and is described in detail in Section 5.6.1.

NAM model outputs will provide a flow trace time series equal to that of the rainfall record available. From this an extreme value analysis can be undertaken to derive peak flows for design return periods. For lower AEPs (higher return periods) relevant growth factors as described in Section 5.4.2 will be applied.

Typical hydrograph shape (storm profiles) will be extracted from the NAM flow trace output regarding the shape of the hydrographs (and hence the response of the HEPs catchments) and the hydrograph shape parameters such as: time of the rising part of hydrographs, time of the recession part of the hydrograph, their ratios, the volume of water, the concentration and the response time of the catchment; as well as the antecedent conditions of the catchment that can be inferred from the NAM model parameters. In addition, the up-scaling of hydrographs to represent the lower AEP design flow events that have not been historically recorded will be undertaken. The corresponding rainfall events that generate the design peak flow per return period will be further analysed in terms of their characteristics: intensity, duration, volume and spatiotemporal distribution (if radar data is used). These rainfall events that cause the design peak flows per return period will be also further compared to the Depth Duration Frequency (FSU Work Package 1.2 – Reference 11) growth curves to infer correlation characteristics.

Each Upstream Limit HEP will be individually reviewed to determine suitability of MIKE NAM modelling. If it is the case that the contributing area to the upstream limit HEP is very small, i.e. less than 25km²; ungauged and fairly homogenous, for example small urban streams, it is generally

considered that rainfall runoff modelling would not be applicable and index flow estimation methods (coupled by the relevant growth factor (Section 5.4.2)) such as Institute of Hydrology Report (IH) No. 124 method (Reference 12) would be more appropriate (**Box 11**). IH 124 (refer to Section 5.6.2) remains the recommended estimation method over FSU for small catchments, as advised by OPW. The factorial standard error associated with the QBAR estimation will also be used to calculate 68% and 95%ile confidence intervals. Gauging station data within HA11 and 12 will be analysed to determine a relationship between QBAR and Q_{med} so that a conversion can be undertaken before the relevant growth factor is applied.

Where hydrograph shapes are required for upstream limit model input, the Flood Studies Supplementary Report (FSSR) (Reference 13) Unit Hydrograph Technique or FSU Hydrograph Shape Generator will be explored in an effort to derive the most appropriate hydrograph shapes. These methods are outlined in Sections 5.6.2, 5.6.3 and 5.6.4.

5.4.3.2 HEPs at Tributary Confluences (Box 5, 11, 12)

5.4.3.2.1 Tributary catchments < 25km²

Similar to small Upstream Limit HEPs, these will be assessed using the IH 124 method for small ungauged catchments; coupled with the relevant derived growth curve. However if such catchments are gauged, a single site analysis may be more appropriate.

In the case of HA13 additional methods will be applied to provide comparative results. The FSU Q_{med} estimator calculates Q_{med} based on catchment descriptors in the first instance then provides an adjustment factor from a selected pivotal station to improve the estimate based on gauged data. However, the pivotal site database from which selections are made is lacking in sites with catchments <25km². As such the application of pivotal sites for small catchments may not be appropriate. Consequently IH124 remains the preferred method for index flow estimation in small catchments as advised by OPW. However, the initial Q_{med} estimation from the FSU estimator using catchment descriptors alone could be a useful comparison with the IH 124 results and this shall be explored in ungauged scenarios. Similarly, index flow estimation using the Flood Studies Report shall be explored.

5.4.3.2.2 Tributary catchments >25km²

These will be analysed using FSU Q_{med} estimation coupled with the relevant derived growth curve. Care will be taken to ensure appropriate pivotal sites are selected, drawing first on those upstream or downstream or at least within the hydrometric area. The FSU Q_{med} estimation spreadsheet will be used to calculate Q_{med} using physical catchment descriptors (Q_{medpcd}) associated with the HEP being considered. Pivotal site(s) are then used to adjust the Q_{med} estimation based on catchment descriptors by donating gauging data from a suitable station. This donation is achieved through the use of an adjustment factor which is the ratio of the Pivotal Site's $Q_{medgauged}$ and Q_{medpcd} . The Q_{medpcd} calculated

at the HEP is then multiplied by the adjustment factor to arrive at a final Q_{med} estimation. This can be further adjusted for urbanisation if required.

Selection of pivotal sites is therefore important to ensure that the optimum adjustment factor is applied. The order of preference for pivotal site selection is:

1. A gauging station downstream of the subject site
2. A gauging station upstream of the subject site
3. A gauging station in geographical proximity to the subject site (see below)
4. A gauging station identified by the hydrological similarity measure (see below):

Geographical closeness is calculated automatically by the FSU Q_{med} estimation spreadsheet based on distance from the HEP. Seven pivotal site options are listed. Hydrological Similarity (dij) is calculated automatically by the FSU Q_{med} estimation spreadsheet using AREA, BFIsoil and SAAR physical catchment descriptors. Seven pivotal site options are listed.

If relying on options 3 or 4 due to lack of gauging stations on the watercourse, the wider range of physical catchment descriptors will also be compared for each Pivotal Site option such as FARL, DRAIN, S_{1085} and ARTDRAIN2. It is important to check similarity of these characteristics (attenuation from rivers and lakes, drainage density, catchment slope and whether or not the pivotal site has been arterially drained), as these will affect how appropriate the gauged data will be for donation to the HEP. To compare these descriptors, charts will be plotted showing the relevant values with respect to the HEP value for the same descriptor. The pivotal site which compares best will be chosen. If two pivotal sites are prominent, both can be used in the adjustment, by applying a weighting to each. This weighting will be based on the user's judgement after having looked closely at the catchment descriptors.

Sensitivity analysis on the choice of pivotal site will also be undertaken by plotting the resulting Q_{med} values from each to identify trends and outliers. This will also be done in the context of the 68% and 95% confidence limits associated with the Q_{medpcd} estimation for the HEP, using the FSU factorial standard error of ± 1.37 . This will ensure that the selected pivotal site results in an adjusted Q_{med} estimation that is within the confidence limits. The latest FSU Q_{med} estimation spreadsheet provided by OPW facilitates this sensitivity analysis by automatically populating a scatter chart with the resulting adjusted Q_{med} values per pivotal site option.

For stations where a CFRAM rating review is undertaken, consideration will be given to updating adjustment factors depending on RPS' recommendation on the robustness of the revised rating. The factorial standard error associated with the Q_{med} estimation will also be used to calculate 68% and 95%ile confidence intervals to assist in pivotal site selection and to inform any adjustments to derived flows in catchment flow calibration.

However, if a larger tributary catchment is gauged (say $>100\text{km}^2$ decided on a case by case basis), it is likely to be more appropriate to construct a rainfall runoff model, calibrated to the gauged data, so that a calibrated inflow hydrograph is derived. This will be undertaken where applicable for example, the Bann River which is a large tributary of the River Slaney in HA12. Flow contributions from tributaries $5\text{km}^2 \sim 100\text{km}^2$ will be estimated using index design flood and growth curve derivation methods.

5.4.3.3 HEPs at Gauging Stations – Check Points - (Box 3, 7, 8, 9)

At gauging station locations along the modelled reach (where flow data is available), HEPs are located as check points for catchment flow calibration. At these points, a NAM model will be constructed for the entire upstream catchment, calibrated to available flow data. The generated AMAX series (and growth curve as needed) will be used to derive peak flows for each design return period at the gauging station HEP. This will be used in Catchment Flow Calibration

5.4.4 Phase 2: Catchment Flow Calibration (Box 13 to 18)

The estimated design event flows at Upstream Limit and Tributary (and Intermediate where top-up is required) HEPs will be simulated in the hydraulic model (which will have been calibrated in terms of model parameters e.g. channel and floodplain roughness; structure coefficients to selected flood events, (refer to Section 5.2.2).

The peak flow output from the design event hydraulic model will be compared with that of the combined NAM Check model output at the HEP Gauging Station Check Point **(Box 14, 15)**. Where differences in discharge occur, the NAM models will be checked in terms of model parameters **(Box 7,8,9)** and point and lateral flow inputs will be iteratively adjusted **(Box 11,12)** within relevant confidence intervals until calibration to the gauged data is achieved for each design event **(Box 16)**. This will be undertaken at each HEP gauging station check point moving downstream, to ensure the appropriate peak flow for the design AEP is simulated throughout the catchment **(Box 17)**. Therefore, final design flow estimation will very much be integrated with the hydraulic modelling process.

Of the nine hydrometric stations located on modelled watercourses in HA11, 12and13, three have water level and flow data available for catchment flow calibration (refer to Table 4.6), and are therefore viable has HEP Check Points. The remaining six stations have water level data only. However this level data could be used to compare observed water levels at the check point with the hydraulic model level outputs for higher AEP (lower return period) events i.e. 50% (2 year return period); 20% (5 year return period).

Design rainfall input to the NAM models will be estimated using probabilistic analysis based on radar derived rainfall data series (if approved for use) and treated as a “truth” input”. Hydrological NAM models will be calibrated by adjusting physical model parameters to achieve mass balance, not rainfall input. However if the calibration exercise exhibits significant differences between simulated and

observed flows at the NAM check points, rainfall input files and the associated analysis to derive them will be checked.

FSU Work Package 3.4 (Reference 14) provides river basin modelling guidance; on how to use catchment descriptors to estimate peak flow inputs from tributaries to ensure that the design AEP flow is simulated in the modelled channel (section 13.5.3). Where gauging stations are available, the guidance is followed in that the observed data will be used to adjust flow inputs as required as described above. Where a tributary joins the modelled channel that is ungauged, Table 13.1 in FSU 3.4 report will be used to estimate the return period (and therefore growth factor) to apply to the index flows calculated for tributary input that will result in the design AEP in the main channel. The provided regression equation in 13.5.4 will be used to estimate the time difference between peaks so that the peak flow can be input to the model at the correct time. Where two modelled channels meet, dependence analysis will also be undertaken following FSU WP 3.4 if HEP Check Points are not available.

In the case of HA13, The Phase 1 estimated design event flows at Upstream Limit, Intermediate and Tributary HEPs will be simulated in the hydraulic model and subjected to flow comparisons and sensitivity analysis since observed data is not available to achieve catchment flow calibration.

The comparison process will involve index flow estimation using a range of methods such as the Flood Studies Update Q_{med} estimator and the Flood Studies Report, bearing in mind that IH124 remains the recommended method in Ireland for catchments smaller than 25km^2 . Sensitivity analysis will also be conducted by varying index flow estimations within the associated confidence intervals and simulating the associated peak flows to determine the effect on hydraulic model outputs. In addition, results from neighbouring Hydrometric Areas, particularly coastal ones, will be looked at to gain a feel for what outputs are deemed realistic. The historical review documents in Section 4.3 will also be of use to draw on any anecdotal information which could inform this process in reaching final design flow estimations.

5.4.4.1 Intermediate / Reporting HEPs (Box 6)

As discussed previously the models may need to be topped up at Intermediate HEPs to ensure all of the contributing catchment is considered (e.g. in a long, narrow catchment with many tributaries $<5\text{km}^2$ entering). Where this is considered necessary the additional contributing catchment will be added via lateral inflows upstream of the Intermediate HEP. Intermediate HEPs will also be continuously identified throughout the hydrological analysis when flow checks are required to verify estimations. For example, flow estimations for a tributary entering a modelled reach will be compared with the difference between flow estimates at intermediate HEPs immediately upstream and downstream of the confluence point. These points will be derived from the FSU un-gauged catchment descriptors dataset as required.

Since Intermediate HEPs are located along the modelled reaches they will be used as flow check points and to denote further points in the model for which flow data will be reported for each design AEP. This will facilitate the completion of tables of peak flood levels for all design event probabilities at key points – upstream and downstream of AFAs; in the centre of AFAs and along MPWs with no distance between nodes greater than 5km. In addition, model points will be assigned at every cross section location and flows will be reported for these in accordance with the specification. Note that reporting points based on AFA extent will not be identified until the hydraulic modelling tasks have been completed and AFA extents fully defined.

5.5 SUMMARY OF HEPs IN HA 11, 12 AND 13 AND ASSOCIATED ANALYSIS

Appendix E contains a map showing the layout of HEPs in HA11, 12 and13, and their category. A map showing the contributing catchments to each HEP is also contained in Appendix E.

Table 5.2 provides a summary of the hydrology analysis that will be undertaken at each HEP according to model number and the HEP category. NODE_ID_CFRAM denotes the unique identification number assigned to each HEP. This hydrology analysis is based on the overall methodology and checking each HEP in terms of catchment area, location and its contribution to the hydraulic models.

Table 5.2: Summary of Hydrology Analysis per HA, HEP and Model Number

HA	NODE_ID_CFRAM	HEP CATEGORY	MODEL NO.	HYDROLOGY
11	11_445_1	HEP Upstream Limit	1	Rainfall Runoff Modelling
11	11_445_4	HEP Tributary	1	Peak Flow Estimation
11	11_403_7	HEP Tributary	1	Peak Flow Estimation
11	11_455_2	HEP DS Limit	1	Flow Check /Reporting
11	11_522_2	HEP DS Limit	1	Flow Check /Reporting
11	11_60000_U	HEP Upstream Limit	1	Rainfall Runoff Modelling
11	11_70000_U	HEP Upstream Limit	1	Rainfall Runoff Modelling
11	11_90000_U	HEP Upstream Limit	1	Rainfall Runoff Modelling
11	11_60000_1	HEP Tributary	1	Peak Flow Estimation
11	11_403_4	HEP Upstream Limit	1	Rainfall Runoff Modelling
11	11_264_1	HEP Upstream Limit	1	Rainfall Runoff Modelling
11	11_70000_1	HEP Tributary	1	Peak Flow Estimation
11	11_80000_1	HEP Intermediate	1	Flow Check / Reporting
11	11_90000_1	HEP Tributary	1	Peak Flow Estimation
11	11_442_1	HEP Tributary	2	Peak Flow Estimation
11	11_474_2	HEP Upstream	2	Rainfall Runoff Modelling

HA	NODE_ID_CFRAM	HEP CATEGORY	MODEL NO.	HYDROLOGY
		Limit		
11	11_110_4	HEP Tributary	2	Peak Flow Estimation
11	11_303_3	HEP Tributary	2	Peak Flow Estimation
11	11_442_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_20000_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_10000_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_50000_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_40000_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_172_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_30000_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_10000_1	HEP Tributary	2	Peak Flow Estimation
11	11001	HEP Gauging Stations	2	Catchment Flow Calibration
11	11_140_3	HEP Upstream Limit	2	Rainfall Runoff Modelling
11	11_442_4_RPS	HEP Tributary	2	Peak Flow Estimation
11	11_30000_1	HEP Tributary	2	Peak Flow Estimation
11	11_40000_1	HEP Tributary	2	Peak Flow Estimation
11	11_50000_1	HEP Tributary	2	Peak Flow Estimation
11	11_257_4	HEP Tributary	2	Peak Flow Estimation
11	11_32_2	HEP DS Limit	3	Flow Check /Reporting
11	11_199_2	HEP Tributary	3	Peak Flow Estimation
11	11_100000_U	HEP Upstream Limit	3	Rainfall Runoff Modelling
11	11_110000_U	HEP Upstream Limit	3	Rainfall Runoff Modelling
11	11_200_U	HEP Upstream Limit	3	Rainfall Runoff Modelling
11	11_110000_1	HEP Tributary	3	Peak Flow Estimation
11	11_188_1	HEP Upstream Limit	3	Rainfall Runoff Modelling
11	11_100000_1	HEP Tributary	3	Peak Flow Estimation
11	11_481_1	HEP Upstream Limit	3	Rainfall Runoff Modelling
11	11_189_1_RPS	HEP Tributary	3	Peak Flow Estimation
12	12_2308_5_RPS	HEP Tributary	1	Peak Flow Estimation
12	12_2308_U	HEP Upstream Limit	1	Rainfall Runoff Modelling
12	12013	HEP Gauging Stations	1	Catchment Flow Calibration
12	12_2309_1	HEP Upstream Limit	1	Rainfall Runoff Modelling

HA	NODE_ID_CFRAM	HEP CATEGORY	MODEL NO.	HYDROLOGY
12	12_2200_2	HEP Tributary	1	Peak Flow Estimation
12	12_1707_2	HEP Tributary	2	Peak Flow Estimation
12	12_531_8	HEP Tributary	2	Rainfall Runoff Modelling
12	12_535_7	HEP Tributary	2	Peak Flow Estimation
12	12_10000_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
12	12_1707_U	HEP Upstream Limit	2	Rainfall Runoff Modelling
12	12005	HEP Gauging Stations	2	Catchment Flow Calibration
12	12006	HEP Gauging Stations	2	Catchment Flow Calibration
12	12_535_1	HEP Upstream Limit	2	Rainfall Runoff Modelling
12	12_539_3	HEP Upstream Limit	2	Rainfall Runoff Modelling
12	12_1727_4	HEP Tributary	2	Peak Flow Estimation
12	12_835_7	HEP Tributary	2	Peak Flow Estimation
12	12_1639_3	HEP Tributary	2	Peak Flow Estimation
12	12_1663_2	HEP Intermediate	2	Rainfall Runoff Modelling
12	12_1656_2	HEP Intermediate	2	Rainfall Runoff Modelling
12	12_10000_1	HEP Tributary	2	Rainfall Runoff Modelling
12	12_1647_1	HEP Intermediate	2	Rainfall Runoff Modelling
12	12_2326_7_RPS	HEP Tributary	3	Peak Flow Estimation
12	12_940_5	HEP Tributary	3	Peak Flow Estimation
12	12_2098_2	HEP Tributary	3	Peak Flow Estimation
12	12_20000_U	HEP Upstream Limit	3	Rainfall Runoff Modelling
12	12001	HEP Gauging Stations	3	Catchment Flow Calibration
12	12_2326_4	HEP Upstream Limit	3	Rainfall Runoff Modelling
12	12_2357_1	HEP Upstream Limit	3	Rainfall Runoff Modelling
12	12_910_6	HEP Tributary	3	Peak Flow Estimation
12	12_968_6	HEP Tributary	3	Peak Flow Estimation
12	12_930_7	HEP Tributary	3	Peak Flow Estimation
12	12_932_5	HEP Tributary	3	Peak Flow Estimation
12	12_946_4	HEP Tributary	3	Peak Flow Estimation
12	12_955_9	HEP Tributary	3	Peak Flow Estimation
12	12_2065_3	HEP Tributary	3	Peak Flow Estimation
12	12_934_6	HEP Tributary	3	Peak Flow Estimation
12	12_2084_5	HEP Tributary	3	Peak Flow Estimation
12	12_2326_6	HEP Intermediate	3	Peak Flow Estimation
12	12_574_1	HEP Intermediate	3	Peak Flow Estimation
12	12_2098_1	HEP Intermediate	3	Peak Flow Estimation

HA	NODE_ID_CFRAM	HEP CATEGORY	MODEL NO.	HYDROLOGY
12	12_2079_2	HEP Tributary	4	Peak Flow Estimation
12	12_2296_3	HEP Tributary	4	Peak Flow Estimation
12	12_2460_2	HEP Tributary	4	Peak Flow Estimation
12	12_1858_2	HEP Tributary	4	Peak Flow Estimation
12	12_2085_5	HEP Tributary	4	Peak Flow Estimation
12	12_2323_4	HEP Tributary	4	Peak Flow Estimation
12	12_2603_2	HEP Tributary	4	Peak Flow Estimation
12	12_2079_U	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_2296_U	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_2460_U	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_1858_U	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_30000_U	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12002	HEP Gauging Stations	4	Catchment Flow Calibration
12	12007	HEP Gauging Stations	4	Catchment Flow Calibration
12	12008	HEP Gauging Stations	4	Catchment Flow Calibration
12	12009	HEP Gauging Stations	4	Catchment Flow Calibration
12	12061	HEP Gauging Stations	4	Catchment Flow Calibration
12	12_2052_3	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_2611_1	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_761_3	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_577_1	HEP Upstream Limit	4	Rainfall Runoff Modelling
12	12_921_2	HEP Tributary	4	Rainfall Runoff Modelling
12	12_2075_5	HEP Tributary	4	Peak Flow Estimation
12	12_958_4	HEP Tributary	4	Peak Flow Estimation
12	12_2601_6	HEP Tributary	4	Rainfall Runoff Modelling
12	12_2605_1	HEP Tributary	4	Rainfall Runoff Modelling
12	12_30000_1	HEP Tributary	4	Rainfall Runoff Modelling
12	12_2604_2	HEP Intermediate	4	Rainfall Runoff Modelling
12	12_2604_1	HEP Intermediate	4	Rainfall Runoff Modelling
12	12_2323_1	HEP Intermediate	4	Peak Flow Estimation
12	12_2329_6	HEP Intermediate	4	Rainfall Runoff Modelling
12	12_2284_1	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_2289_1	HEP Tributary	5	Peak Flow Estimation
12	12_2284_3	HEP DS Limit	5	Peak Flow Estimation

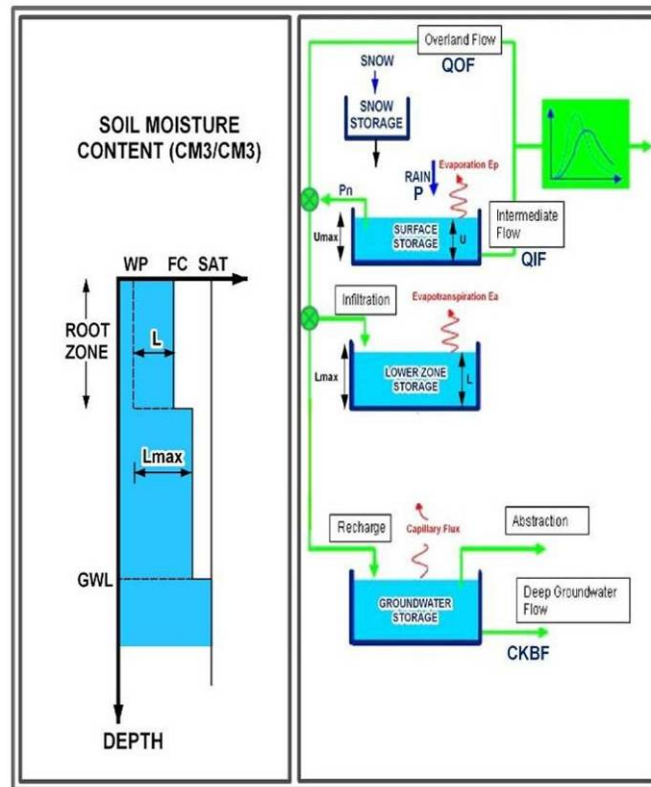
HA	NODE_ID_CFRAM	HEP CATEGORY	MODEL NO.	HYDROLOGY
12	12_2289_7	HEP DS Limit	5	Peak Flow Estimation
12	12_2334_2	HEP DS Limit	5	Peak Flow Estimation
12	12_2147_U	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_2289_U	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_40000_U	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_50000_U	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_50002_U	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_50001_U	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_50003_1	HEP Tributary	5	Peak Flow Estimation
12	12_50003_U	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12064	HEP Gauging Stations	5	Catchment Flow Calibration
12	12_2597_6	HEP Tributary	5	Peak Flow Estimation
12	12_2579_2	HEP Tributary	5	Peak Flow Estimation
12	12_2565_2	HEP Tributary	5	Peak Flow Estimation
12	12_2545_2	HEP Tributary	5	Peak Flow Estimation
12	12_2147_2	HEP DS Limit	5	Peak Flow Estimation
12	12_50001_1	HEP Tributary	5	Peak Flow Estimation
12	12_2456_3	HEP DS Limit	5	Peak Flow Estimation
12	12_766_2	HEP Upstream Limit	5	Rainfall Runoff Modelling
12	12_50002_1	HEP Tributary	5	Peak Flow Estimation
13	13081	HEP Gauging Stations	1	NO FLOW DATA
13	13_146_2	HEP Tributary	1	Peak Flow Estimation
13	13_491_1	HEP Upstream Limit	1	Peak Flow Estimation

5.6 DETAILS ON DIFFERENT HYDROLOGICAL ESTIMATION METHODS

5.6.1 Rainfall Runoff Catchment Modelling – MIKE NAM

Hydrological modelling for the GIS-delineated catchments of the identified HEPs will be carried out using NAM rainfall-runoff simulator of the MIKE 11 modelling software. MIKE NAM is a deterministic lumped hydrological rainfall-runoff model that operates by continuously accounting for the runoff and soil moisture content in three different and mutually interrelated storages (nonlinear reservoirs), which represent physical elements of a catchment (surface storage, root zone and ground water storages) as illustrated by Figure 5.3 below. Being a lumped model, it treats each sub-catchment as one unit;

therefore the parameters and variables considered represent average values for the catchment areas and are very sensitive as calibration parameters.



- (U_{MAX}) - maximum water content in the surface storage– affects overland flow, recharge, amounts of evapotranspiration and intermediate flow;
- (L_{MAX}) - maximum water in the lower zone/root zone storage– affects overland flow, recharge, amounts of evapotranspiration and intermediate flow;
- (CQ_{OF}) - overland flow coefficient– affects the volume of overland flow and recharge;
- (CK_{IF}) - intermediate flow drainage constant– affects the amount of drainage from the surface storage zone as intermediate flow;
- (TOF) - overland flow threshold– affects the soil moisture content that must be satisfied for quick flow to occur;
- intermediate flow threshold (TIF) - affects the soil moisture content that must be satisfied for intermediate flow to occur;
- ($CK_{1,2}$) - time constant for overland flow– affects the routing of overland flow along catchment slopes and channels;
- (TG) - deep groundwater recharge threshold - affects the soil moisture content that must be satisfied for groundwater recharge to occur;
- (CKBF1- time constant for deep groundwater flow) - affects the routing of groundwater recharge in the regional aquifers.
- Q_{OF} - Overland flow
- Q_{IF} - Intermediate flow

Figure 5.3: NAM model structure (SWRBD/RPS, Reference 15)

MIKE NAM utilises all available rainfall data as hydrological model input, together with parameters to describe catchment response. The post calibration output is a flow trace matching the time series of available rainfall data. This will provide hydrograph shape, and an extended AMAX series from which peak flows can be derived using growth curves as required (refer to Section 5.4.2). The benefit of this approach is that a discharge file will be generated for the entire length of rainfall record available, as opposed to limiting the AMAX series to the length of the hydrometric record. This maximises the length of AMAX series from which to calculate peak flows per AEP (using derived growth curves where required). Furthermore, using the NAM hydrological models, simulation of the typical shape of

the hydrograph as a response of the catchment area for the peak flows per return periods will be undertaken. This will provide the key parameters describing the shape of the hydrograph per event, such as the time of concentration – T_c , rising time of the hydrograph – T_p , recession time of the hydrograph – T_r and their ratios.

5.6.1.1 NAM Parameters

The NAM model includes 5 state variables and 9 model parameters. The state variables are: SS - initial snow storage; U - upper zone storage (U/U_{max}); L - lower zone storage (L/L_{max}); QR1 - Initial runoff from routing reservoir #1; QR2 - Initial runoff from routing reservoir #2.

The model parameters are:

- U_{max} (mm) – the maximum water content in the surface storage;
- L_{max} (mm) the maximum water content in the root zone storage;
- CQOF - is the overland flow runoff coefficient;
- CKIF (hrs) – the interflow time constant routing parameter;
- CKBF - is the time constant for deep groundwater flow;
- CK_{12} - is the time constant for overland flow routing, this is an important parameter and it depends on the size of the catchment and how fast it responds to rainfall;
- TOF - time transfer factor for the overland storage;
- TIF - time transfer factor for the interflow storage;
- TG - time transfer factor for the groundwater storage.

Based on previous NAM hydrological modelling studies (including parameters sensitivity analysis), RPS and HydroLogic will use a physically-based approach to estimate the values of some of the key NAM model parameters using a decision tree and utilising the available GIS data sets for the Eastern CFRAM Study area. The following parameters will be estimated based on a decision tree methodology:

- The **surface storage U_{max}** [mm] is defined as the volume of water stored on foliage and generally on the surface following rainfall, but also in dips and puddles and subsurface non groundwater storage, which can feed the interflow discharge component. It is usually in the order of 5-25 [mm], is available for immediate evaporation and excludes moisture stored in soil and subsoil. Steep ground tends to have less surface storage compared to for example drumlin landscapes, also for large vegetation types i.e. trees or shrub the storage is greater compared to grass or rocky surfaces. Calibration of this parameter is often achieved through assessment of the overall water balance; this requires good evaporation information ideally varying on a weekly or monthly interval. Once the surface storage is depleted interflow ceases to exist in the model and evaporation takes place from the lower or soil moisture storage at a

slower rate. Overland flow is only present while the surface storage is fully replenished in the model.

- The maximum amount of overland flow is given by the **overland flow runoff coefficient CQOF** [/], which is often higher compared to other deterministic models, as the actual runoff is also proportioned in relation to the soil moisture at each time step.
- The time constant for **interflow CKIF** [hour] controls how fast water can be discharged from the surface storage into the stream, though as with the overland flow this is proportioned by the ratio of available soil moisture to the total soil moisture storage.
- The **discharge from the ground water** reservoir is simulated through a recession relationship defined by a time constant **CKBF** [hour]. As the constant already suggests the flow simulated is baseflow, i.e. a very slowly varying stream flow component, often attributed to the groundwater reservoir, though in some instances this might also be due to large peat layers in the catchments. Attempts have been made to simulate this behaviour through splitting the baseflow into two components with varying discharge time constants often found in peat catchments in wet and dry seasons.

As part of the Water Framework Directive further characterisation study ‘An Integrated Approach to Quantifying Groundwater and Surface Water Contributions of Stream Flow’ (Reference 15), a series of decision tables were developed to determine four NAM parameters - the coefficient for overland flow (CQOF), the time constant for overland flow (CK1,2), the surface storage zone (Umax), the time constant for interflow (CKIF) and the time constant for baseflow (CKBF). The decision tables were based on the assessment of GIS datasets, as well as expert judgement (e.g. gravels scenario).

An example decision tree for determination of the NAM model parameters is presented in Table 5.3 below. Similar decision trees (lookup tables) are available for the rest of the NAM model parameters.

Table 5.3: Example decision table for the determination of the NAM surface storage zone (U_{max}), (SWRBD, RPS, 2008)

NAM Parameter	Corine	Range of NAM parameter value	Slope	Lakes	Poorly drained soils	Urban	GIS estimation for sub-catchment
U_{max} (mm)	>5% Forestry and Semi-natural areas	15 -25	Steep slope (>5%): lower end of limit	Lakes > 1%: 15 – 20	High percentage of poorly drained soils (>50%): upper end of limit	If >2% urban areas: upper end of limit	1A, 2B, 3C
	Forestry 0 – 5% and Pastures > 40%	10 – 20	Relatively flat slope (<5%): upper end of limit		Low percentage of poorly drained soils (<20%): lower end of limit		1B, 2C
	Forestry 0%, Pastures <40% and Bare rock >20%	8 - 15					4A, 4B

The example decision table presented in Table 5.3 is to determine the value of U_{max} (*surface storage zone*) for each catchment. U_{max} is controlled by vegetation - which can intercept moisture - and depressions in a catchment. The amount of water that is stored in the surface storage zone is also controlled by evaporation and drainage to the subsurface. The range of U_{max} values are controlled by the proportion of forestry, agricultural land and outcropping rock. Forestry has a higher potential to intercept the moisture from rainfall compared to agricultural land and bare rock. The 'Corine' column in Table 5.3 gives upper and lower limits of percentage cover of forestry, agricultural land and outcropping rock. The catchment under investigation is assigned to one of the three categories (depending on its land cover), with a broad range of U_{max} values given in the adjacent column.

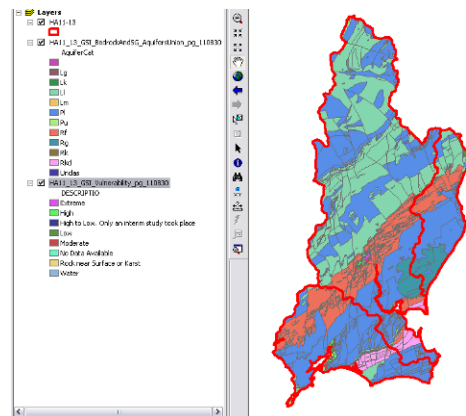
The selected value of U_{max} for a catchment can be further refined dependent upon the average slope, coverage by lakes, coverage by wet soils and the amount of urban area. For example, the U_{max} value would be expected to be at the lower end of the land cover ranges if the average slope of a catchment is relatively steep (>5%). Also, a high percentage of lakes will act as storage resulting value of U_{max} at the upper end of the land cover ranges. Similarly, a high proportion of wet soils and urban areas will intercept rainfall and affect U_{max}.

River catchments are not necessarily composed of one aquifer type and more often than not contain mixed aquifers. The method for estimating the NAM parameters CQOF, CKIF and CKBF is based on single aquifer types. For the mixed aquifer scenarios an *area percentage of each aquifer type in the catchment* approach will be used to estimate these NAM parameters.

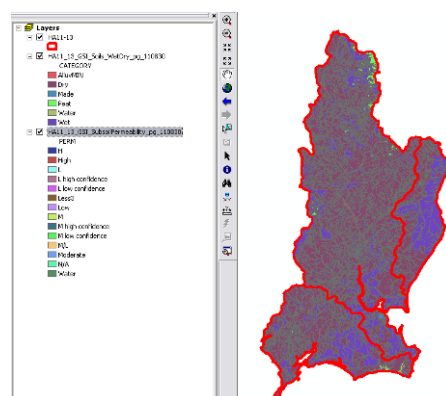
The initial estimation of these 4 parameters (Umax, CQOF, CKIF and CKBF) driving the rainfall-runoff process will be done using the available GIS datasets, namely:

- GSI_BedrockAndSG_AquifersUnion_pg_110830 - *aquifer type*
- GSI_Soils_WetDry_pg_110830 - *poorly drained soils*
- GSI_SubsoilPermeability_pg_110830 – *permeability*
- GSI_Vulnerability_pg_110830 – *ground water vulnerability*
- DTM
- Corine Land Use GIS layer

Bedrock Aquifer Type and Groundwater Vulnerability



Sub Soil Permeability and Soil Drainage



Land Use

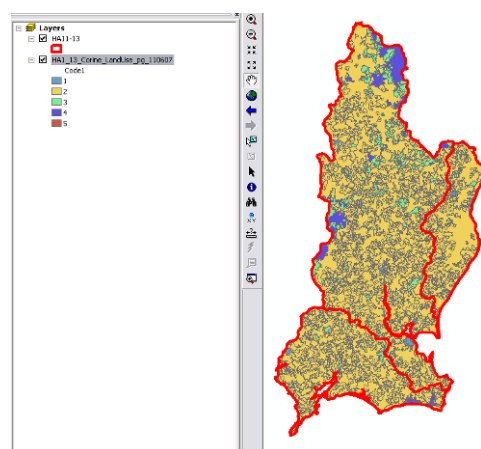


Figure 5.4: Available GIS datasets for deriving the NAM model parameters in HA11, 12 and 13

The parameters for the NAM modelling that have not been estimated based on the aforementioned WFD Study are the maximum soil moisture content in the root zone, storage available for vegetative transpiration (Lmax, measured in mm) and the threshold values for overland flow, intermediate flow and deep groundwater flow (the L/Lmax value at which that component of flow occurs).

Based on NAM modelling undertaken for the Neagh Bann catchment study in Northern Ireland (Reference 16) it is suggested to use the following default values for the initial modelling of further catchments:

- Maximum soil moisture content in the root zone storage L_{max} : 120mm;
- Threshold value for overland flow: 0.6;
- Threshold value for interflow: 0.5;
- Threshold value for groundwater flow: 0.4.

The value of these parameters should be altered during the modelling to improve the correlation and water balance. There are certain circumstances within catchments that will indicate the threshold values. If a catchment has mainly dry soils or high permeability subsoils then the threshold value for overland flow will tend towards one i.e. the root zone storage must be saturated before overland flow will occur. If a catchment contains mainly exposed karst aquifers or gravel aquifers then the threshold value for overland flow will tend towards 1 and the threshold value for intermediate flow will tend towards zero i.e. flow will be routed to the intermediate component almost as soon as precipitation occurs.

HydroLogic is currently looking at developing ArcGIS scripts that will automate the estimation of the NAM model parameters:

- Based on the defined HEP and delineated catchment area using the national DTM provided by OPW;
- Overlay the catchment boundary (polygon) with the available GIS layers.
- Use the look-up decision trees (see tables) to initially estimate the 4 parameters: U_{max} ,
- Write / update the NAM model input files.

This methodology will provide a more realistic narrowed range of values for the most sensitive NAM model parameters. For example, if using the decision tree one estimates from the GIS data for a given HEP catchment area $U_{max} = 15-25$ [mm], initially the mid value will be used to instantiate the NAM model ($U_{max} = 20$ [mm], in this case). If measured data is available (water levels / flows) at HEPs Gauging Station check points further autocalibration procedures will be used to fine-tune the model parameters and generate a better fit between the measured and simulated flows, as described below. Note that during the autocalibration process the allowable values for the model parameters (U_{max} in this example) will be set within the estimated narrowed bands, $U_{max} = 15-25$ [mm] in this case. For HEPs without gauged hydrometric data, NAM model autocalibration procedure will not be carried out and the values of the model parameters estimated by the decision tree approach will be used for hydrological modelling. These will then be revisited if hydraulic model simulation at NAM check points identifies differences between hydraulic model flow and observed flow at the hydrometric station. (Refer to Figure 5.2: Two Phased Hydrology Analysis Process Chart).

5.6.1.2 MIKE NAM Calibration

Where gauged data is available, i.e. at 9 locations along modelled watercourses as shown in Figure 4.2, MIKE NAM models will be calibrated to produce a discharge file as similar as possible to the actual gauged data. The NAM model software has an autocalibration function which will be utilised for each of the gauged catchment rainfall-runoff models. Recorded discharge data from the appropriate gauge will be entered into the model as part of the autocalibration process. The models will then be run in autocalibration mode where the software allocates appropriate values to the NAM parameters and uses the rainfall and evaporation data (as provided by Met Éireann) to produce a discharge file as similar as possible to the actual gauged data. This autocalibration exercise will result in a roughly calibrated model. Calibration Plots will be produced to compare the discharge file with gauged data, after which a second phase of calibration will be undertaken by adjusting NAM parameter values until satisfactory calibration is achieved.

- Optimisation Stage 1: optimising the water balance using multi-objective genetic algorithm.
- Optimisation Stage 2: optimising the hydrograph shape using multi-objective genetic algorithm.

The objective function can be a combination from different error measures (goodness of fit) between the measured flow and the computed flow, such as Root Mean Square Error (RMSE); Coefficient of correlation (CC) and determination (COD); Coefficient of variance (CV); Second momentum (MM); Proportional error estimate (PEE) specialising on both, peak and base flows. Additional tools for analysis of the calibrated NAM models will be also provided, see Figure 5.5.

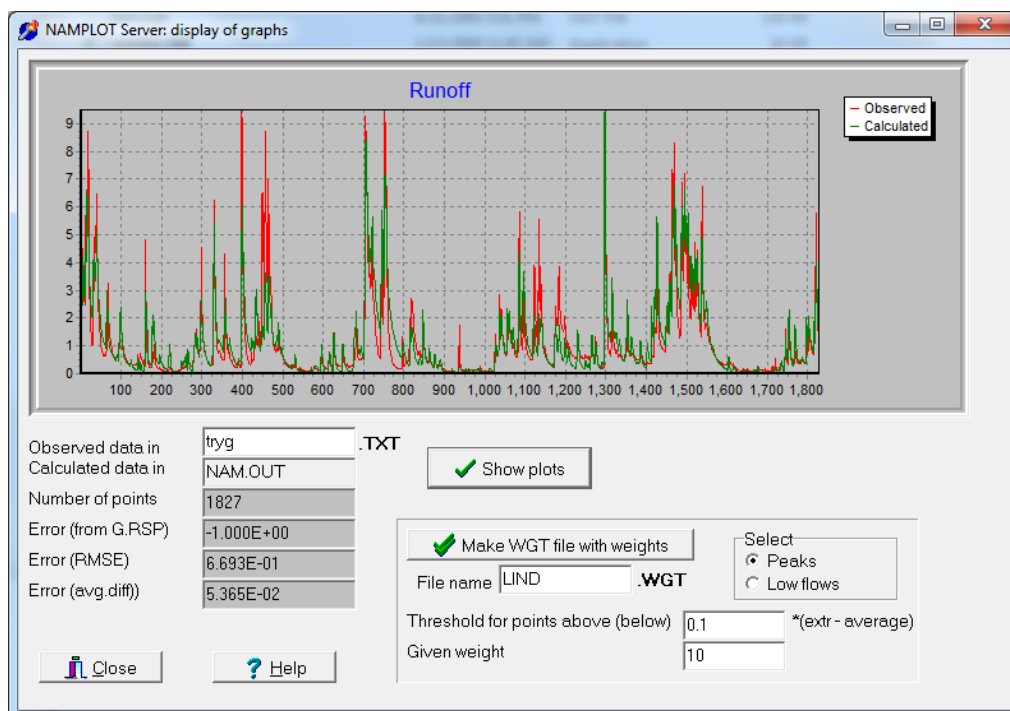


Figure 5.5: Visualization tools for the NAM model calibration component.

It may be necessary in urban areas such as Enniscorthy, to utilise the Urban function of MIKE NAM to more accurately simulate runoff in highly impervious areas. Where Urban models are created, they will be joined with the NAM models in Combined hydrological models.

As outlined in Sections 5.4.3.3 and 5.4.4, for catchment flow calibration, where NAM models are used at upstream limits HEPs (upstream boundary conditions), the calibration of the models for a hydrometric station which is further downstream will be undertaken by setting-up an integral NAM model at the hydrometric station which will have the sub-catchments of the upstream models included. For example, in HA12, Hydraulic Model 1 at Baltinglass has two upstream limit NAM model with a HEP Gauging Station Check Point further downstream of the town. In this case, three NAM models will be set up - one NAM model at the HEP upstream limit and one joint NAM model at the HEP gauging station in order to undertake the catchment based NAM model calibration.

For NAM models at HEP tributaries which have significant contributing flows to the main stream as hydrodynamic model (MIKE 11), a joint hydrological and hydrodynamic calibration will be carried out.

Based on the initial HEPs catchments analysis, it is estimated that approximately 30% of the NAM models will have gauging stations that will enable full NAM model calibration. Typically for these models our experience is that 70% of the available data is used for model calibration with the remainder held for validation along with any new flow data that may become available during the modelling period.

The RPS hydrology methodology is not dependent on simulated rainfall profiles being identified as the complete rainfall record will be input to the NAM models and following calibration against hydrometric gauge records, the NAM modelling will determine the rainfall events which will dictate the size of the index flood, Q_{med} . If the rainfall radar trials are successful and this method of analysis is rolled out to the entire Eastern CFRAM area the rainfall inputs used in the NAM modelling process will be generated from a combination of rain gauge data and radar data using the methodology outlined in Appendix C. In the event that the rainfall radar approach is not adopted the rainfall profiles will be derived from gauge data alone and distributed using Thessian polygons or similar approaches, with reference to the FSU Depth Duration Frequency (FSU Work Package 1.2 – Reference 10) recommendations where appropriate.

5.6.2 Institute of Hydrology Report No. 124

This statistical method was developed by the Institute of Hydrology (IH) in the UK for small catchments (<25km²). It was developed in 1994 and does not contain any Irish catchment data. However, it is the preferred method for smaller catchments in Ireland and it is still recommended by OPW.

There are two applications within the loH 124 report:

1. Replacement of Time to Peak Equation in FSSR Unit Hydrograph method (refer to Section 5.6.4) for small catchments so that a hydrograph can be generated
2. Use of QBAR estimation equation by catchment characteristics and a growth curve to estimate Q_t where peak flows only are required. The Factorial Standard Error associated with this method for QBAR estimation is 1.651. The relationship between QBAR and Q_{med} must then be derived from relevant gauging data so that Q_{med} can be calculated.

5.6.3 Flood Studies Update (FSU) Q_{med} Estimation

As referred to in Section 5.4 the OPW have been preparing an extensive update of the Flood Study Report for Ireland. This is referred to as the FSU Programme and is to provide improved methods of extreme rainfall and flood estimation at both gauged and ungauged locations in Ireland (FSU, Alpha Testing Users Guide, 2011 – Reference 17). It has been in development since 2004 and is in the final stages of completion.

A software application in under development however pending its completion the OPW provided excel automated spreadsheets for the following calculations:

1. Q_{med} estimation for ungauged sites based on catchment descriptors and factored based on gauging information at suitable pivotal sites.
2. Pooled Frequency Analysis to estimate the appropriate growth curve and associated factor for obtaining Q values for required return periods. This process also uses pivotal stations to compile pooling groups of data.
3. Generation of Hydrograph Shape using the parametric method based on catchment descriptors and the Q value obtained in Step 2. This process also uses pivotal site data, but the number of stations across the country deemed suitable for this purpose is smaller than for Q_{med} estimation.

The factorial standard error value associated with this method is 1.37 for Q_{med} estimation.

The recommended method for flood estimation in small catchments (approx $<25\text{km}^2$) is still IH 124 as there is not enough gauged data from small catchments to serve as pivotal sites in the FSU as of yet.. OPW are working on augmenting the gauged data with smaller catchments at present.

If hydrographs are required as model input at HEP tributary locations consideration will be given to applying the FSU derived flood peak to a hydrograph shape derived from the FSSR Unit Hydrograph method. Whilst FSU hydrograph shape generation is relatively new, FSU derived flows may be better applied using a bridging method between the FSU and the Flood Studies Supplementary Report (FSSR) rainfall runoff Unit Hydrograph Method. The report on Work Package 3.5 of the FSU (Reference 18) discusses such an approach calling it an Interactive Bridge Invoking the Design Event Method (IBIDEM) and aims at providing a bridge between the FSU method of estimating a design

flood hydrograph and the FSSR design method that it replaces. If it is found that the FSU Hydrograph Shape generator does not yield usable hydrographs e.g. infinite receding limb; inaccurate representation of water volume, this option will be considered. It may also be the case that nearby NAM model outputs provide an indication of catchment response and a typical hydrograph shape. This will also be considered when deriving appropriate hydrograph shapes to inform the overall process.

5.6.4 FSSR Unit Hydrograph Method

The FSSR Unit Hydrograph method is a deterministic method for estimating design hydrographs (Reference 13). It is a rainfall runoff method based on estimating a unit hydrograph using catchment descriptors and estimating critical rainfall for design storm duration i.e. rainfall and catchment response to develop the storm hydrograph.

The Flood Studies Report undertook a comprehensive analysis of rainfall and discharge data in UK and Ireland up to 1970 and contains a series of maps of various quantities derived for rainfall data.. Regional analysis was undertaken in the UK, but Ireland was taken as a single region which is widely accepted as an inaccurate representation of the east-west differences on the Island. In cases where this method is applied to Upstream Limit or Tributary HEPs in this Study, appropriate rainfall profiles will be used based on the rainfall data analysis described in Section 5.1.3.

A spreadsheet calculation will be used to input relevant catchment descriptors to calculate Time to peak, data intervals, storm duration, rainfall amount for the required return period, standard percentage run off and base flow. ISIS software then facilitates an automated convolution process to draw the hydrograph shape and provide the Q and time data necessary for hydraulic model input.

6 DETAILED METHODOLOGY REVIEW

The discussion regarding data collection, gaps and outstanding information, presented in Section 2 of this South Eastern CFRAM Study Inception Report - HA11, HA12 and HA13 (Owenavorrhagh, Slaney and Wexford Harbour and Ballyteigue-Bannow), informs the methodology risks and opportunities review.

The following general mechanisms are available for methodology amendments:

- Technical notes – used to expand or update methodology at appropriate project planning stages;
- Inception report (this report) – used to expand or update methodology in response to formal data review six months into the contract; and
- Agreed changes to scope of services (under Clause 2.6.2 of the National Flood Risk Assessment and Management Programme, South Eastern River Basin District Catchment-based Flood Risk Assessment and Management (CFRAM) Study Stage II Tender Documents: Instructions to Tenderers – used to add or remove specified contract items.

Given the tightly prescribed work scope and tender specification and the fact that most of the datasets are as expected in terms of quality and availability, there have been a small number of methodology amendments in the HA11, HA12 and HA13 to date.

A brief summary of the status with regard to tendered methodology for each of the individual project tasks is as follows:

- General Requirements – there has been no methodology change with regard to level of detail, management arrangements, project inception, web-based work platform, project website, use of digital media and GIS and health and safety requirements. These activities are all either complete or currently in place and ongoing during the study. Technical training and National Technical Coordination Group participation have not yet commenced awaiting delivery/ procurement of other CFRAM Study partners however these are not currently critical path and no associated methodology changes are proposed at present. There is a requirement under the South Eastern CFRAM Study brief to liaise with the Suir CFRAM Pilot Study, reporting and technical activities in this regard are summarised in Section 6.2.
- Data Collection – section 2 of this report details the collection of relevant datasets and the initial phase has concluded in accordance with the tendered methodology. Further data or updates will be pursued on an as needed basis or as they emerge. Flood event response activities will remain ongoing in accordance with the Generic CFRAM Study Brief and a project specific flood event response plan is detailed in a Technical Note (Section 6.2).

- Flood Risk Review – this task is complete and the final report with RPS recommendations to OPW has been issued. The methodology for this task was updated as detailed in a Technical Note (Section 6.1).
- Surveys – there are a number of issues regarding survey contract award and subsequent delivery timescales which pose potential project time constraints for the follow on tasks of hydraulic modelling and flood mapping and may jeopardise delivery and consultation milestones in 2013. These risks and possible mitigation measures are discussed in more detail in Section 6.1.
- Hydrological Analysis – section 4 of this inception report expands on the tendered hydrological methodology as applied to HA11, HA12 and HA13. In addition a proposal to improve the rainfall inputs to the hydrological and hydraulic models by using RADAR rainfall data is being implemented on a staged basis as detailed in a Technical Note (Section 6.2).
- Hydraulic Analysis – there is no tendered methodology change proposed in HA11, HA12 and HA13 to date.
- Flood Risk Assessment – there is no tendered methodology change proposed in HA11, HA12 and HA13 to date.
- Environmental Assessment – there is no tendered methodology change proposed in HA11, HA12 and HA13 to date.
- Consultation And Engagement – there is no tendered methodology change proposed in HA11, HA12 and HA13 to date.
- Development Of Flood Risk Management Options – there is no tendered methodology change proposed in HA11, HA12 and HA13 to date.
- Preparation Of Flood Risk Management Plans – there is no tendered methodology change proposed in HA11, HA12 and HA13 to date.
- Reporting And Deliverables – there is no tendered methodology change proposed in HA11, HA12 and HA13 to date.

RPS maintains a live project risk and opportunities register to consider implications for programme, quality and budget for the South Eastern CFRAM Study, which is reviewed at regular project working group meetings. This process has identified a small number of risks and opportunities that have a direct bearing on task methodology which are discussed in the following report sections.

6.1 RISKS AND PROPOSED METHODOLOGY AMENDMENTS

Flood Risk Review – the methodology applied in the South Eastern CFRAM study followed that developed for the Eastern CFRAM Study detailed in Technical Note 1 (IBE0601 TN0001). This details an updated methodology for flood risk review (FRR) in the South Eastern study area based on the progress with the Preliminary Flood Risk Assessment (PFRA) between time of generic specification and tender and the South Eastern CFRAM Study FRR. Updated consultation, scoring and modelling approaches were set out in the document in order to progress the task in the absence of some data sets (such as flood defence databases) which were not available at the time of the FRR due to the delayed start date of the overall project.

Surveys – the Generic CFRAM Study brief requires the following surveys:

- Defence asset condition survey – project specific specification applies to HA11, HA12 and HA13, these surveys are not yet scheduled to commence (programmed for June 2012 – September 2012 these surveys are subject to locations being identified by structure and cross section survey contracts), no methodology change is proposed at this stage.
- Property survey – project specific specification applies to HA11, HA12 and HA13, these surveys are not yet scheduled to commence, no methodology change is proposed at this stage.
- Floodplain survey – project specific specification applies to HA11, HA12 and HA13, the LiDAR survey is progressing at national level, due to programme slippage RPS have not yet been able to undertake any data quality assessment, RPS have undertaken additional work to review the survey extents so that complete coverage of revised Areas of Further Assessment (AFAs) is obtained and RPS are also considering prioritisation of LiDAR survey deliverables to accommodate programming constraints.
- Channel and structure survey – project specific specification applied to HA11 and HA13, but excluded HA12, all surveys are progressing in the field. Due to concerns regarding survey resourcing across several simultaneous CFRAM Study contracts RPS proposed the following methodology amendments.

Following completion of the Flood Risk Review and subsequent delineation of all watercourses within AFAs to optimise the quantity of rivers to be surveyed, RPS proposed a substantial reduction in the length of the rivers specified in SC4. Further to this, RPS identified that the quantity of cross sections removed from SC4 was equivalent to that proposed for the survey contract covering HAs 11, 13 & 17. RPS therefore proposed to OPW that these two contracts could be merged, thus offering a time and cost saving and additionally providing CCS with a contract of the magnitude of which they originally tendered. This was proposal was accepted by OPW and subsequently CCS were awarded a contract covering the whole of the South Eastern CFRAM Study area.

There are no further additional risks and associated methodology amendments identified at present in the HA11, HA12 and HA13 Unit of Management.

6.2 OPPORTUNITIES AND PROPOSED METHODOLOGY AMENDMENTS

Data Collection – South Eastern CFRAM Study Technical Note 1 (IBE0601 TN0001) details RPS's proposed Flood Event Response Plan so that the response team members are appraised of requirements before an event occurs.

Hydrological Analysis – Eastern CFRAM Study Technical Note 3 (IBE0600 TN0003) details a potential opportunity to utilise RADAR rainfall data to provide a more accurate representation of the spatial and temporal hydrological inputs to the hydraulic models made possible by the availability of Met Éireann's RADAR datasets. A demonstration of the method was provided to OPW 26/10/11 and a staged basis of service delivery accepted by OPW in their letter of 14 December 2011. The staged trial initially applies to the Dodder catchment and subject to the success of stage 1 a fourth stage would apply to the whole South Eastern study area and therefore HA11, HA12 and HA13.

Study Integration - The involvement of RPS in providing modelling support to the OPW team undertaking the Suir CFRAM study and in the preparation of the SEA for this catchment provides an opportunity to ensure harmonisation between the two projects particularly in terms of hydrological and coastal analyses. In order to facilitate integration of the Suir and South Eastern CFRAM Studies there are a number of formal reporting and technical actions in place:

- An update on the Suir CFRAM is included in the South Eastern CFRAM progress meeting agenda;
- RPS are provided with regular Suir CFRAM progress reports; and
- Information sharing is ongoing, particularly at this stage focussing on ongoing technical activities including hydrological analysis methodologies and joint probability analysis of the downstream modelled watercourse boundary where the Barrow and Suir meet at Cheekpoint.

In addition, given the small number of AFAs in HA11 and HA 13, an opportunity for integration of the technical study outputs of these Units of Management with the larger and geographically close HA12 (Slaney) Unit of Management has been identified within the South Eastern CFRAM study. For example hydrological reporting could be combined thus reducing the number of reports that have to be reviewed by the Local Authorities It is however still intended that three separate plans will be produced unless the number of AFAs in any units decreases resulting in further review of the requirement to have a plan for each Unit of Management.

There are no further additional opportunities and associated methodology amendments identified at present in the HA11, HA12 and HA13 Unit of Management..

7 REFERENCES

- Reference 1:** EC Directive on the Assessment and Management of Flood Risks (2007/60/EC) (2007)
- Reference 2:** SI 122 of 2010 European Communities (Assessment and Management of Flood Risks) Regulations, 2010
- Reference 3:** Office of Public Works, 2011: “National Flood Risk Assessment and Management Programme, Eastern River Basin District Catchment-based Flood Risk Assessment and Management (CFRAM) Study, Stage II Tender Documents: Project Brief”
- Reference 4:** Office of Public Works, 2010: “National Flood Risk Assessment and Management Programme, Catchment-based Flood Risk Assessment and Management (CFRAM) Studies, Stage I Tender Documents: Project Brief”
- Reference 5:** Office of Public Works, 2006: “Flood Studies Update - Work Package 2.1, Review of Flood Flow Ratings for Flood Studies Update, Final Report J2194”
- Reference 6:** Office of Public Works, 2005: “Report on October 2004 Flooding in County Wexford”
- Reference 7:** Office of Public Works, 2003: “Tullow Pre-Feasibility Flood Relief Study”
- Reference 8:** Office of Public Works, 2004: “Pre Feasibility Report on the Enniscorthy Flooding Problem – Appendices”
- Reference 9:** Office of Public Works, 2004: “Feasibility Report on the Enniscorthy Flooding Problem”
- Reference 10:** Office of Public Works, 2009: “Flood Studies Update - Work Package 2.2 - Frequency Analysis”
- Reference 11:** Met Éireann, 2004: “Flood Studies Update - Work Package 1.2 – Estimation of Point Rainfall Frequencies”
- Reference 12:** Institute of Hydrology, 1994: “Report No. 124, Flood Estimation for Small Catchments”
- Reference 13:** Natural Environmental Research Council (NERC), 1985 “The FSR rainfall-runoff model parameter estimation equations updated”, Flood Studies Supplementary Report (FSSR) No. 16 December 1985.
- Reference 14:** Office of Public Works, JBA, 2010: “Flood Studies Update - Work Package 3.4, Guidance for River Basin Modelling”
- Reference 15:** RPS, SWRBD, 2008, “Further Characterisation Study: An Integrated Approach to Quantifying Groundwater and Surface Water Contributions of Stream Flow”
- Reference 16:** Bell, A. K., Higginson, N., Dawson, S., Glasgow, G., and Elsaesser, B. 2005. Understanding and managing hydrological extremes in the Lough Neagh Basin, Tullamore National Hydrology Seminar, Proceedings, 1-10.
- Reference 17:** Office of Public Works, 2011: “Flood Studies Update, Alpha Testing Users Guide”

Reference 18: Office of Public Works, JBA, 2009: “Flood Studies Update - Work Package 3.5 – IBIDEM (Interactive Bridge Invoking the Design Event Method)”


APPENDIX A

HYDROMETRIC DATA STATUS TABLES

Hydrometric Data Status Table
HA11, HA12 HA13 - Hydromteric Stations

[illegible]

Key

	Annual Max Data
	Daily Data
	15 Min Data

APPENDIX B

DAILY AND HOURLY RAINFALL

DATA STATUS TABLES

Catchment 6
Daily Rain - Data Status Table

B1

[illegible]

Daily Rain - Data Status Table

[illegible]

Daily Rain - Data Status Table

[illegible]

Daily Rain - Data Status Table

[illegible]

Daily Rain - Data Status Table

[illegible]

Daily Rain - Data Status Table

[illegible]

Daily Rain - Data Status Table

[illegible]

Daily Rain - Data Status Table

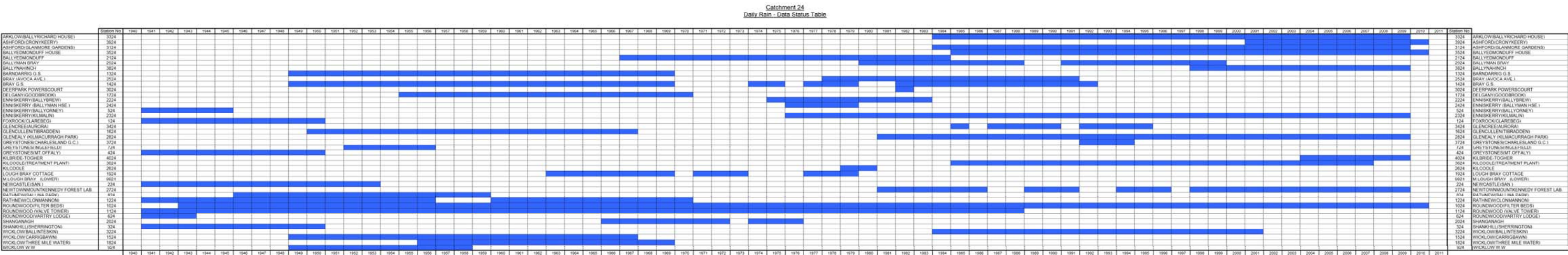
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
ADAMINE HOUSE(MIDDLE TOWN HSE)	1770																															
BLACKWATER G.S.	610																															
CANORE(K.MICHAEL HOUSE)	1130																															
CLONEVAN G.S.	736																															
COOL GREANE VIST MARTINI	1610																															
COOLGREANY G.S.	416																															
COURTOWN HARBOUR G.S.	516																															
GORE VICO COURTOWN HSE	116																															
GORE V KNOCKMALLIN	5316																															
GORE V	216																															
GORE V VIKKEA(TIMEY HOUSE)	5716																															
GOREY G.S.	816																															
KILDERMOT	1516																															
KILMUCKRIDGE(MORRIS CASTLE)	1016																															
KILMUCKRIDGE(UPTON HYDRO)	316																															
MONAGLIN	1416																															
QUARRY G.S.	816																															
ADAMINE HOUSE(MIDDLE TOWN HSE)	1770																															
BLACKWATER G.S.	610																															
CANORE(K.MICHAEL HOUSE)	1130																															
CLONEVAN G.S.	736																															
COOL GREANE VIST MARTINI	1610																															
COOLGREANY G.S.	416																															
COURTOWN HARBOUR G.S.	516																															
GORE VICO COURTOWN HSE	116																															
GORE V KNOCKMALLIN	5316																															
GORE V	216																															
GORE V VIKKEA(TIMEY HOUSE)	5716																															
GOREY G.S.	816																															
KILDERMOT	1516																															
KILMUCKRIDGE(MORRIS CASTLE)	1016																															
KILMUCKRIDGE(UPTON HYDRO)	316																															
MONAGLIN	1416																															
QUARRY G.S.	816																															

Daily Rain - Data Status Table

[illegible]

Daily Rain - Data Status Table

[illegible]



IBE0601Rp0007

[illegible]

APPENDIX C

RAINFALL RADAR DATA ANALYSIS TO PROVIDE INPUT TO HYDROLOGICAL MODELS

If the use of radar data for hydrological input is rolled out to the entire South Eastern CFRAM Study area; rainfall radar data for Dublin and Shannon Airport for the period 1997-2011 will be processed by HydroLogic. Preliminary calibration of radar data on a monthly basis using ground observation data from rain gauges will be undertaken. Rainfall input for hydrological models will be generated using weighted averaging of the radar pixels above each HEP catchment area.

Daily and hourly rainfall data provided by Met Éireann and Local Authorities will be used to calibrate Dublin rainfall radar data as applied to HA 11, 12 and 13. The number of rain gauges used for calibration of radar is variable; the results calibration depends on the number of high quality rain gauges. Rain gauge data quality assessment and labelling includes several data checks including:

- detection of gaps,
- detection of physically impossible data,
- detection of constant intensities,
- values above set thresholds,
- detection of too high or too low daily sums compared to neighbouring stations.

Only periods of plausible data are taken for calibration and verification procedures.

The combination of spatial distributed rainfall intensities from radar and accurate rainfall amounts from rain gauges will result in an improved dataset for use in hydrological modelling, both in terms of spatial resolution (1 x 1 kilometre grid) and temporal resolution (hourly data). The result of the preliminary radar calibration will be verified using independent stations (not used for calibration of radar).

Improved calibration of radar data will consist of several consecutive calibration steps on an hourly or 15 minute basis, similar to the steps described by Holleman (2007)¹:

1. Calculate the parameter (RG) describing the relation between the amount of precipitation from rain gauges (G) and the corresponding radar pixels (R) for each pair of G and R:

$$RG = 10^{10} \log\left(\frac{R}{G}\right)$$

2. Bias correction: the average of all available RG values is used to correct for any bias, for example calibration errors. Moreover, the calculated standard deviation is used to perform a quality control on the RG values, and thus the radar and rain gauge observations.

¹ I. Holleman. (2007) Bias adjustment and long-term verification of radar-based precipitation estimates. Meteorological Applications 14:2, pp.195-203.

3. Distance correction: correction for the height of the radar beam above earth surface and related underestimation of the precipitation intensity at that location. This correction is described as a function of the distance from the radar (r); RG and r are then fitted to a parabola.
4. Spatial correction: an inverse-distance method of the RG values is used to correct for local effects in the radar composite. This analysis yields a smooth field fitted to the data points.

Existing HydroNET tools will be used together with the SCOUT software by hydroandmeteo (www.hydrometeo.de). These tools are already widely used in the Netherlands and internationally. The result is a self describing dataset in the NetCDF format; a format which is well-known and widely used in meteorology.

A phased approach to the use of radar rainfall data will be applied within the overall Eastern CFRAM Study hydrology methodology. The phasing is based on determining the accuracy and applicability by trialling it on a pilot area, then rolling it out to the entire Eastern and Southern CFRAM areas if proven beneficial.

Stage 1 of the Dublin radar data analysis for the Dodder catchment indicated that the usage of the Dublin radar data, although with variable quality, can bring a significant improvement in the estimation of the rainfall inputs when compared to the area weighted rainfall estimation (traditionally used) for the hydrologic and hydrodynamic modelling for each HEPs. For hydrological modelling and estimation of the designed flows in the Study area, radar-based NAM inputs will be generated (subject to the results of the first phase of trialling, using polygon shape files describing catchment areas for each individual HEP (refer to Section 5.3 and 5.4)

Since radar data is available only for the period 1997- 2011, the spatio-temporal distribution for the periods before 1997 will be estimated using the daily and sub-daily time series of the additionally available rainfall data from the rain gauges (provided by Met Éireann and the Local Authorities). From the processed and calibrated radar data (period 1997-2011) typical rainfall parameters (daily and monthly sums) will be generated for each month for the HEP catchment areas. Those sums will be scaled to relative weights using grid-based weighing techniques (inverse-distance, radial basis functions or others). The daily and the sub-daily precipitation patterns for the HEP catchment areas will then be generated by multiplying the radar patterns (relative weights) with the time recorded series for the periods before 1997 for the length of the available time series. In cases where it is impossible to generate averaged radar-based patterns, we will use standard Thiessen polygons or other interpolation techniques (such as IDW) to generate spatially-weighted time series rainfall inputs for the hydrological models. This will result in the production of rainfall input files for each NAM HEP for the entire length of rainfall time series data provided.

APPENDIX D

Hydrology Method Process Chart – Used Datasets Table

Box Number (Figure 2.2)	GIS Shapefile of River Network	DTM, Mapping, Aerial Imagery	FSU Ungauged Catchment Descriptors GIS Point File	FSU Gauged Catchment Descriptors GIS Point File	FSU Ungauged and Gauged Catchment Outlines GIS Polygon Layer	Rainfall Radar Data (if approved)	Daily and Hourly Rainfall Station Data	Met Eireann Evaporation Data	GSI Soil and Bedrock /Aquifer GIS Layers	Corine 2006 Landuse GIS Layer	Hydrometric Data
1	✓	✓	✓	✓	✓						
2	✓	✓	✓	✓	✓						✓
3	✓		✓	✓	✓						
4	✓		✓	✓	✓						
5	✓		✓	✓	✓						
6	✓		✓	✓	✓						
7						✓	✓				
8	✓					✓	✓	✓	✓	✓	✓
9	✓	✓	✓	✓	✓			✓	✓	✓	✓
10	✓	✓	✓	✓	✓						✓
11	✓	✓	✓	✓	✓						✓
12	✓	✓									
13											✓
14						✓					✓
15						✓					✓
16						✓					✓
17											
18											

APPENDIX E

HEP and Catchment Diagrams



