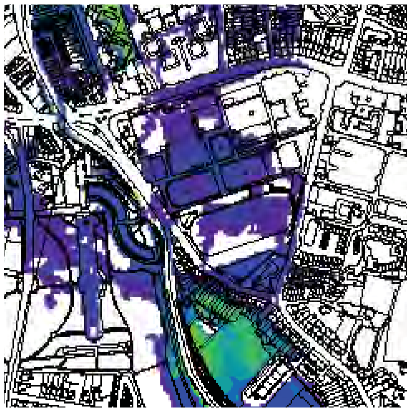
RPS

NORTH WESTERN
NEAGH BANN
CFRAM
STUDY
CATCHMENT FLOOD RISK
ASSESSMENT AND MANAGEMENT

North Western - Neagh Bann CFRAM Study

UoM 01 Hydraulics Report
4.22 Moville

IBE0700Rp0011



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NWNB CFRAM Study

HA01 Hydraulics Report

Moville Model

DOCUMENT CONTROL SHEET

Client	OPW
Project Title	NWNB CFRAM Study
Document Title	IBE0700Rp0011_HA01 Hydraulics Report
Model Name	Moville

Rev.	Status	Author(s)	Modeller	Reviewed by	Approved By	Office of Origin	Issue Date
D01	Draft	Various	I. Bentley	G. Glasgow	G. Glasgow	Limerick/Belfast	11/06/14
F01	Draft	Various	I. Bentley	L. Arbuckle	G. Glasgow	Belfast	10/12/2014
F02	Draft	Various	I. Bentley	L. Arbuckle	G. Glasgow	Belfast	13/08/2015
F03	Draft	Various	J. Deery	S. Patterson	G. Glasgow	Belfast	08/07/2016

Table of Reference Reports

Report	Issue Date	Report Reference	Relevant Section
North Western Neagh Bann CFRAM Study Flood Risk Review	**May 2012**	2011s5232 NW&NB CFRAM FRR Report	**Table 4.1**
North Western Neagh Bann CFRAM Study UoM01 Inception Report	**February 2013**	IBE0700Rp0002_UoM 01 Inception Report	**4.3.2**
North Western Neagh Bann CFRAM Study Hydrology Report UoM01	**July 2013**	IBE0700Rp0006_UoM 01 Hydrology Report	**4.4**
North Western Neagh Bann CFRAM HA01_06_36 Survey Contract Report	**October 2013**	IBE0700Rp0007_HA01_06_36 NWNB_CFRAM_Survey Contract Report	**ALL**

4 HYDRAULIC MODEL DETAILS

4.22 MOVILLE MODEL

4.22.1 General Hydraulic Model Information

(1) Introduction:	
The NWNB CFRAM Flood Risk Review (**2011s5232 NW&NB CFRAM FRR Report_Final_v2.0**) highlighted Moville as an AFA for 'mechanism 1 tidal', 'mechanism 2 wave overtopping' flooding; and fluvial flooding based on a review of historic flooding and the extents of flood risk determined during the PFRA. Moville AFA is located on the western shore of Lough Foyle on the Inishowen Peninsula. The Bredagh Glen is the main river which flows through the town but one of its tributaries and the Coolnasillagh stream on the eastern edge of the town have also been identified as sources of fluvial flood risk. The Bredagh catchment is less than 20km^2 with its smaller tributary catchment just over 1km^2. The catchment area of the Coolnasillagh stream is also just over 1km^2. These catchments are steep with a high proportion of peat / bog (up to 50%). There is one gauging station site within the town but it is only a staff gauge site and as such no flow data was provided at this station. The model is considered to be totally ungauged for the purposes of flow estimation. There are no FSU pivotal sites located in Hydrometric Area (HA) 40 and the FSU ungauged catchment estimates have not been adjusted based on a pivotal site, refer to UoM 01 Hydrology Report, Chapter 4.4 (Rp0006_F01) for full details on hydrology estimation. The Bredagh Glen and its tributary are both HPW and have been modelled as 1D-2D using ISIS. The Coolnasillagh watercourse, located to the east of the AFA, is also a HPW. This watercourse drains separately to the sea and has been modelled using a separate ISIS 1D-2D model. These two ISIS 1D-2D models have been used to determine both fluvial and coastal flooding extents. In channel flow has been modelled in ISIS 1D, refer to Chapter 3 and Section 4.22.2 for further details. The approach to overtopping of structures is discussed in Section 3.3.4 and detailed in 4.22.3(5).	
(2) Model Reference:	UOM01_MOV4 (Model 4)
(3) AFAs included in the model:	MOVILLE

(4) Primary Watercourses / Water Bodies (including local names):

Reach ID	Name
0153M	COOLNASILLAGH
0154M	BREDAGH GLEN
0155M	MOVILLE

(5) Software Type (and version):

(a) 1D Domain:	(b) 2D Domain:	(c) Other model elements:
ISIS v3.7.1	ISIS 2D v3.7.1 ('Mechanism 1 tidal' and fluvial flooding) MIKE 21 - Flexible Mesh (2012) ('Mechanism 2 wave overtopping' flooding)	N/A

4.22.2 Hydraulic Model Schematisation

(1) Map of Model Extents:

Figures 4.7.1 and 4.7.2 illustrate the extent of the modelled catchment, river centre line, HEP locations and AFA extent. Figure 4.7.1 provides an overview; Figure 4.7.2 provides a closer look at the AFA.

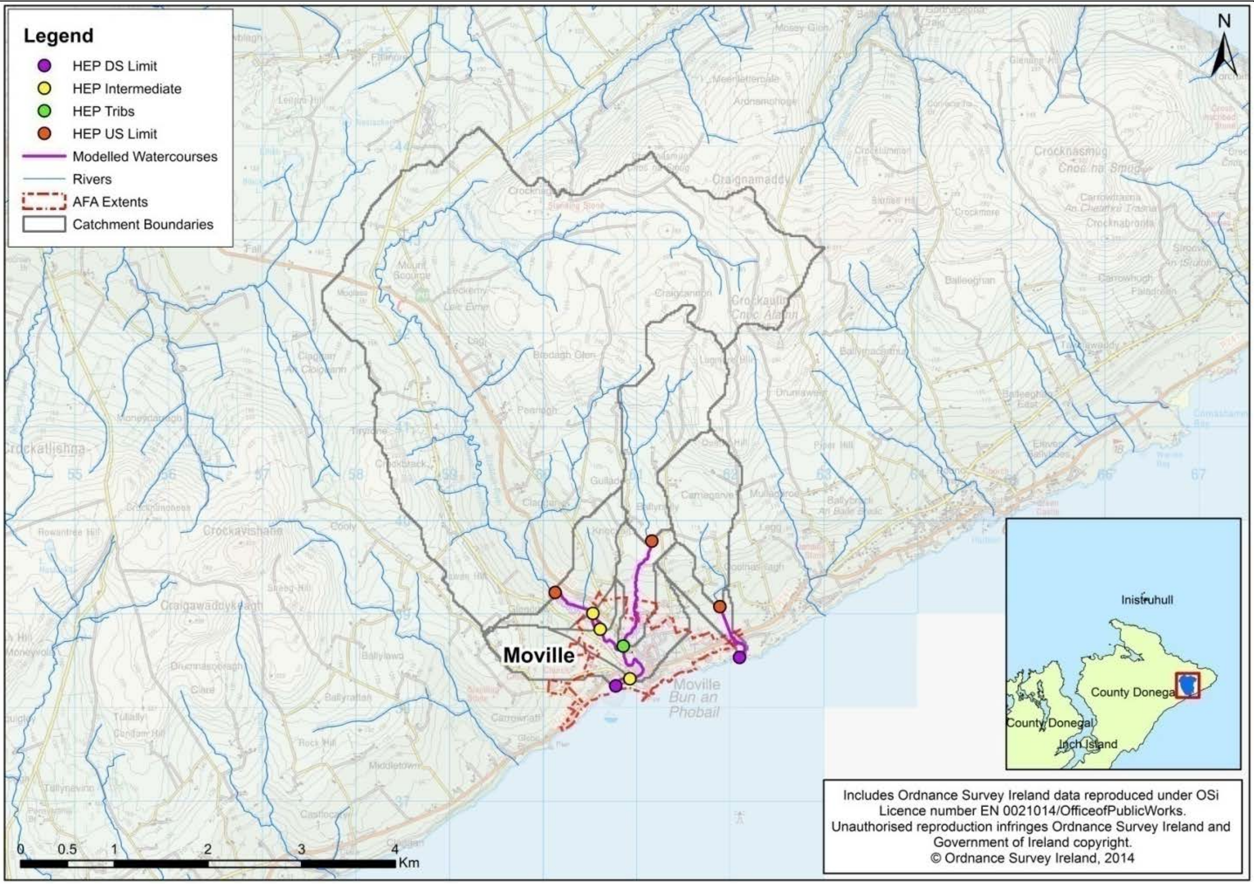


Figure 4.22.1: Map of Model Extents – Moville

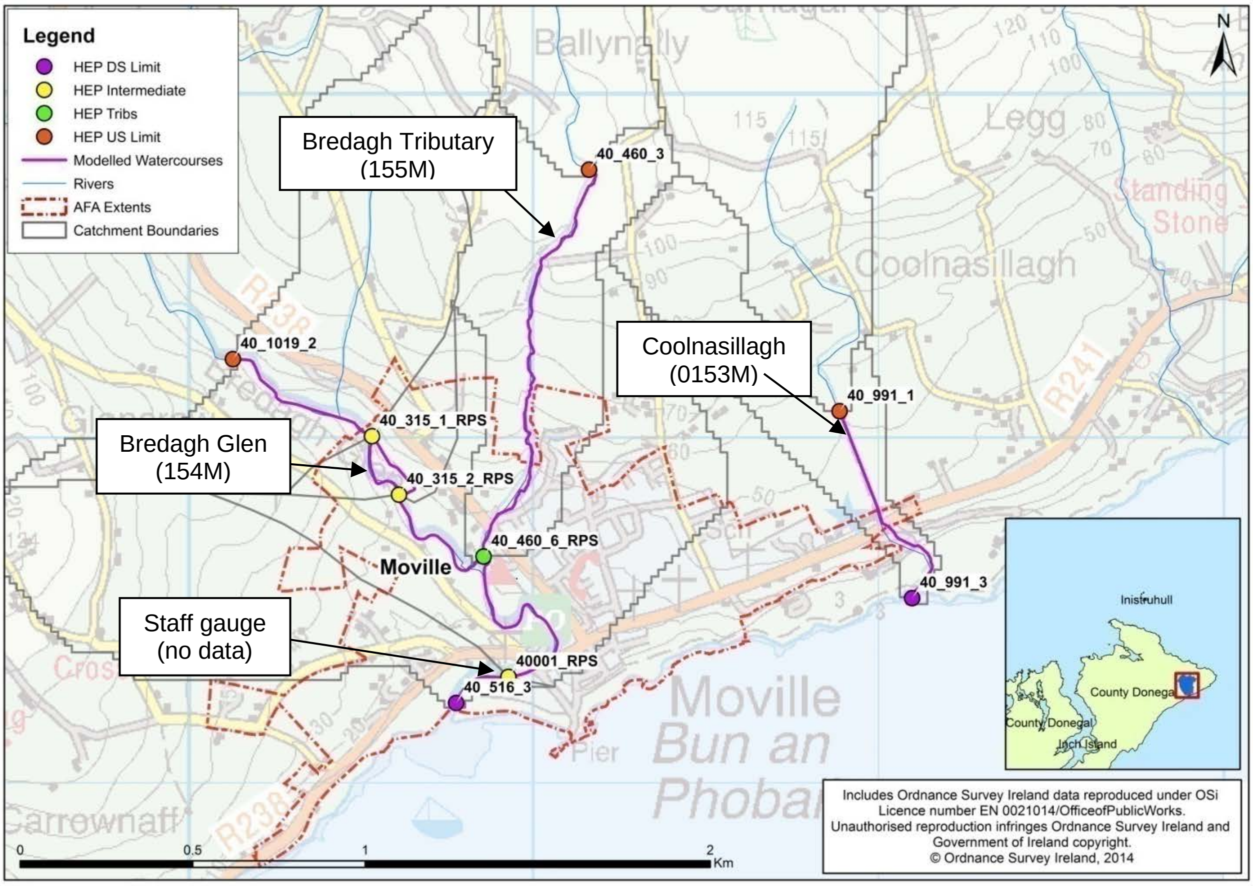


Figure 4.22.2: Map of Model Extents – Moville

The Moville model catchment contains 3no. Upstream Limit HEPs, one for each modelled watercourse. There is 1no. HEP Tributary where the tributary joins the River Bredagh. There are 3no. Intermediate HEPs and 2no. Downstream limit HEPs. There are no HEP Gauging Stations. A staff gauge is located near the downstream limit of the model (refer to Figure 4.22.2) but no flow or water level data is available. Therefore it is redefined as an Intermediate HEP.

In channel flow has been modelled in ISIS 1D, (refer to Chapter 3). The 1D model has been linked with ISIS 2D, with any overtopping flow passing into ISIS 2D to simulate the floodplain flow. In defining the left and right channel banks in ISIS 1D an assessment was made of the surveyed channel data to estimate where out of bank flow would occur. The 1D reaches and the 2D domain have been linked by means of 1D/2D links which are defined as polyline shapefiles. These shapefiles contain attribute fields that define the ISIS 1D model nodes that the 2D model links with. All HPW and MPW have been modelled as 1D in bank with the floodplain element in 2D.

(2) x-y Coordinates of River (Upstream extent):

River Name		x	y
0153M	COOLNASILLAGH	261887	439075
0154M	BREDAGH GLEN	260128	439227
0155M	MOVILLE	261174	439752

(3) Total Modelled Watercourse Length:	4km (approx)
(4) 1D Domain only Watercourse Length: 0 (km)	**(5) 1D-2D Domain Watercourse Length:** 4km (approx)
(6) 2D Domain Mesh Type / Resolution / Area:	0153M – 2m ISIS 2D grid, 0.67 km^2 0154M – 2m ISIS 2D grid, 2.01 km^2 0155M – 2m ISIS 2D grid, 1.32 km^2

(7) 2D Domain Model Extent:

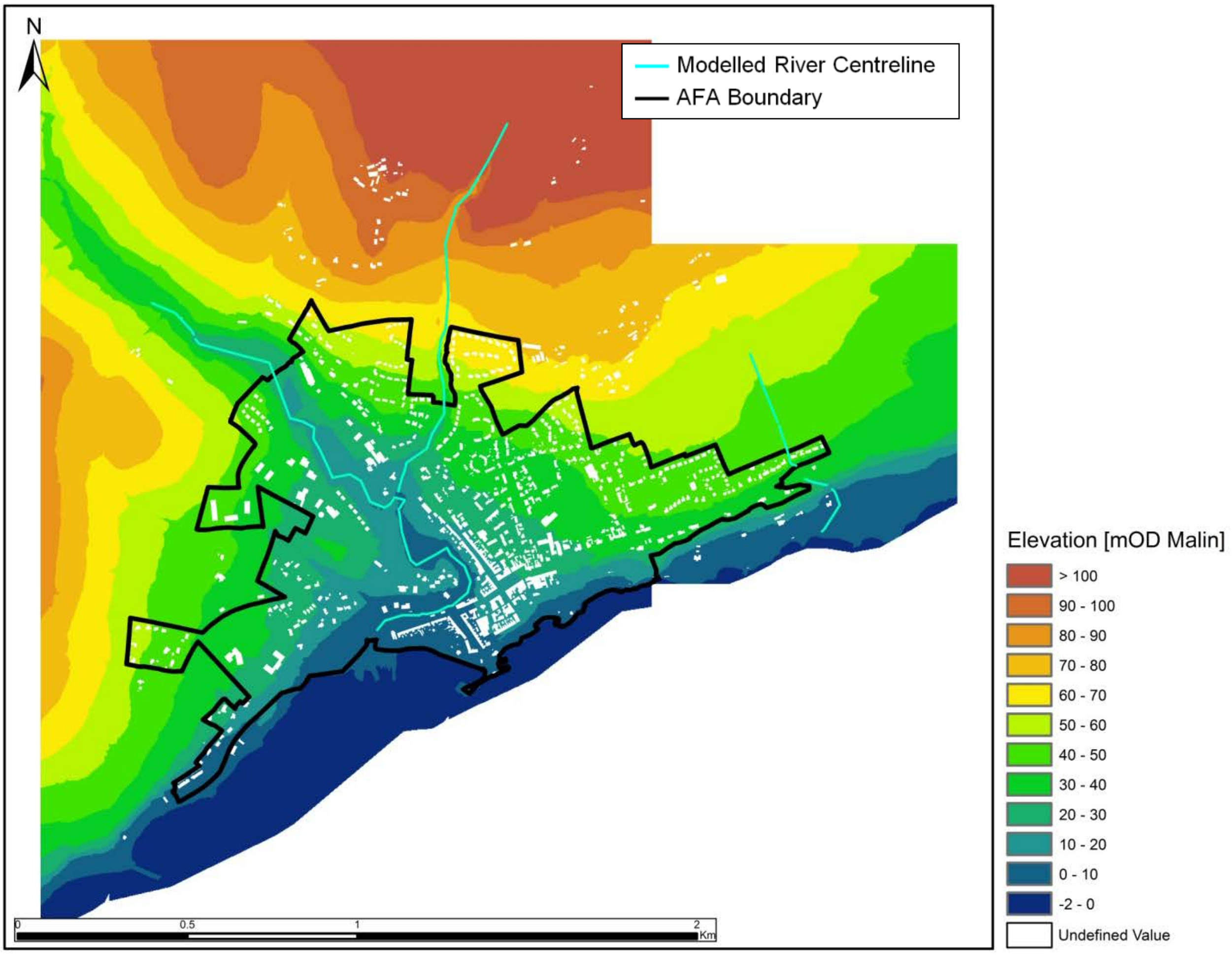


Figure 4.22.3: 2D Model Domain - Moville

Figure 4.22.3 illustrates the modelled extents and general topography. The spatial extent of the AFA boundary is outlined in black. The reach centre-lines are presented in light-blue which also represents the

1D modelled extent that is within the 2D area. Buildings are excluded from the mesh and therefore represented as white spaces, refer to Chapter 3 for details on representation of buildings in the model.

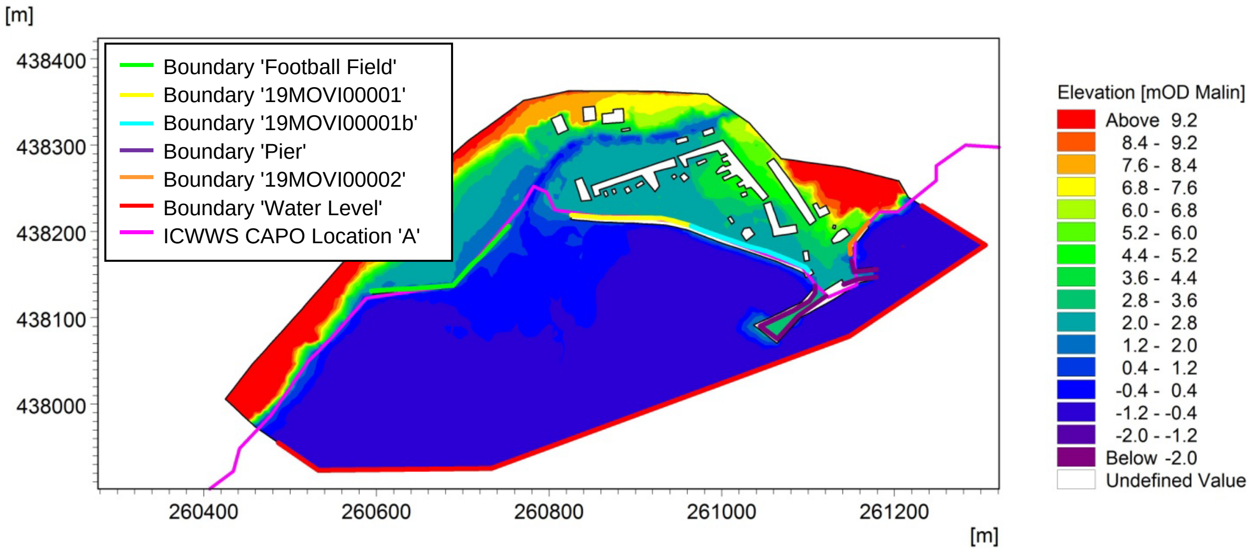


Figure 4.22.4: 2D Model Domain for 'Mechanism 2 Wave Overtopping' design runs

Figure 4.22.44 illustrates the extents of the 2D domain used during the ‘mechanism 2 wave overtopping’ design runs. There is one ICWWS CAPO Prediction Location within the Moville AFA - 'A', as signified by the pink line. Five distinct areas of coastline were found to be at risk of flooding due to wave overtopping following further analysis, so these were defined as discharge boundaries 'Football Field', '19MOVI00001', '19MOVI00001b', 'Pier' and '19MOVI00002' as annotated above. In order to accurately represent the hydraulic effect of both tidal inundation and wave overtopping, a time-varying water level boundary representing the modelled Total Water Level in Lough Foyle was applied to the edge of the mesh as signified by the red line in Figure 4.22.44. It should be noted that the ‘mechanism 2 wave overtopping’ 2D domain is considerably smaller than the overall mesh for analysing ‘mechanism 1 tidal’ flooding as the area of interest is much more localised.

Figure 4.22.5 shows an overview drawing of the model schematisation. Figures 4.22.6 and 4.22.7 show detailed views. The overview diagram covers the model extents, showing the surveyed cross-section locations, AFA boundary and river centreline. It also shows the area covered by the 2D model domain. The detailed views are provided where there is the most significant risk of flooding. These diagrams include the surveyed cross-section locations, AFA boundary and river centreline. They also show the location of the critical structures as discussed in section 4.22.3(1), along with the location and extent of the links between the 1D and 2D models. For clarity in viewing cross-section locations, the detail diagrams show the full extent of the surveyed cross-sections. Note that the 1D model considers only the cross-section between the 1D-2D links.

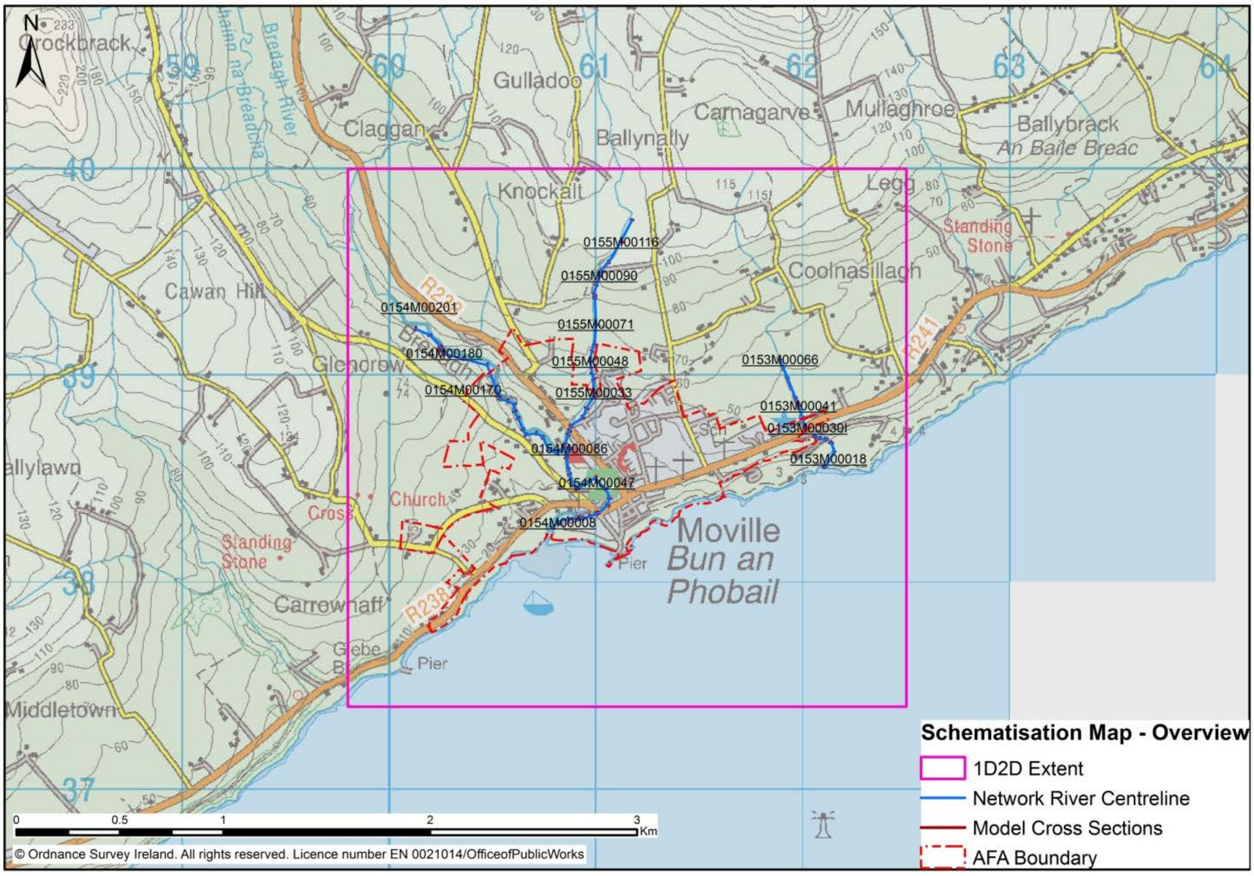


Figure 4.22.5: Model Schematisation Overview Map (Moville)

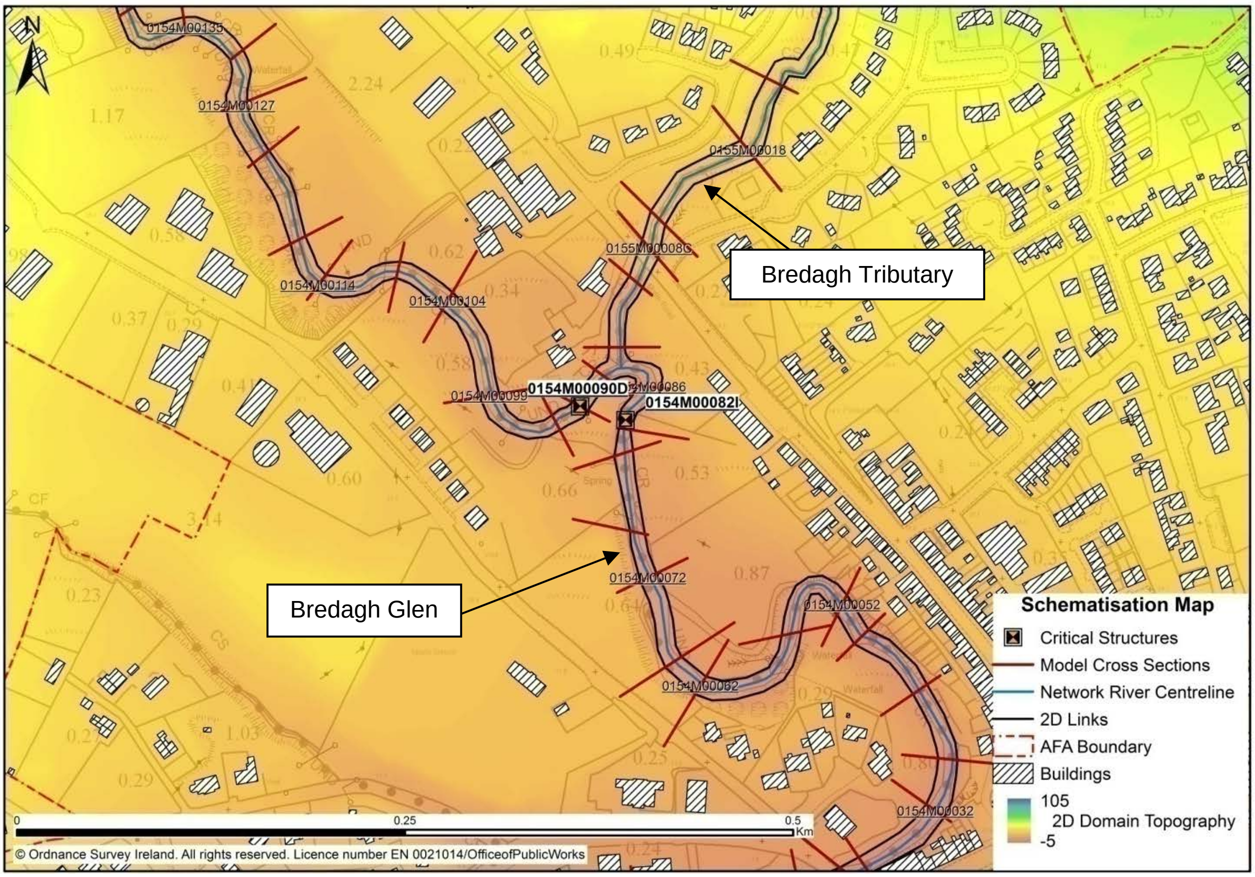


Figure 4.22.6: Detailed Area of Model Schematisation showing Critical Structures on the Bredagh Glen

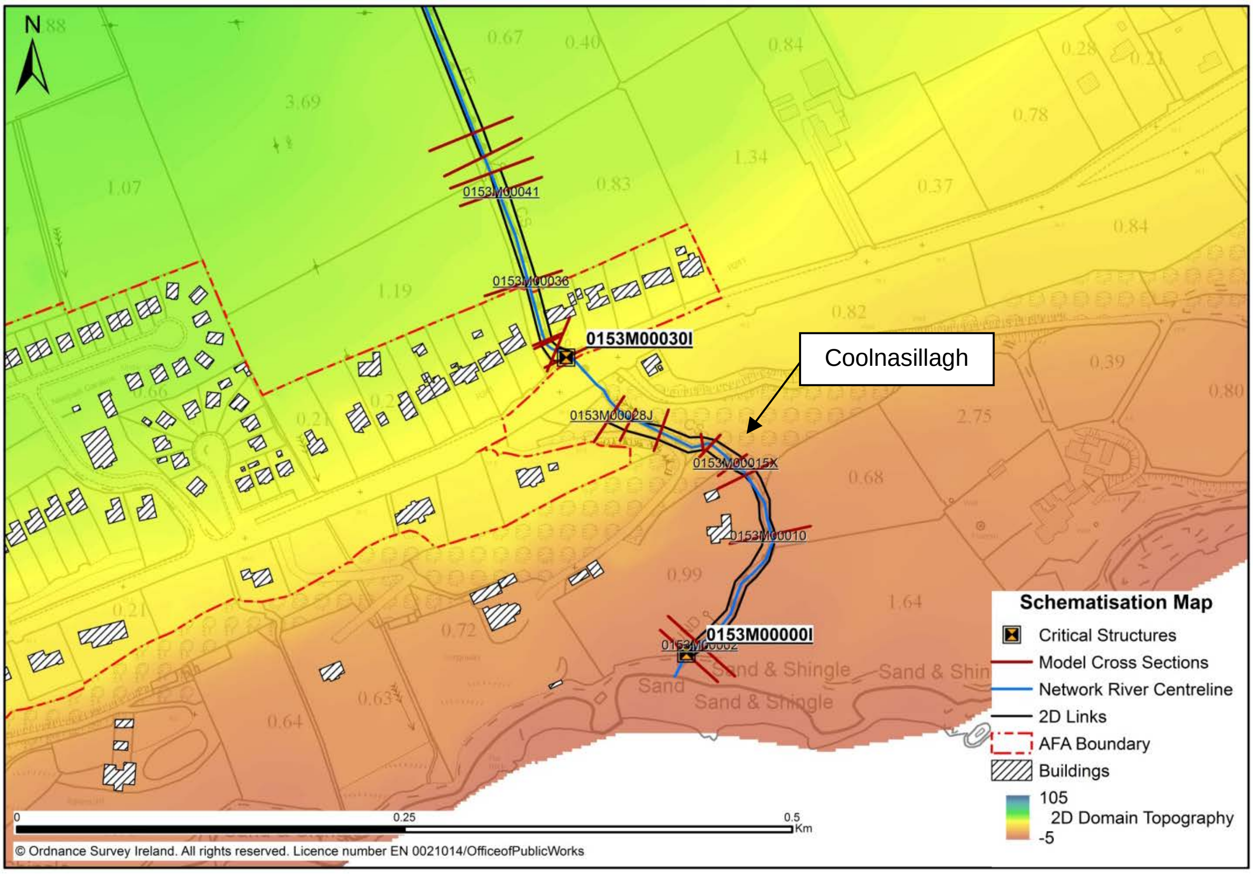


Figure 4.22.7: Detailed Area of Model Schematisation showing Critical Structures on the Coolnasillagh Watercourse

(8) Survey Information

(a) Survey Folder Structure:

First Level Folder	Second Level Folder	Third Level Folder
Murphy_NW1_M04_WP3_0154M_V1_130308 *Moville* Murphy: Surveyor Name NW1: North Western CFRAM Study Area, Hydrometric Area 1 M04: Model Number 4 0154M: River Reference WP3: Work Package 3 Version: V1 *130308*: Date Issued (08th MAR 2013)	V0_20130301_Ascii	
	V0_20130301_Other	Floodplain Photos
	V1_20130308_Dwgs	
	Photos *(Naming convention is in the format of Cross-Section ID and orientation - upstream, downstream, left bank or right bank)*	

(b) Survey Folder References:

Reach ID	Name	File Reference
0153M	COOLNASILLAGH	Murphy_NW1_M04_WP3_0153M_V1_130208
0154M	BREDAGH GLEN	Murphy_NW1_M04_WP3_0154M_V1_130308
0155M	MOVILLE	Murphy_NW1_M04_WP3_0155M_V1_130308

(9) Survey Issues

Details of checks carried out on survey data as well as comparison with LiDAR are incorporated in Section 2.2. The methodology on which topographic adjustments were made is detailed in Section 3.4.2.

The coastal bathymetry incorporated 2m resolution LiDAR DTM data. Checks were carried out this data along the coastline of Moville to ensure it was representative of the coastal bathymetry. It was found that the full combined tidal and surge curves were facilitated with no areas identified to be dry. This was deemed representative of the coastal bathymetry at Moville and no changes were made.

The 2D domain used for modelling 'mechanism 2 wave overtopping' flooding, as shown in Figure 4.22.4, was constructed using 2m resolution LiDAR DTM data. No post-processing of this data was carried out.

No survey issues were raised for this AFA.

4.22.3 Hydraulic Model Construction

(1) 1D Structures (in-channel along modelled watercourses):	See Appendix A.1 4 Culverts 5 Bridges 4 Weirs Note: Detailed information on the chainage of these structures and how they have been represented within the hydraulic model is presented in Appendix A.1.

The survey information recorded includes a photograph of each structure, which has been used to determine the Manning's n value. Further details are included in Chapter 3.5.1. A discussion on the way structures have been modelled is included in Chapter 3.3.4.

The location of critical structures included in the model is presented in Figure 4.21.5. Details of these structures are also presented in Appendix A.1.

The presence of a single arched bridge on the Bredagh watercourse (Figure 4.22.8, Ch 1098) restricts flow and causes out of bank flooding during the less frequent (higher magnitude) AEP modelled fluvial scenarios (1 and 0.1% AEP).

Figure 4.22.8: Arched Bridge 0154M00090D

A piped culvert on the Bredagh Watercourse (Figure 4.22.9, Ch 1189m) has insufficient capacity for the 1% AEP fluvial event. However the area affected by the resultant flooding is quite small since overtopping can occur without a large increase in water levels.

Figure 4.22.9: Culvert 0154M00082I

Flooding and bypassing of bridge shown in Figure 4.22.10 (Ch 485m) occurs on the right bank of the Moville watercourse during the 1% and 0.1% AEPs. This is related to water spilling over the right bank further upstream, due to inadequate channel capacity.

Figure 4.22.10: Culvert 0155M00084D

The culvert in Figure 4.22.11 is located on the Coolnasillagh watercourse (Ch 365m) and conveys flow under the R241. The presence of this culvert restricts the flow during the modelled 1% and 0.1% AEP fluvial scenarios, resulting in flooding of the road and land to the south of the road, including one property. The capacity of the culvert is limited by the pipe at its downstream end (shown on Figure 4.22.12).

Figure 4.22.11: Culvert 0153M00030I

Figure 4.22.12: 0153M00028J - Downstream End of Culvert Beneath R241 (0153M00030I)

The culvert in the figure below is located on the modelled downstream extent of the Coolnasillagh River (Ch 650m). The presence of this culvert restricts the flow during all modelled fluvial scenarios, resulting in flooding of adjacent agricultural fields.

Figure 4.22.13: Culvert 0153M00000I

(2) 1D Structures in the 2D domain (beyond the modelled watercourses):	None
(3) 2D Model structures:	None
(4) Standard of Protection of Existing Formal Defences:	None

(5) Model Boundaries - Inflows:

Full details of the flow estimates are provided in the Hydrology Report (IBE0700Rp0006_UoM 01 Hydrology Report_F01-Section 4.4 and Appendix C) using the methodology detailed in Section 2.3.3 of the same report. The boundary conditions implemented in the model are shown below.

Table 4.22.1: Model Boundary Conditions

	Boundary Type	Branch Name	Boundary HEP
1	Upstream	Bredagh	40_1019_2
2	Upstream	Moville	40_460_3
3	Upstream	Coolnasillagh	40_991_1
4	Lateral	Bredagh	40_1019_2 and 40_315_2_RPS
5	Lateral	Moville	40_460_3 and 40_460_6_RPS
6	Lateral	Coolnasillagh	40_991_1 and 40_991_3

Figure 4.22.14 provides an example of the associated upstream inflow hydrographs on the Bredagh (0154M), its tributary (Moville, 0155M) and the Coolnasillagh (0153M) watercourses at HEPs 40_1019_2, 40_4060_3 and 40_991_1 respectively for a 0.1% AEP event. The model flow at checkpoints was examined during initial development runs and adjustment of timing of inflow hydrographs was not required for anchoring of the model to estimated flows. Appendix A.3 contains further details of comparison of estimated flows with simulated flows in the model.

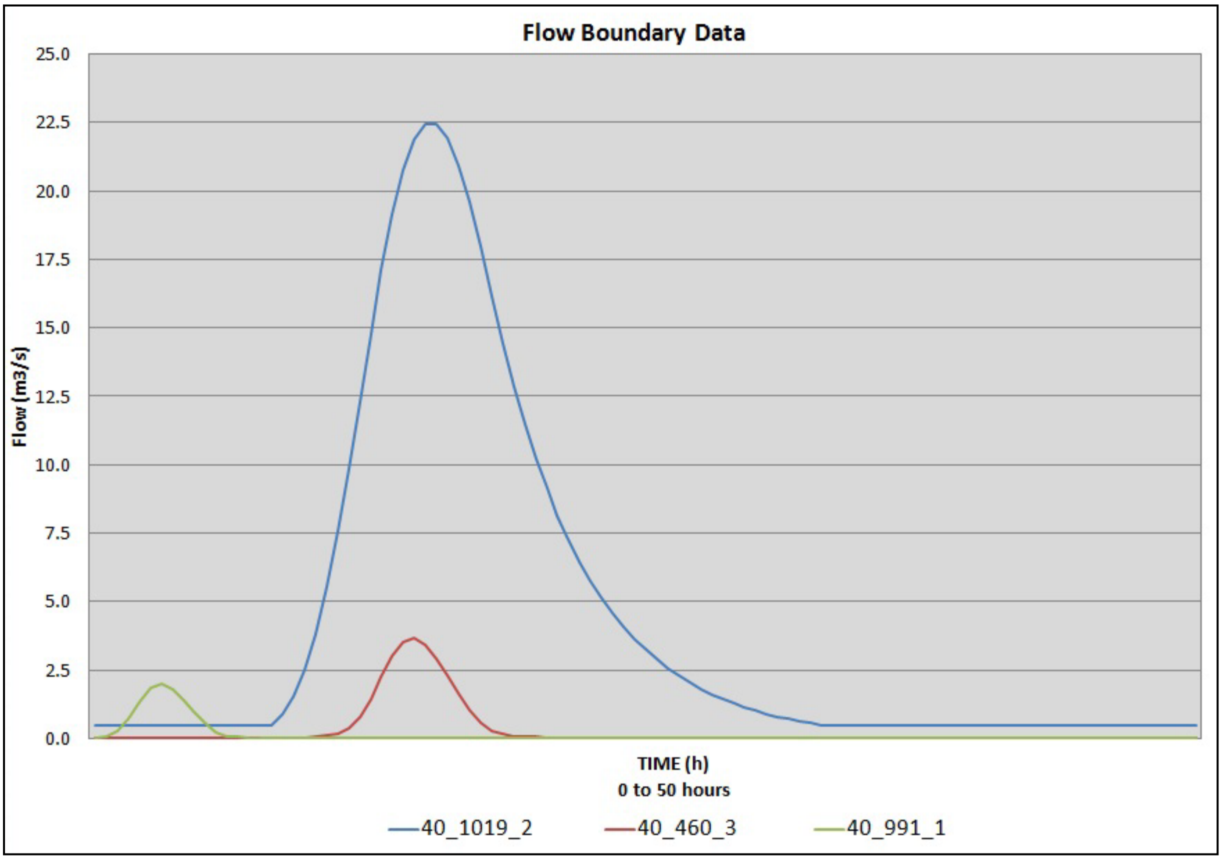


Figure 4.22.14: Upstream Hydrograph Inputs, 0.1% AEP fluvial event

Both 1D-2D models include head-time (HTBDY) boundaries at their downstream ends to represent coastal water levels. This downstream model boundary is reflective of a Total Water Level (TWL). This was applied to reflect the influence of coastal water levels upon fluvial flooding scenarios. This TWL has been calculated using predicted tidal levels combined with the surge residual. Outputs from the Irish Coastal Protection Strategy Study (ICPSS) have produced extreme tidal and storm surge water levels at nodes around the Irish Coast for a range of AEPs. ICPSS node NW52 (Irish Grid ref. 269403_443095) was used to generate extreme water levels for Lough Foyle, as shown on Figure 4.22.15. This ICPSS node is positioned approximately 8.5 km ENE from downstream extent of the Coolnasillagh watercourse (0153M). The associated AEP water levels for NW52 are listed in Table 4.22.2.

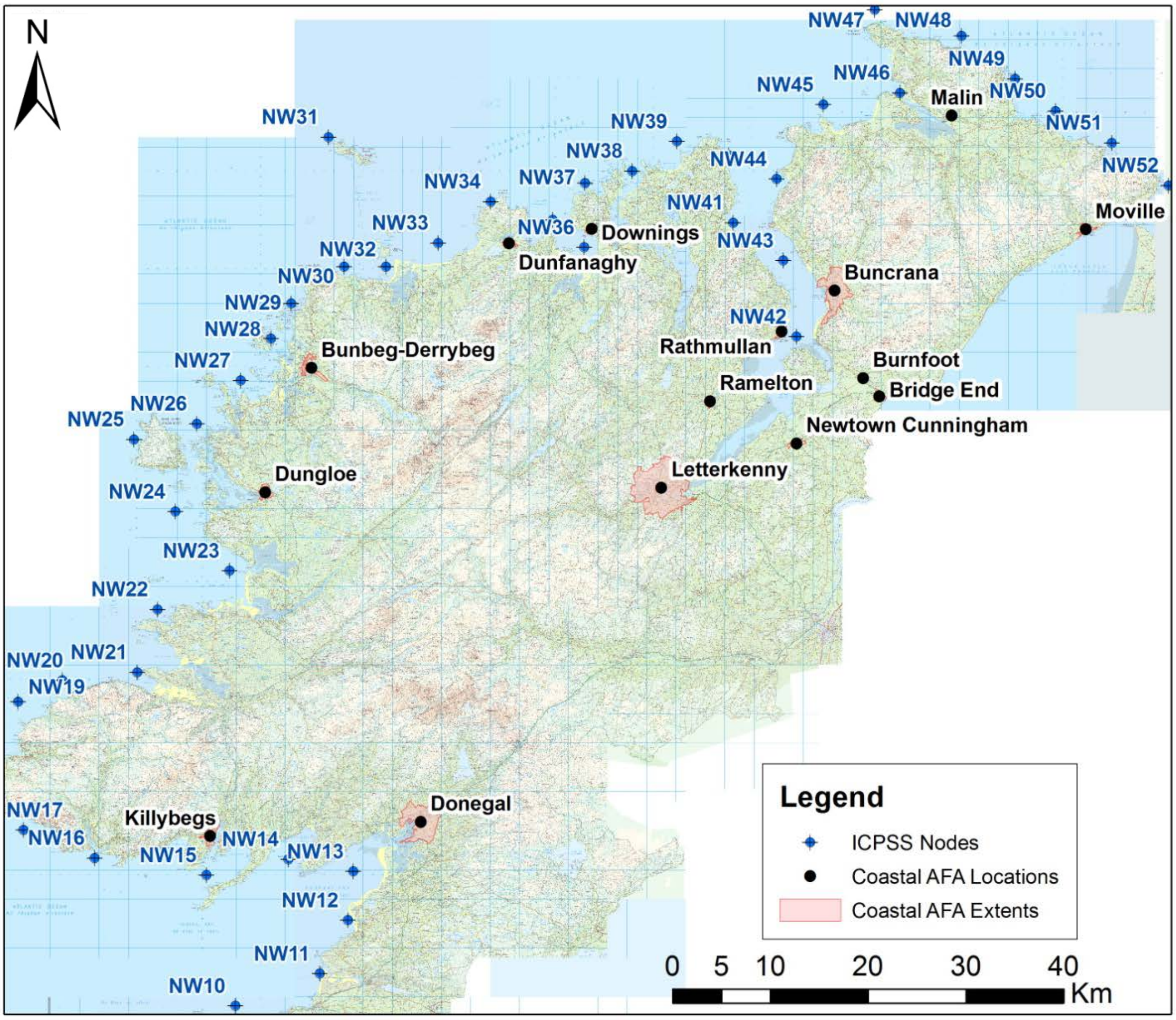


Figure 4.22.15: ICPSS Node Locations (IBE0700Rp0006_UoM01 Hydrology Report_F01)

Table 4.22.2: ICPSS extreme water levels – Node NW52

AEP (%)	50	20	10	5	2	1	0.5	0.1
NW52 (m AOD Malin)	1.83	1.97	2.07	2.16	2.28	2.37	2.47	2.68

The Bredagh Glen 1D model was extended by 1km at its downstream end using a copy of cross section 0154M00003, with the x values increased (to minimise frictional effects in the dummy reach) and y values reduced, to allow the full tidal curve to be included (low water levels are below the bed level in the original cross section). A 50% AEP coastal boundary as taken from the ICPSS has been used for the fluvial model runs, specifically at ICPSS node NW52. The water levels listed above are 'still' water levels used to model inundation from 'mechanism 1 tidal' flooding. 'Mechanism 2 wave overtopping' flooding at Moville is considered separately and uses data including extreme coastal water levels extracted from the ICWWS.

The ICPSS water levels TWLs comprising tidal and surge components which together yield a joint probability event of a particular AEP.

Using information from the Admiralty Tide Tables, a tidal water level was established. A tidal curve was generated by fitting this tide level to a sinusoidal curve. A normalised surge profile of 48 hour duration was scaled based on the difference between the peak water level of the generated tidal profile and the target TWL from Table 4.22.2. The scaled residual surge profile was then appended to the tidal profile to obtain the total combined water level time series as required for the relevant AEPs.

Figure 4.22.16 illustrates the tidal profile, storm surge profile and resultant combined total water level profile for a 50% AEP design event. The total water level profile was applied as a level boundary to the Northern edge of the 2D domain, representing tidal conditions at Moville.

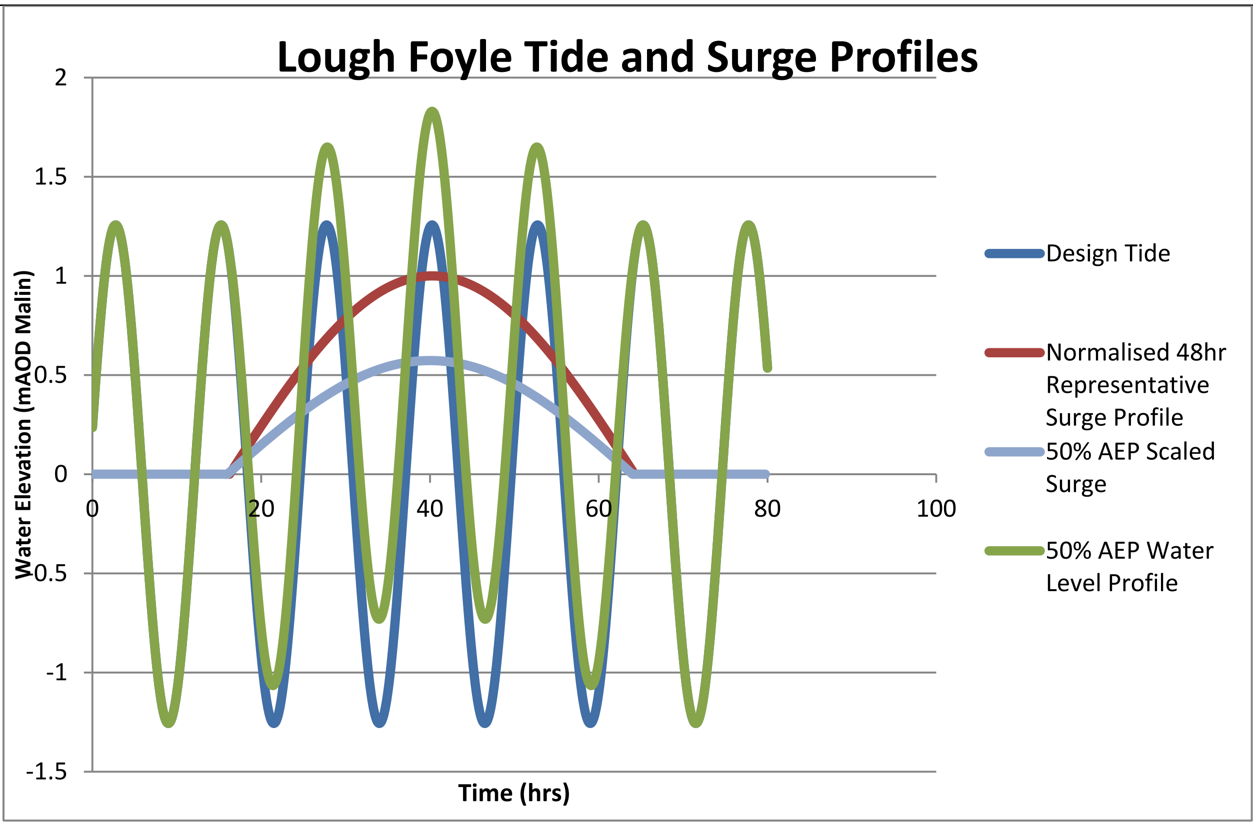


Figure 4.222.16: Tide and Surge Profiles

In order to simulate 'mechanism 2 wave overtopping' flooding at the Moville AFA, data from the ICWWS was used including peak shoreline water levels and wave heights, periods and directions for each AEP event. An example of this data for the Moville AFA is shown in Figure 4.22.1717 and Table 4.22.3.

Figure 4.22.17: ICWWS CAPO Moville Prediction Locations

Table 4.22.3: ICWWS CAPO Moville Wave Climate and Water Level Data

Prediction Location Reference: Moville_Location A				
Bed Level -2.77m OD Malin				
		Wind Wave Component		
AEP	WL (OD Malin)	Hm0 (m)	Tp (s)	MWD (°)
0.1%	1.415	1.639	4.032	193
0.1%	1.548	1.655	4.050	193
0.1%	1.648	1.651	4.070	194
0.1%	1.879	1.603	4.102	194
0.1%	2.069	1.525	4.119	195
0.1%	2.284	1.385	4.111	196

In order to calculate the overtopping discharge rate for each scenario at various locations along the shoreline, the empirical method calculator tools outlined by the EurOtop manual were used in addition to levels of the structures to be overtopped. The largest calculated discharge rate out of the six possible combinations of water levels and wave heights, periods and directions was used for each design AEP event.

It should be noted that when the peak discharge rate was less than 0.03l/s/m, no further analysis was required. Two surveyed sections were taken at Moville, as shown in Figure 4.22.1818. Construction drawings supplied by OPW of the Moville coastal protection works (constructed in 1969) were also used to

calculate an overtopping discharge where a surveyed section was not available. The locations of the final discharge boundaries within the model are shown in Figure 4.22.4. None of the boundary locations analysed in Moville were found to have a peak discharge less than the threshold value of 0.03l/s/m, so all locations were taken forward for modelling.

Once the discharges for simulation had been ascertained, an idealised water level profile was produced in order to calculate the discharge rate across the tidal cycle, as the rate determined by EurOtop was specific to the peak water level only. A storm duration of 12 hours beginning and ending at low-water was assumed. The discharge rate profile was then scaled based on the length of the exposed shoreline in order to produce a discharge profile in m^3/s, as shown in Table 4.22.4 and Figure 4.22.. It should be noted that the discharge profile 'Pier' was split into three segments in order to be input into the model, and segments 2 and 3 were of equal length so the input profile for these segments was identical.

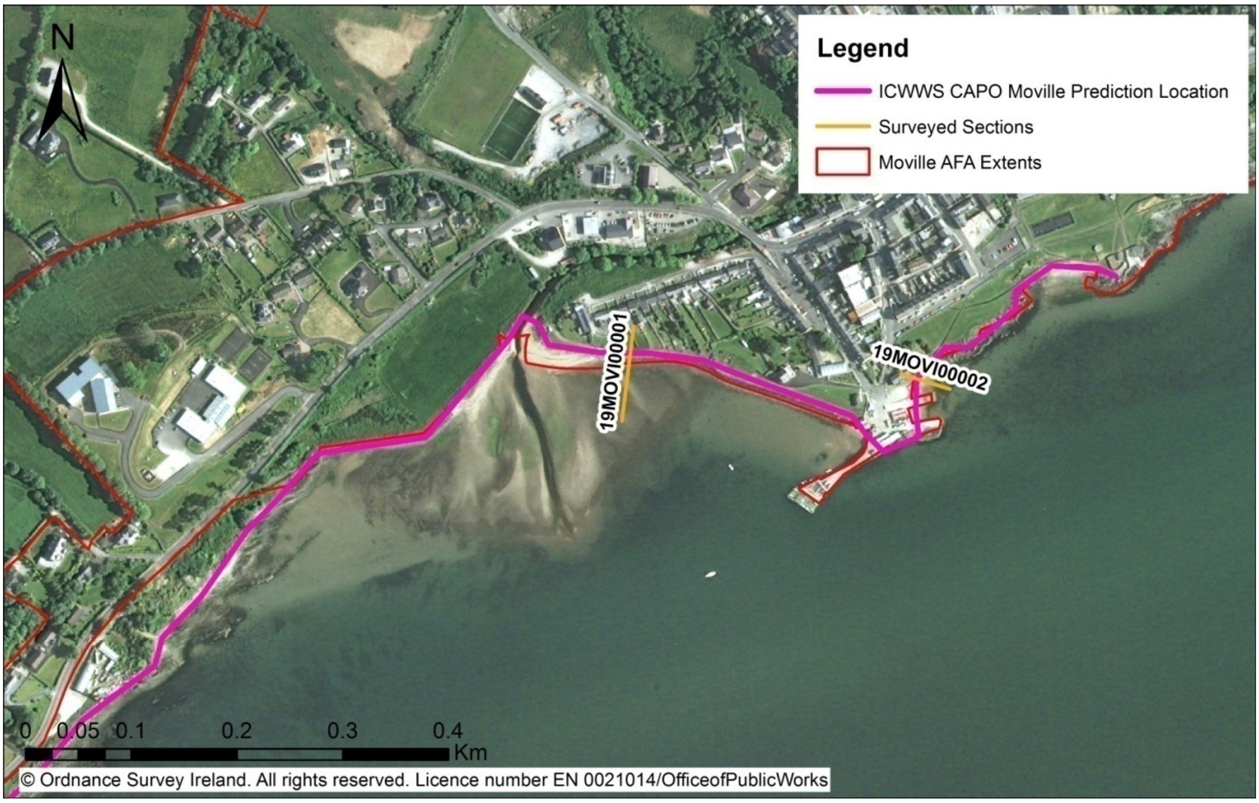


Figure 4.22.18: Moville Surveyed Section Locations

Table 4.22.4: Peak wave climate and associated discharges for modelled boundaries

Boundary	AEP	WL (OD Malin)	Hm0 (m)	Tp (s)	MWD (°)	Discharge Rate (l/s/m)	Discharge (m^3/s)
Football Field	**10%**	1.98	0.91	3.77	199	0.67	0.13
Football Field	**0.5%**	2.28	1.12	3.98	197	27.90	5.27
Football Field	**0.1%**	2.28	1.39	4.11	196	53.57	10.12
19MOVI00001	**10%**	1.98	0.91	3.77	199	0.67	0.09
19MOVI00001	**0.5%**	2.28	1.12	3.98	197	27.90	3.91
19MOVI00001	**0.1%**	2.28	1.39	4.11	196	53.57	7.50
19MOVI00001b	**10%**	1.98	0.91	3.77	199	0.05	0.01

19MOVI00001b	**0.5%**	2.28	1.12	3.98	197	1.56	0.23
19MOVI00001b	**0.1%**	2.28	1.39	4.11	196	6.14	0.90
Pier (Part 1)	**10%**	1.98	0.91	3.77	199	14.40	2.65
Pier (Part 1)	**0.5%**	2.28	1.12	3.98	197	46.54	8.56
Pier (Part 1)	**0.1%**	2.28	1.39	4.11	196	80.53	14.82
Pier (Part 2&3)	**10%**	1.98	0.91	3.77	199	14.40	0.56
Pier (Part 2&3)	**0.5%**	2.28	1.12	3.98	197	46.54	1.82
Pier (Part 2&3)	**0.1%**	2.28	1.39	4.11	196	80.53	3.14
19MOVI00002	**10%**	1.98	0.91	3.77	199	2.10	0.09
19MOVI00002	**0.5%**	2.28	1.12	3.98	197	7.01	0.31
19MOVI00002	**0.1%**	2.28	1.39	4.11	196	18.70	0.83

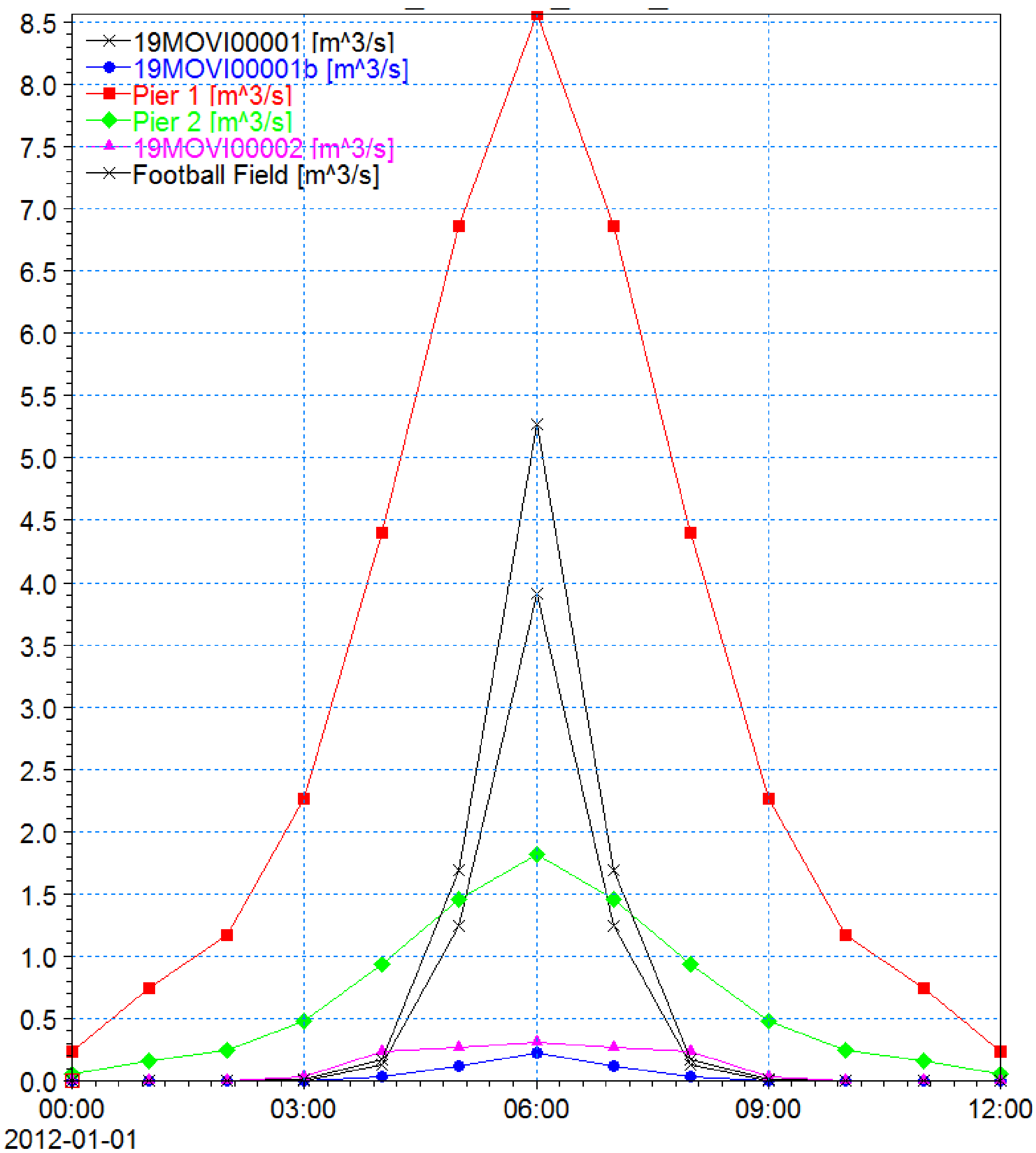


Figure 4.22.19: Modelled Discharge Profiles During 0.5% AEP Design Run

(6) Model Boundaries – Downstream Conditions: A water level boundary was applied at the downstream extent of the Bredagh Glen and Coolnasillagh watercourses where it discharges to Lough Foyle (chainage 1973.531 and 650.522 respectively). This enables the transfer of flow between the 1D and 2D domain.		
(7) Model Roughness: (see Chapter 3.6.1 'Roughness Coefficients')		
(a) In-Bank (1D Domain)	Minimum 'n' value: 0.040	Maximum 'n' value: 0.050
(b) MPW Out-of-Bank (1D)	Minimum 'n' value: N/A	Maximum 'n' value: N/A
(c) MPW/HPW Out-of-Bank (2D)	Minimum 'n' value: 0.060 (Inverse of Manning's 'M')	Maximum 'n' value: 0.080 (Inverse of Manning's 'M')

Map of 2D Roughness (Manning's n)

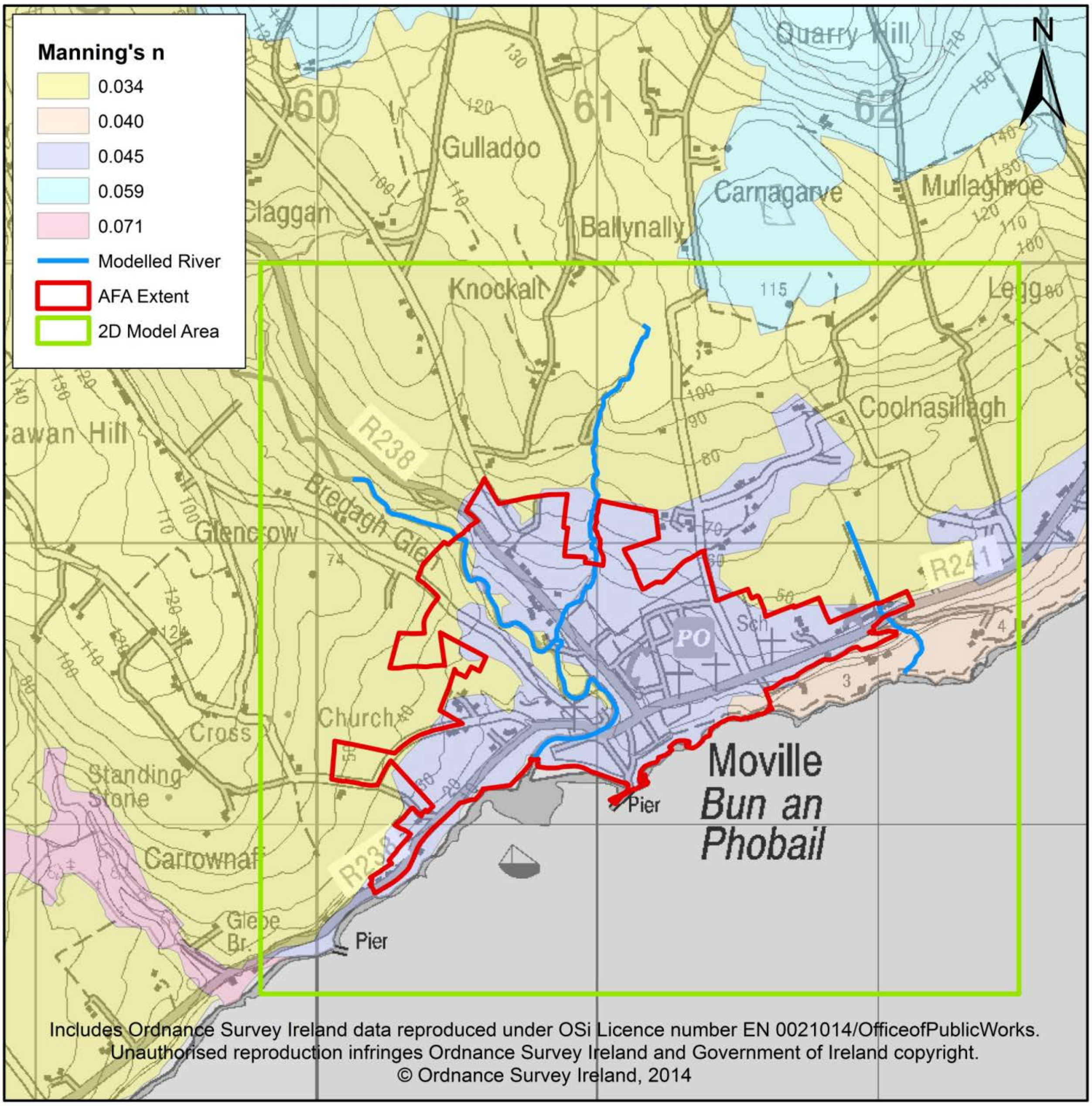


Figure 4.22.20: Map of 2D Roughness (Manning's n)

Figure 4.22.20 illustrates the roughness values applied within the 2D domain of the model. Roughness in the 2D domain was applied based on land type areas defined in the CORINE Land Cover Map with representative roughness values associated with each of the land cover classes in the dataset. Any values seaward of the high water were also taken as 0.033 unless otherwise specified.

(d) Examples of In-Bank Roughness Coefficients

Figure 4.22.21: 0155M00013US

(Moville River)

Manning's n = 0.050

Natural stream - winding, pools, shoals, stoney with some weeds.

Figure 4.22.23: 0154M00019US

(Bredagh Glen)

Manning's n =0.040

Natural stream - weedy, winding, some pools and shoals.

Figure 4.22.22: 0153M00027US

(Coolnasillagh River)

Manning's n = 0.050

Natural stream - winding, pools, shoals, stoney with some weeds.

Figure 4.22.24: 0153M00041DS

(Coolnasillagh River)

Manning's n = 0.040

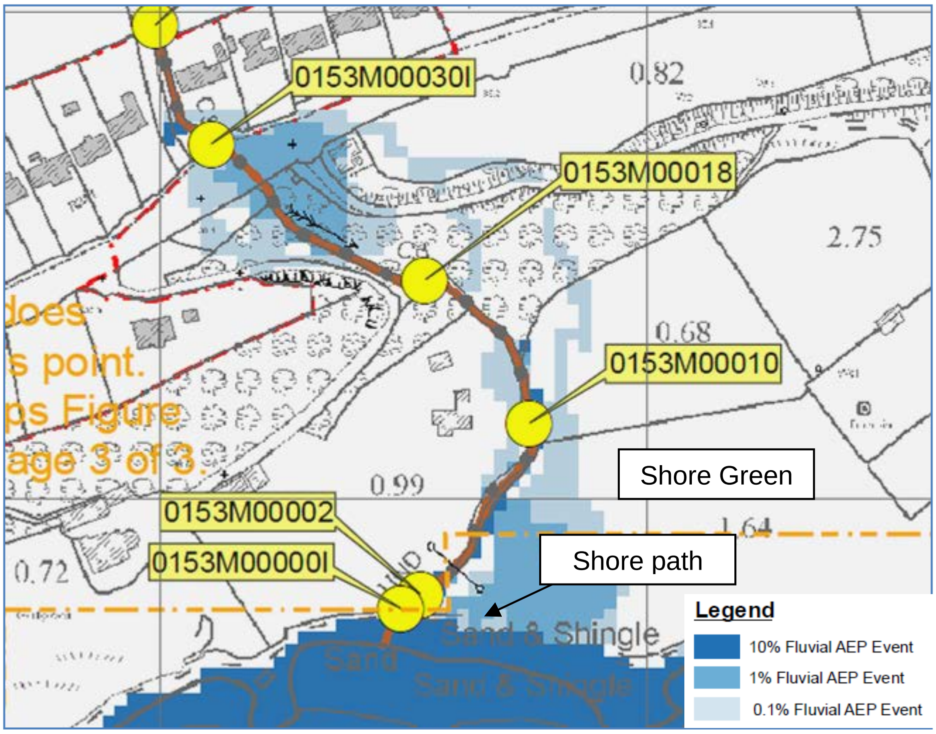
Natural stream - weedy, winding, some pools and shoals.

4.22.4 Sensitivity Analysis

To be completed for final version of report

4.22.5 Hydraulic Model Calibration and Verification

(1) Key Historical Floods (From IBE0700Rp0002_UoM 01 Inception Report_F02 unless otherwise specified):	
(a) **NOV 2011.**	An internet search indicated that flooding occurred in Donegal, Downings, Letterkenny and Moville on 28th November 2011. A website (www.donegaldaily.com) reported that more than 50mm of rain fell across Co. Donegal and there were floods on dozens of rural roads. This website stated that there were reports of flooding in Donegal, Downings and Moville; however no details were available on the extents of the flooding at these locations. There are no local rainfall records are available for this event in Moville. Records at the closest daily rainfall gauges (Greencastle 264600_440800 and Craughaulin MTN 262500_442000) do not cover this date. Flooding on roads around Moville were noted to be flooded, but a lack of detailed spatial information means this cannot be used for calibration purposes.
(c) **AUG 2009.**	It was reported on www.inishowennews.com that Moville experienced a period of flash flooding (23rd August 2009) following a period of intense rainfall. Daily rainfall data taken at Greencastle 264600_440800 on this date recorded 20.1mm. Using the FSU DDF model (FSU WP 1.2 'Estimation of Point Rainfall Frequencies') this indicates a less than 1 year return period (i.e. very high frequency). However this estimation is based on a duration of 24 hours since a higher temporal resolution is not available. This gauge is approximately 4km to the north east of the AFA. The closest rain gauge to the AFA at Craughaulin MTN (262500_442000), does not have records covering this date. To get more representative rainfall duration, data recorded from the Hourly Gauge at Malin Head, 27km to the north west of Moville was used. This gauge indicates that 19.6mm fell in 6 hours on 23rd August 2009. This is also indicative of a less than 1 year return period rainfall event using the FSU DDF model. The website reported that parts of Moville's scenic Shore Green flooded due to flood-waters that originated from higher ground. The seaside Shore Path (Sli na Slainte) was submerged, but remained mostly passable. The modelled flood extents for the 1% and 0.1% AEP events have indicated that there is flooding at the downstream

	extent of Coolnasillagh River. This location is generally referred to as Shore Green, as mentioned in the previous report. The model has indicated that during higher magnitude (<1%AEP) fluvial events, this location is susceptible to flooding, as shown on Figure 4.22.25.  **Figure 4.22.25: Coolnasillagh Watercourse Modelled Flood Extent - 1% AEP Fluvial Event**
(e) **1828**	The internet search revealed details of a flood event which occurred in Moville in 1828. A Consultant's report stated that Moville Bridge was swept away by the greatest flood ever recorded in the Moville River. Further information on the event was found on a website (www.movillerecords.com) and this surmises that the flood "must have been caused by a cloudburst in the Bredagh Glen. The flood swept down upon Gulladuff House, entirely submerged the old bridge, rose four feet within the house itself and then carried away the bridge into the lough". Although rainfall data is not available for this date to derive a design rainfall frequency, this report is useful for model verification since it has provided several spatial references. Gulladuff House is located close to Bredagh Glen and Moville River confluence. Modelled flood extents have illustrated that this location is susceptible to fluvial flooding during the higher magnitude fluvial flood scenarios (≤1%AEP).

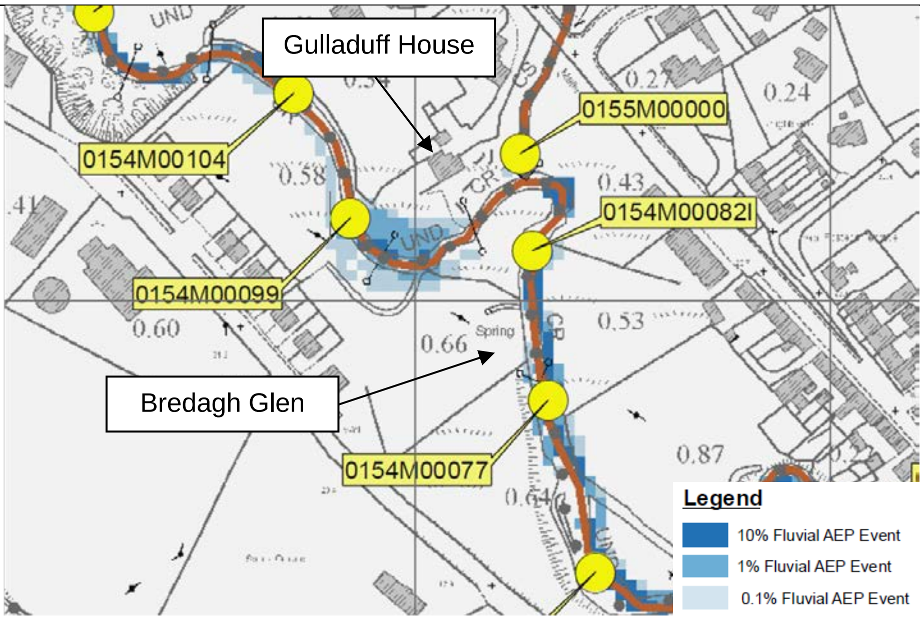


Figure 4.22.26: Modelled Flood Extents in Relation to Gulladuff House

Summary of Calibration

Due to the lack of quantitative data on previous fluvial and coastal flood events it has not been possible to calibrate the model with historical events. With the limited information available it was possible to compare certain areas that were identified to have flooded in the past and ascertain that the model is producing similar results. As such, there has not been any information presented in previous flood events that warrant any adjustment of the model parameters.

A staff gauge is located within Moville, although due to the lack of water level of flow information this gauge has not been used.

Model flows were checked against the estimated flows at HEP check points where possible to ensure the model is well anchored to the hydrological estimates. There are 6no. HEP check flow points for model flow comparison. For example at 40_315_1_RPS the estimated flow during the 0.1% AEP event was 37.14 m^3/s and the modelled flow was 39.50 m^3/s. The modelled flows generally agree well with the check flows; however, the modelled flows at HEP points 40001, 40_516_3 and 40_991_3 are influenced by tidal effects, resulting in large differences between these flows and the corresponding check flows. Full details are included in Appendix A.3.

Checks have been carried out on the ISIS mass balance model outputs for the 1% AEP events on the Moville models which may give an indication as to the robustness and stability of the model. These methods are discussed in Chapter 3.12.

Comparing 1D-2D link flow with flow in and out of the 2D domain indicated a difference of 0.94% for the combined Bredagh Glen and its tributary and a difference of 1.52% for the Coolnasillagh. For the Bredagh and river and its tributary, the average Qe (mass balance error) was recorded to be 0.30%; while the Coolnasillagh model indicated an average Qe of 0.09%. These percentage differences are within tolerances relating to mass balance stated by ISIS.

Minor instabilities that exist are discussed later in Section 4.22.6(2). This section also includes changes made to parameters to prevent instabilities. For example, the minimum flow at the upstream end of the tributary of the River Bredagh (reach 0155M) was set to 0.6m^3/s to prevent stability problems. Overall the results imply both models are robust. To illustrate this, screenshots of a 'maximum stage long-section plot' relating to each watercourse at peak flow are presented in Appendix A.2. No significant model instabilities have been identified.
(2) Post Public Consultation Updates:
Following informal public consultation and formal S.I. public consultation periods in 2015, general model updates were applied to refine model resolution and improve model stability, mapping issued as Final reflects these changes.
(3) Gauging Stations:
There is one gauging station site associated with Moville. Since this is only a staff gauge with no recorded data, this model is considered to be totally ungauged. There are no FSU pivotal sites within HA40 and a review of the closest and most hydrologically similar FSU pivotal sites nationally did not support adjustment of the catchment descriptor based design flow estimates.
(4) Other Information:
There are several recent reports and some video footage that has been published on the internet (http://www.craicon.com/new-pictures-of-flooded-moville/); that refer to the January 2014 storms. Several reports have described how the Bredagh 'burst' its banks and flowed down River Row (street) towards the town. These reports have also described how high tide/surge levels in Lough Foyle contributed to this flooding episode. In detail, two residential areas were reported to have been affected including River Row and Bay Field. A Progress Group Member identified a property on Quay Street that flooded in this event. Model outputs identify this property to be at risk in the 0.5% and 0.1% coastal AEP events. This report is useful for verifying model flood extent results, since several spatial references and flooding descriptions have been provided.

4.22.6 Hydraulic Model Assumptions, Limitations and Handover Notes

(1) Hydraulic Model Assumptions:
a) The culvert at cross section 0153M00030I on the Coolnasillagh watercourse is an arch at its upstream end and circular at its downstream end. A transition is assumed to occur midway along the culvert. b) Post-processing of draft final maps was carried out regarding bridge inundation, where flood extents were removed from the appropriate AEP event where inundation does not occur.
(2) Hydraulic Model Limitations and Parameters:

a) A 2D model grid size of 4m was used for the Bredagh Glen and Coolnasillagh watercourses for both the fluvial and coastal dominated simulations.

b) The ADI (Alternating Direction Implicit) Solver was used in ISIS 2D, as is to be used for most coastal, fluvial and surface water models. Small isolated pockets with Froude number greater than one were identified from the model outputs, although a map showing maximum Froude for the full duration of the model suggests there are not any areas deemed as significant in proximity to receptors. The ADI solver is considered to 'produce acceptable solutions as it includes methods to reduce the effects of instabilities around supercritical flows', and therefore is considered to be appropriate for this AFA. This information was taken from Section 1.2 of the ISIS 2D User Manual.

c) The minimum flow at the upstream end of the Moville watercourse (reach 0155M) was set to 0.6 m^3/s to prevent model stability problems.

d) The minimum flow at the upstream end of the Coolnasillagh watercourse (reach 0155M) was set to 0.25 m^3/s to prevent model stability problems.

e) The DFLOOD parameter was increased to 4m for reaches 0154M and 0155M to prevent model stability problems due to glass walling.

f) The DFLOOD parameter was increased to 5m for reach 0153M to prevent model stability problems due to glass walling.

g) The Maxitr parameter was increased to 13 for reach 0153M to improve model convergence.

(3) Design Event Runs & Hydraulic Model Handover Notes:

a) The culvert under the R241, on the Coolnasillagh watercourse causes flooding during the modelled 1% and 0.1% AEP fluvial events (see section 4.22.3, above).

b) The culvert at the downstream end of the Coolnasillagh watercourse restricts flow with significant flooding shown to occur on the left hand bank (see section 4.22.3). Much of the flooding may also be related to channel capacity, with flood water leaving the channel some distance upstream of the culvert. Some instability has been identified in this area, where the culvert is significantly inundated. This relates to insignificant variation in stage.

c) The bridge at cross section 0154M00090D restricts flows during the 1% and 0.1% AEP events, causing flooding (see section 4.22.3).

d) A lack of capacity in the culvert at cross section 0154M00082I causes a small amount of flooding during the 1% and 0.1% AEP events, due to overtopping / bypassing of this structure (see section 4.22.5).

(4) Hydraulic Model Deliverables:

Please see Appendix A.4 for a list of all model files provided with this report.

(6) Quality Assurance:

Model Constructed by:	Ian Bentley
Model Reviewed by:	Stephen Patterson

Model Approved by:	Malcolm Brian

APPENDIX A.1

Structure details – bridges & culverts								
River branch	**Chainage**	**ID****	**Length (m)**	**Opening shape**	**Height (m)**	**Width (m)**	**Spring height from invert (m)**	**Mannings n (or colebrook white k)**
Bridges								
COOLNASILLAGH	355	0153M00031D	1.5	ARCH	1.06	1	1.06	0.04
BREDAGH GLEN	1098	0154M00090D	3.897	ARCH	3.59	3.28	1.9	0.04
BREDAGH GLEN	1742	0154M00026D	10.25	ARCH	4.05	10	1.333	0.04
MOVILLE	485	0155M00084D	2.34	ARCH	2.71	2.39	2.71	0.05
MOVILLE	1238	0155M00008D	8.83	ARCH	5.74	5.44	3.12	0.05
CULVERTS								
COOLNASILLAGH	219	0153M00044I	11	CIRCULAR (DOUBLE BARREL)	0.45/0.6	0.45/0.6	N/A	0.02
COOLNASILLAGH	365	0153M00030I	57.2	SPRUNG	0.98	1.72	0.67	0.03
COOLNASILLAGH	650	0153M00000I	2	CIRCULAR	0.45	0.45	N/A	0.03
BREDAGH GLEN	1189	0154M00082I	5.631	CIRCULAR	0.9 x 6	0.9 x 6	N/A	0.03

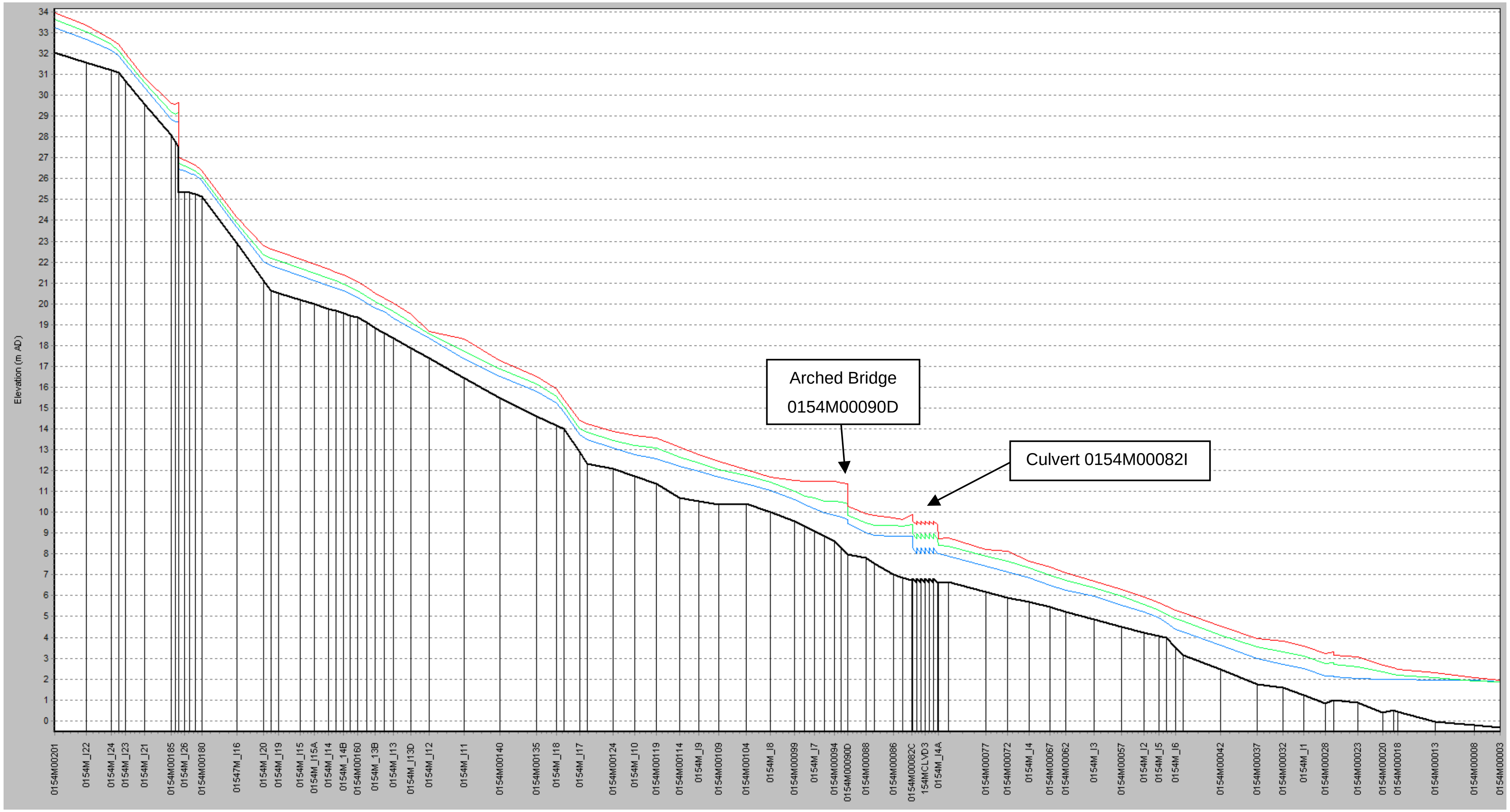
** Structure ID Key:
D – Bridge Upstream Face; **E** – Bridge Downstream Face; **I** – Culvert Upstream Face; **J** – Culvert Downstream Face

All bridges and culverts listed in this table were represented in the model based on surveying and photographic information. The Manning's n number was considered to reflect the resistance that a series of cross channels might produce during a flooding event.

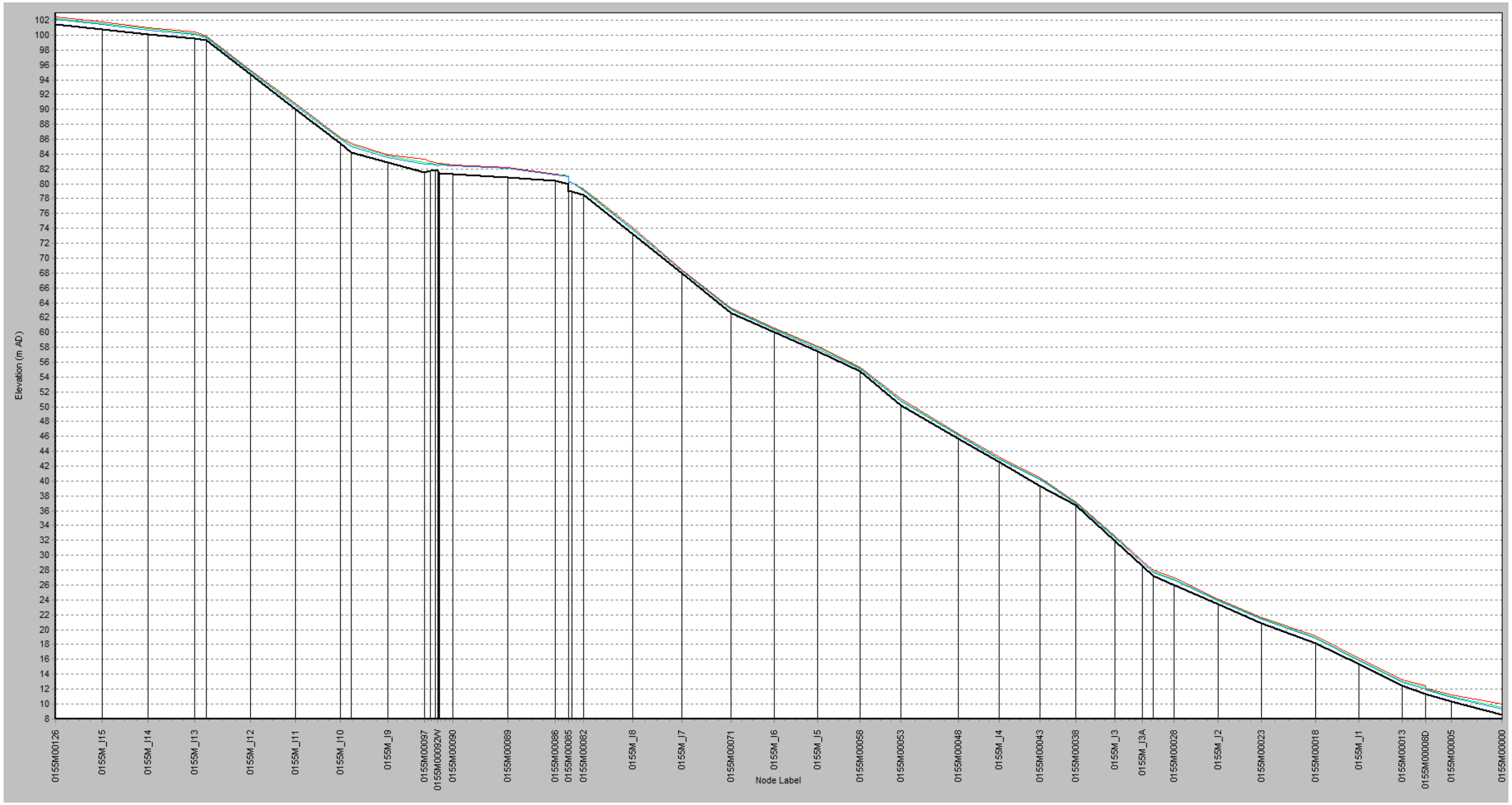
Structure Details - Weirs			
RIVER BRANCH	**CHAINAGE**	**ID**	**Type**
Coolnasillagh	345	0153M00033W	Natural Weir
Coolnasillagh	479	0153M00017W	Natural Weir (unsurveyed)
Bredagh Glen	172	0154M00184W	Natural Weir
Moville River	368	0155M00092W	Natural Weir

APPENDIX A.2

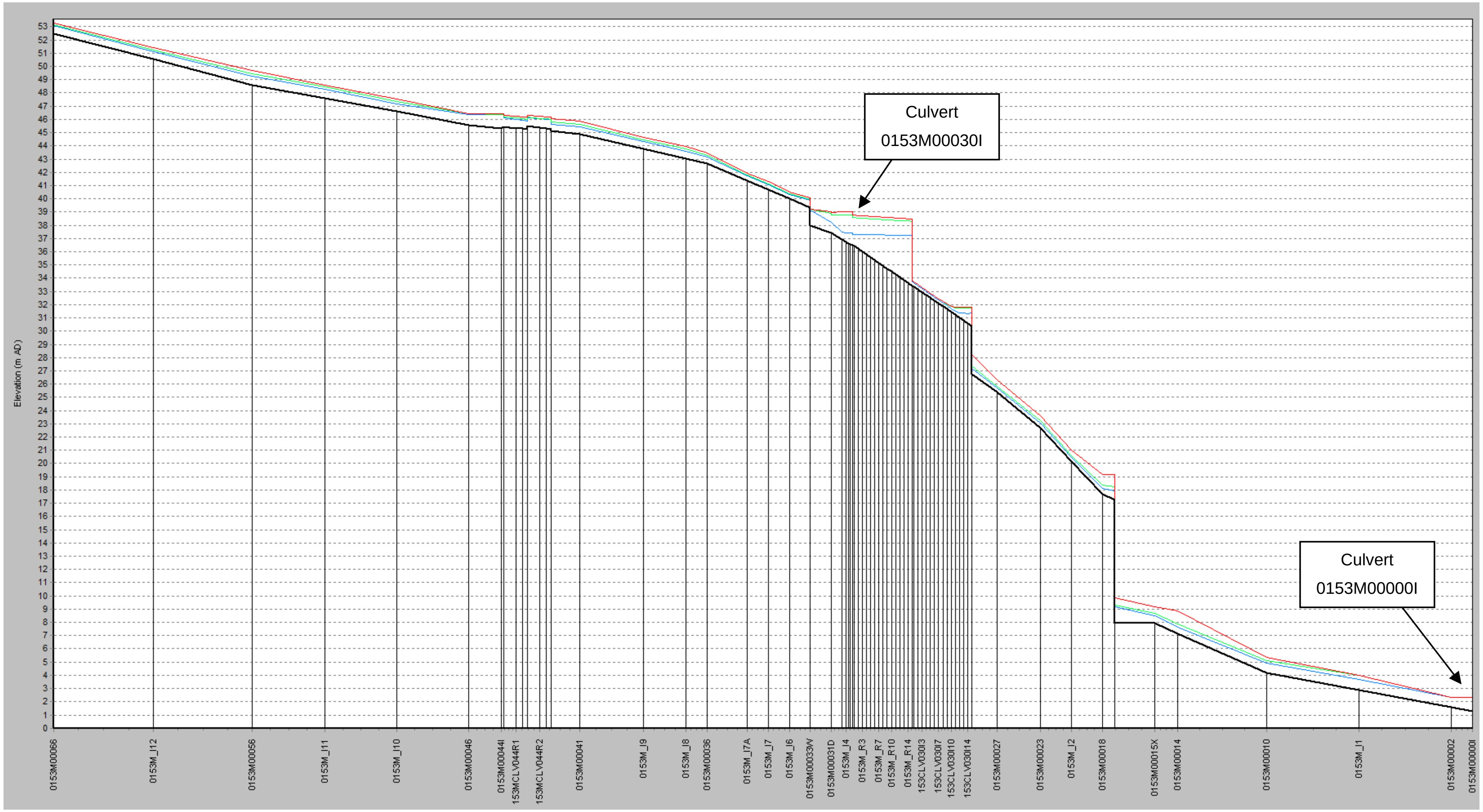
Long section plots



Reach 0154M: Bredagh Glen. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP events



Reach 0155M: Moville River. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP events



Reach 0153M: Coolnasillagh. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP events

APPENDIX A.3

Flow Comparison at HEP Check Points

Watercourse	HEP Point	AEP	Check Flow (m^3/s)	Model Flow (m^3/s)	Difference (%)
Bredagh Glen	40_315_1_RPS	10%	14.44	14.78	+2.33
		1%	23.18	24.34	+5.02
		0.1%	37.14	39.98	+7.63
Bredagh Glen	40_315_2_RPS	10%	14.67	15.38	+4.84
		1%	23.54	25.34	+7.63
		0.1%	37.73	40.71	+7.90
Moville	40_460_6_RPS	10%	3.16	3.14	-0.76
		1%	5.14	5.10	-0.93
		0.1%	8.38	8.41	+0.37
Bredagh Glen*	40001_RPS	10%	17.82	20.27	+13.74
		1%	28.4	32.87	+15.75
		0.1%	44.7	52.42	+17.27
Bredagh Glen*	40_516_3	10%	17.95	21.01	+17.08
		1%	28.06	33.50	+19.36
		0.1%	43.49	52.46	+20.62
Coolnasillagh*	40_911_3	10%	1.76	1.63	-7.20
		1%	2.85	3.36	+17.66
		0.1%	4.65	12.49	+168.57

*Subject to tidal influence

The table above provides details of flow in the model at HEP check points. These flows have been compared with the hydrology flow estimation and a percentage difference provided.

The downstream limit checkpoints 40001_RPS and 40_516_3 on the Bredagh Glen and 40_911_3 on the Coolnasillagh are subject to tidal influences from Lough Foyle. The discharge at these HEP points in the model is a combination of fluvial and tidal components. As a result it is not possible to reliably check the model flow at these points against the hydrological estimation which only considers the fluvial component of flow at this location.

In general the model is well anchored to hydrological estimates as all other modelled flows are within 10% of check flows.

APPENDIX A.4

Model Files provided with this report

ISIS 2D .xml Files*	ISIS 1D .ief Files*	Sub-Folders
UOM01_MOV4A_1D_DES_Q10C.xml	UOM01_MOV4A_1D_DES_Q10C.ief	ISIS 1D
UOM01_MOV4A_1D_DES_Q10F.xml	UOM01_MOV4A_1D_DES_Q10F.ief	ISIS 2D
UOM01_MOV4A_1D_DES_Q100C.xml	UOM01_MOV4A_1D_DES_Q100C.ief	Results
UOM01_MOV4A_1D_DES_Q100F.xml	UOM01_MOV4A_1D_DES_Q100F.ief	
UOM01_MOV4A_1D_DES_Q1000C.xml	UOM01_MOV4A_1D_DES_Q1000C.ief	
UOM01_MOV4A_1D_DES_Q1000F.xml	UOM01_MOV4A_1D_DES_Q1000F.ief	
UOM01_MOV4B_1D_DES_Q10C.xml	UOM01_MOV4B_1D_DES_Q10C.ief	
UOM01_MOV4B_1D_DES_Q10F.xml	UOM01_MOV4B_1D_DES_Q10F.ief	
UOM01_MOV4B_1D_DES_Q100C.xml	UOM01_MOV4B_1D_DES_Q100C.ief	
UOM01_MOV4B_1D_DES_Q100F.xml	UOM01_MOV4B_1D_DES_Q100F.ief	
UOM01_MOV4B_1D_DES_Q1000C.xml	UOM01_MOV4B_1D_DES_Q1000C.ief	
UOM01_MOV4B_1D_DES_Q1000F.xml	UOM01_MOV4B_1D_DES_Q1000F.ief	

*Note - Suffix 'F' denotes fluvial design run, 'C' denotes 'mechanism 1 tidal' (surge) coastal design run.

1st Level Sub-Folder	2nd Level Sub-Folder	3rd Level Folder	Files
ISIS 2D	Bredagh_0154M	Active Area	UOM01_MOV4A_2D_DES_ACTVA.dbf UOM01_MOV4A_2D_DES_ACTVA.shp UOM01_MOV4A_2D_DES_ACTVA.shx
		Links	UOM01_MOV4A_2D_DES_ACTVA_0155M_RB.shp UOM01_MOV4A_2D_DES_ACTVA_0155M_RB.dbf UOM01_MOV4A_2D_DES_ACTVA_0155M_RB.shx UOM01_MOV4A_2D_DES_ACTVA_0155M_LB.shp UOM01_MOV4A_2D_DES_ACTVA_0155M_LB.dbf UOM01_MOV4A_2D_DES_ACTVA_0155M_LB.shx UOM01_MOV4A_2D_DES_ACTVA_0154M_RB.shp UOM01_MOV4A_2D_DES_ACTVA_0154M_RB.dbf UOM01_MOV4A_2D_DES_ACTVA_0154M_RB.shx UOM01_MOV4A_2D_DES_ACTVA_0154M_LB2.shp UOM01_MOV4A_2D_DES_ACTVA_0154M_LB2.dbf UOM01_MOV4A_2D_DES_ACTVA_0154M_LB2.shx UOM01_MOV4A_2D_DES_ACTVA_0154M_LB1.shp UOM01_MOV4A_2D_DES_ACTVA_0154M_LB1.dbf UOM01_MOV4A_2D_DES_ACTVA_0154M_LB1.shx UOM01_MOV4A_2D_DES_ACTVA_0154M_DSBDY.shp UOM01_MOV4A_2D_DES_ACTVA_0154M_DSBDY.dbf UOM01_MOV4A_2D_DES_ACTVA_0154M_DSBDY.shx
	Coolnasillagh_0153M	Active Area	UOM01_MOV4B_2D_DES_ACTVA.shp UOM01_MOV4B_2D_DES_ACTVA.dbf UOM01_MOV4B_2D_DES_ACTVA.shx
		Links	UOM01_MOV4B_2D_DES_RB.shp UOM01_MOV4B_2D_DES_RB.dbf UOM01_MOV4B_2D_DES_RB.shx UOM01_MOV4B_2D_DES_LB.shp UOM01_MOV4B_2D_DES_LB.dbf UOM01_MOV4B_2D_DES_LB.shx
	DTM		UOM01_MOV4_2D_BLD.shp UOM01_MOV4_2D_BLD.dbf UOM01_MOV4_2D_BLD.shx UOM01_MOV4A_2D_2MDTM.asc UOM01_MOV4B_2D_2MDTM.asc
	2D Roughness		UOM01_MOV4_2D_MANN.asc

1st Level Sub-Folder	2nd Level Sub-Folder	3rd Level Folder	Files
ISIS 1D	Bredagh_0154M		UOM01_MOV4A_1D_DES.DAT UOM01_MOV4A_1D_DES_Q2F.IED UOM01_MOV4A_1D_DES_Q10C.IED UOM01_MOV4A_1D_DES_Q10F.IED UOM01_MOV4A_1D_DES_Q100F.IED UOM01_MOV4A_1D_DES_Q200C.IED UOM01_MOV4A_1D_DES_Q1000C.IED UOM01_MOV4A_1D_DES_Q1000F.IED
	Coolnasillagh_0153M		UOM01_MOV4B_1D_DES.DAT UOM01_MOV4B_1D_DES_Q2F.IED UOM01_MOV4B_1D_DES_Q10C.IED UOM01_MOV4B_1D_DES_Q10F.IED UOM01_MOV4B_1D_DES_Q100F.IED UOM01_MOV4B_1D_DES_Q200C.IED UOM01_MOV4B_1D_DES_Q1000C.IED UOM01_MOV4B_1D_DES_Q1000F.IED

1st Level Sub-Folder	2nd Level Sub-Folder	3rd Level Folder	Files
Results	ISIS 1D MIN-MAX		UOM01_MOV4A_1D_DES_Q10C.csv UOM01_MOV4A_1D_DES_Q10F.csv UOM01_MOV4A_1D_DES_Q100F.csv UOM01_MOV4A_1D_DES_Q200C.csv UOM01_MOV4A_1D_DES_Q1000C.csv UOM01_MOV4A_1D_DES_Q1000Fcsv UOM01_MOV4B_1D_DES_Q10C.csv UOM01_MOV4B_1D_DES_Q10F.csv UOM01_MOV4B_1D_DES_Q100F.csv UOM01_MOV4B_1D_DES_Q200Ccsv UOM01_MOV4B_1D_DES_Q1000C.csv UOM01_MOV4B_1D_DES_Q1000F.csv
	ISIS 1D UNSTEADY RESULTS		UOM01_MOV4A_1D_Q10C.zzn UOM01_MOV4A_1D_Q10F.zzn UOM01_MOV4A_1D_Q100F.zzn UOM01_MOV4A_1D_Q200C.zzn UOM01_MOV4A_1D_Q1000C.zzn UOM01_MOV4A_1D_Q1000F.zzn UOM01_MOV4B_1D_Q10C.zzn UOM01_MOV4B_1D_Q10F.zzn UOM01_MOV4B_1D_Q100F.zzn UOM01_MOV4B_1D_Q200C.zzn UOM01_MOV4B_1D_Q1000C.zzn UOM01_MOV4B_1D_Q1000F.zzn UOM01_MOV4A_1D_Q10C.zzl UOM01_MOV4A_1D_Q10F.zzl UOM01_MOV4A_1D_Q100F.zzl UOM01_MOV4A_1D_Q200C.zzl UOM01_MOV4A_1D_Q1000C.zzl UOM01_MOV4A_1D_Q1000F.zzl UOM01_MOV4B_1D_Q10C.zzl UOM01_MOV4B_1D_Q10F.zzl UOM01_MOV4B_1D_Q100F.zzl UOM01_MOV4B_1D_Q200C.zzl UOM01_MOV4B_1D_Q1000C.zzl UOM01_MOV4B_1D_Q1000F.zzl
	ISIS 2D MAX DEPTH		UOM01_MOV4A_1D_DES_Q10C.asc UOM01_MOV4A_1D_DES_Q10F.asc UOM01_MOV4A_1D_DES_Q100F.asc UOM01_MOV4A_1D_DES_Q200C.asc UOM01_MOV4A_1D_DES_Q1000C.asc UOM01_MOV4A_1D_DES_Q1000Fasc UOM01_MOV4B_1D_DES_Q10C.asc UOM01_MOV4B_1D_DES_Q10F.asc UOM01_MOV4B_1D_DES_Q100F.asc UOM01_MOV4B_1D_DES_Q200C.asc UOM01_MOV4B_1D_DES_Q1000C.asc UOM01_MOV4B_1D_DES_Q1000F.asc

'Mechanism 2 Wave Overtopping' Model Files		
MIKE 21	**MIKE 21 - DFS0 FILE**	**MIKE 21 RESULTS**
HA01_MOVI4_M21FM_WAV_8_Q10	HA01_MOVI4_DFS0_Q10	HA01_MOVI4_M21FM_WAV_8_Q10
HA01_MOVI4_M21FM_WAV_8_Q200	HA01_MOVI4_DFS0_Q200	HA01_MOVI4_M21FM_WAV_8_Q200
HA01_MOVI4_M21FM_WAV_8_Q1000	HA01_MOVI4_DFS0_Q1000	HA01_MOVI4_M21FM_WAV_8_Q1000
HA01_MOVI4_MESH_7		
HA01_MOVI4_MESH_7_FPR		

GIS Deliverables - Hazard

Flood Extent Files (Shapefiles)	Flood Depth Files (Raster)	Water Level and Flows (Shapefiles)
Fluvial N35EXFCD001F0 N35EXFCD010F0 N35EXFCD100F0 Coastal N35EXCCD001F0 N35EXCCD005F0 N35EXCCD100F0	Fluvial N35DPFCD001F0 N35DPFCD010F0 N35DPFCD100F0 Coastal N35DPCCD001F0 N35DPCCD005F0 N35DPCCD100F0	Fluvial N35NFCDF0 Coastal N35NCCDF0
Flood Zone Files (Shapefiles)	**Flood Velocity Files (Raster)**	**Flood Defence Files (Shapefiles)**
N35ZNA_MCDF0 N35ZNB_MCDF0	Fluvial N35VLFCD001F0 N35VLFCD010F0 N35VLFCD100F0 Coastal N35VLCCD001F0 N35VLCCD005F0 N35VLCCD100F0	N/A

GIS Deliverables - Risk

Specific Risk - Inhabitants (Raster)	General Risk - Economic (Shapefiles)	General Risk-Environmental (Shapefiles)
Fluvial N35RIFCD100F0 N35RIFCD010F0 N35RIFCD001F0 Coastal N35RICCD100F0 N35RICCD005F0 N35RICCD001F0		