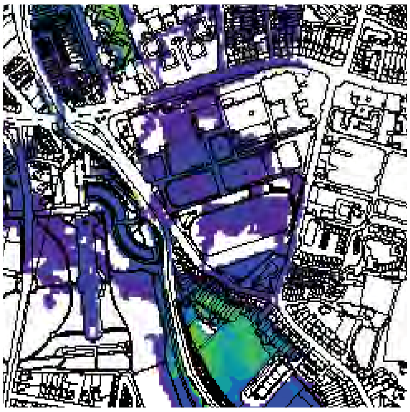
NORTH WESTERN
NEAGH BANN
CFRAM
STUDY
CATCHMENT FLOOD RISK
ASSESSMENT AND MANAGEMENT

North Western - Neagh Bann CFRAM Study

UoM 01 Hydraulics Report
4.14 Dungloe

IBE0700Rp0011



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Photographs of flooding on cover provided by Rivers Agency

North Western-Neagh Bann

CFRAM Study

HA01 Hydraulics Report

Dungloe Model

DOCUMENT CONTROL SHEET

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

Rev.	Status	Author(s)	Modeller	Reviewed by	Approved By	Office of Origin	Issue Date
D01	Draft	M. Houston	D. Irwin	I Bentley	G. Glasgow	Belfast	17/01/2014
D02	Draft	T. Carberry	D. Irwin	S. Patterson	G. Glasgow	Belfast	20/06/2014
F01	Draft	E Holland	D. Irwin	L. Arbuckle	G. Glasgow	Belfast	13/11/14
F02	Draft	E Holland	D. Irwin	L. Arbuckle	G. Glasgow	Belfast	13/08/2015
F03	Draft Final	E Holland	D. Irwin	S. Patterson	G. Glasgow	Belfast	06/07/2016

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_Final_v2.0**	**Executive Summary**
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**	**4.16, 6.2**
North Western Neagh Bann CFRAM HA01_06_36 Survey Contract Report	**October 2013**	**IBE0700Rp0007_HA01_06_36 NWNB_CFRAM_Survey Contract Report**	**TBC**
North Western Neagh Bann CFRAM Study Hydraulics Report	**October 2014**	**IBE0700Rp0011_UoM 01_Hydraulics Report**	**3**

4 HYDRAULIC MODEL DETAILS

4.14 DUNGLOE MODEL

4.14.1 General Hydraulic Model Information

(1) Introduction:

The NWNB CFRAM Flood Risk Review (2011s5232 NW&NB CFRAM FRR Report_Final_v2.0) highlighted Dungloe as an AFA for coastal and fluvial flooding based on a review of historic flooding and the extents of flood risk determined during the PFRA.

The Dungloe model represents the reach of the Dunglow River flowing out of Dunglow Lough and into the sea. The Dunglow River catchment is a medium sized catchment (40km^2), which is characterised by a high level of attenuation with a number of on-line loughs along the length of the river. The river channel itself is fairly flat along its length. The catchment area has over 85% peat coverage.

There are no gauging stations available within the modelled extents of the Dunglow River catchment which have continuous flow data available (Station 38006 in the centre of town is a staff gauge only site). The nearest gauging station with flow data available is at Lough Anure (Station 38071) to the north of the catchment. The Lough Anure catchment is hydrologically similar to the Dunglow River catchment regarding its size and both are heavily attenuated. However the flow data which is available was not deemed suitable for use as a pivotal site under FSU. The flow is derived from a lake level to lake outflow relationship and no quality data exists regarding the rating. For these reasons it is not considered prudent to use the data for adjustment of initial Q_{med} estimates for the model. The affect of attenuation in the Dungloe catchment appears to be well captured in the FSU catchment descriptors (FARL value of 0.624). The two most hydrologically similar FSU pivotal sites suggest that the FSU ungauged catchment descriptor equation captures the Q_{med} accurately with adjustment factors for sites 31002 and 39008 of 1.00 and 0.93 respectively.

The watercourse in this model has been identified as HPW, and so has been modelled as 1D-2D using the MIKE suite of software. Channel markers have been located at the right and left banks of all cross sections. Flow within these markers is calculated by the 1D model component; however when the water level rises sufficiently to meet the bank markers, flow can enter the 2D domain which represents the floodplain.

Dungloe AFA was identified as at risk from both fluvial and coastal flooding during the PFRA. An initial screening process was undertaken to ascertain whether the flooding mechanisms in Dungloe warrant further consideration of joint probability of occurrence. (Hydrology Report, IBE0700Rp0006_UoM 01 Hydrology Report_F01, Chapter 6.3.2). This analysis identified that there was a small overlap of fluvial and flood outlines within the AFA extents. Therefore joint probability scenarios were considered for this area. These scenarios included three fluvial-dominated events each combined with a coastal event and three coastal-dominated events each combined with a fluvial event as described in Chapter 3.7.3.

(2) Model Reference:	HA01_DUNG16
(3) AFAs included in the model:	Dungloe
(4) Primary Watercourses / Water Bodies (including local names):	
Reach ID	**Name**
0114M	DUNGLOW RIVER
(5) Software Type (and version):	

(a) 1D Domain:	**(b) 2D Domain:**	**(c) Other model elements:**
MIKE 11 (2012)	MIKE 21 - Flexible Mesh (2012)	MIKE FLOOD (2012)

4.14.2 Hydraulic Model Schematisation

(1) **Map of Model Extents:**

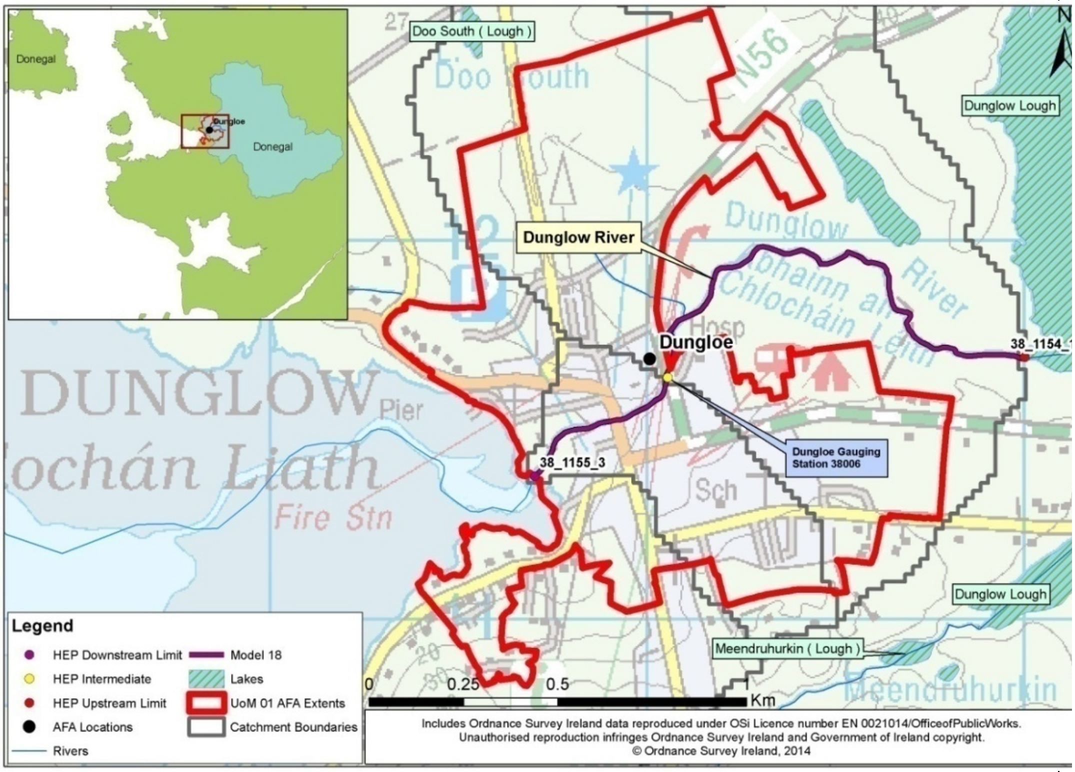

Figure 4.14.1: Map of Model Extents

Figure 4.14.1 illustrates the extent of the modelled catchment, river centre line, HEP locations and AFA extent. The catchment contains 1no. Upstream Limit HEP, 1no. Downstream Limit HEP and 1no. Intermediate HEP. There are no gauging stations or tributary HEPs.

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

River Name		Easting	Northing
0114M	Dunglow River	177978	411693

(3) Total Modelled Watercourse Length:		1.8 km (approx)	
(4) 1D Domain only Watercourse Length:	0 km	**(5) 1D-2D Domain Watercourse Length:**	1.8 km (approx.)
(6) 2D Domain Mesh Type / Resolution / Area:		Flexible / 5-60 metres / 13.4 km^2 (approx.)	

(7) 2D Domain Model Extent:

Figure 4.14. illustrates the modelled extents and general topography. The AFA boundary is shown in red. Buildings are represented in black; refer to Chapter 3 for details on representations of buildings in the model. There were no significant edits made to the LiDAR data while generating the 2D domain.

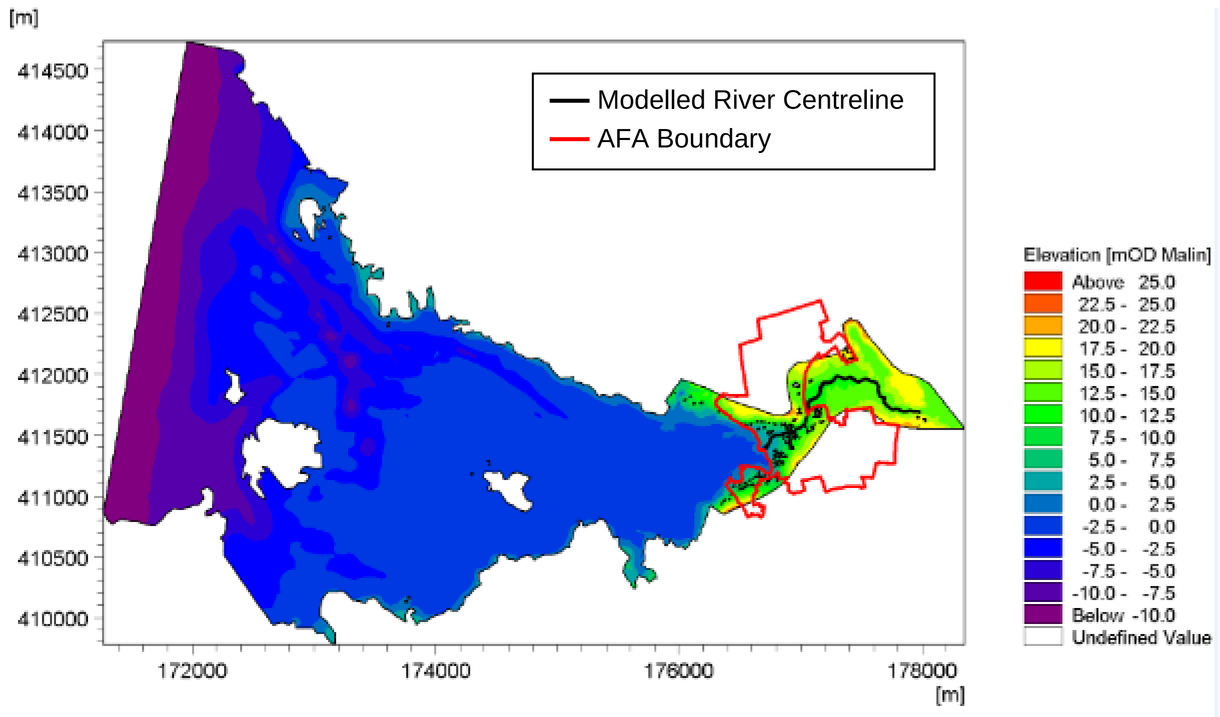

Figure 4.14.2: 2D Model Extent

Figure 4.14.1 shows an overview drawing of the model schematisation. Figure 4.14.2 shows a more detailed view. The overview diagram covers the model extents, showing the surveyed cross-section locations, AFA boundary and river centre line. It also shows the area covered by the 2D model domain. Figure 4.14.2 shows the detailed area where there is the most significant risk of flooding. These diagrams include the surveyed cross-section locations, AFA boundary and river centre. Figure 4.14.2 also shows the location of the critical structures as discussed in Section 4.14.3 (1), along with the location and extent of the links between the 1D and 2D models.

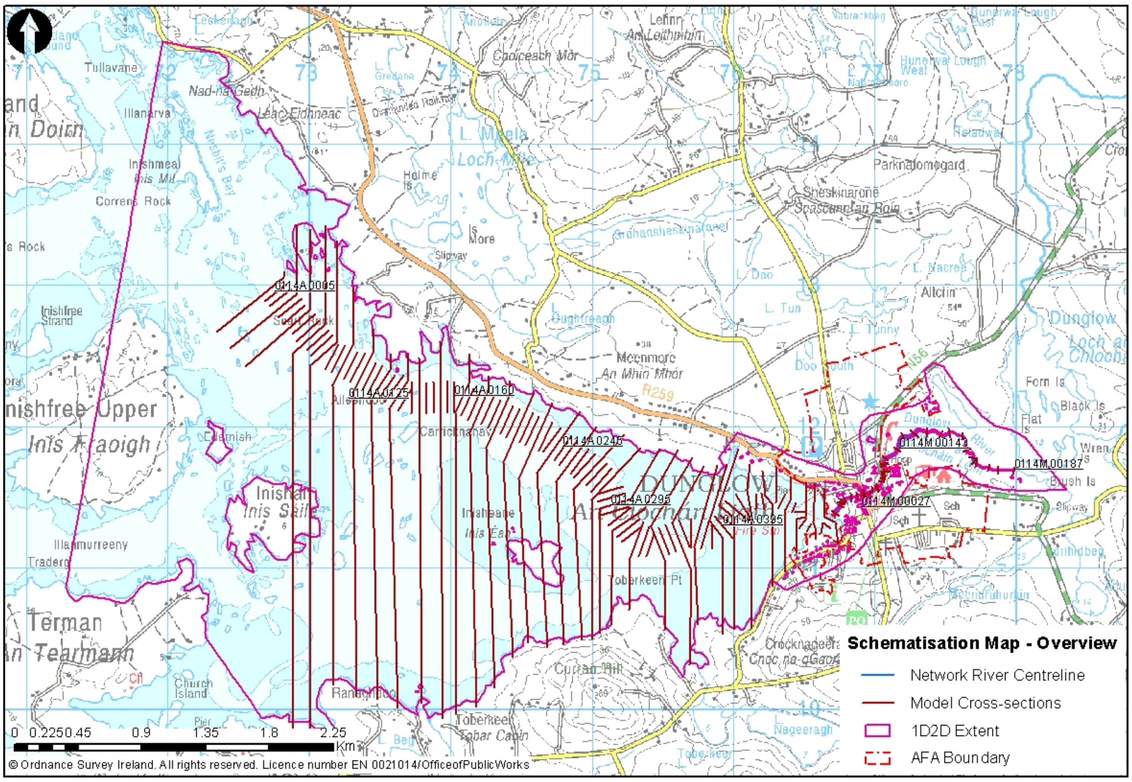

Figure 4.14.1: Overview Drawing of Model Schematisation

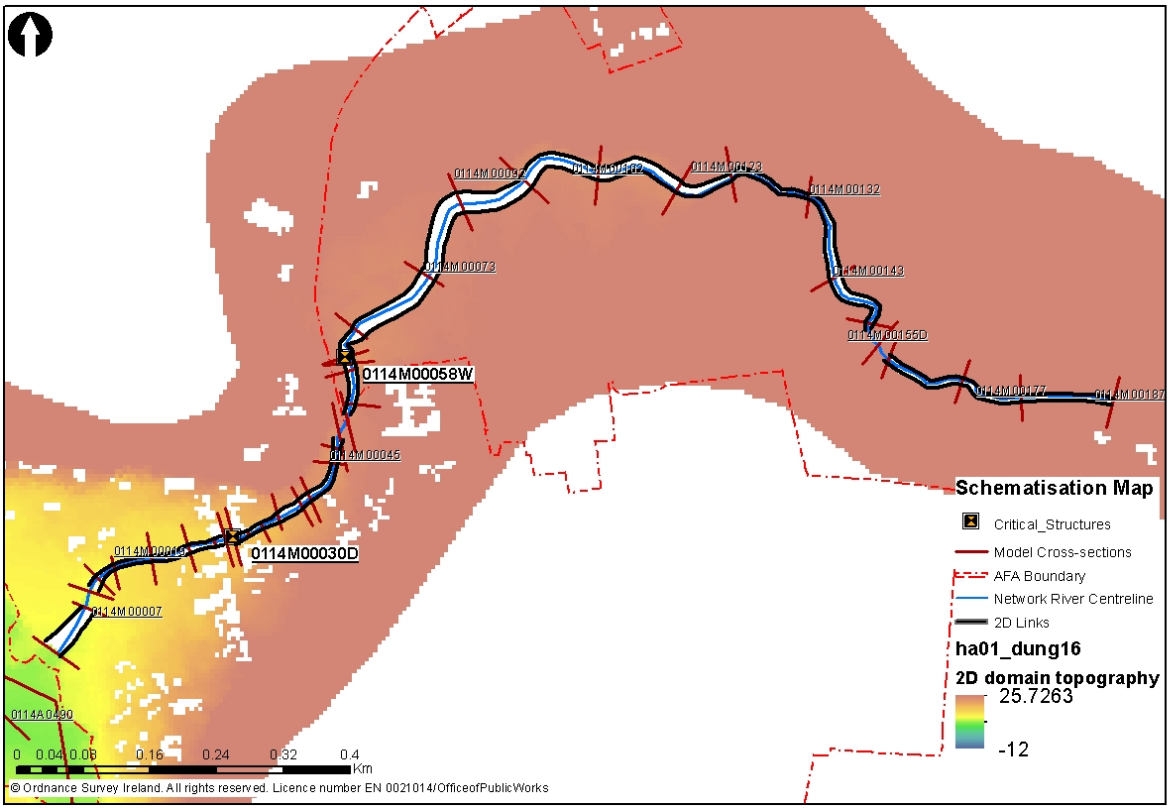

Figure 4.14.2: Detailed Area of Model Schematisation showing Critical Structures

(8) Survey Information

(a) Survey Folder Structure:

<table>
<tr><th>First Level Folder</th><th>Second Level Folder</th><th>Third Level Folder</th></tr>
<tr><td rowspan="7">Murphy_NW1_M16_WP5_0014A_V0_130701
Where: Dungloe
Murphy – Surveyor Name
NW1 – North-West CFRAM Study Area, Hydrometric Area 01
M16 – Model Number 16
WP5 – Work Package 5
0014A – River Reference
V0 - Version
130701– Date Issued (1st July 2013)</td><td rowspan="4">GIS and Floodplain Photos</td><td>Floodplain photos and shapefiles</td></tr>
<tr><td>Structure Register</td></tr>
<tr><td>Surveyed Cross Section Lines</td></tr>
<tr><td>Watercourse Register</td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td>Ascii</td><td></td></tr>
<tr><td>Photos (Naming convention is in the format of Cross-Section ID and orientation - upstream, downstream, left bank or right bank)</td><td></td></tr>
</table>

(b) Survey Folder References:

Reach ID	**Name**	**File Ref.**
0114M	Dunglow River	Murphy_NW1_M16_WP5_0114M_V1_130410
0114A	Dunglow Bay	Murphy_NW1_M16_WP5_0114A_VO_130701

The bathymetry of the 2D model used depth information extracted from Admiralty chart data as digitally supplied by CMAP of Norway, LiDAR, and the topographic surveys that were carried out for at Dunglow Bay for this study. Further details on the bathymetry data sources are presented in Chapter 2.2.3.

(9) Survey Issues:

No Survey queries.

Global Mapper was used to interpolate the surveyed cross-sections of Dunglow Bay into a grid of points with a resolution of 2m. This generally produced satisfactory results however a small number of manual alterations were undertaken in the centre of Dunglow Bay where erroneous values were created due to the interaction between cross-sections taken at significantly different angles.

At the mouth of Dunglow Bay seaward of the last surveyed cross section, additional scatter data was added along the approximate contour lines displayed on Admiralty charts of this area. This improved mesh interpolation and ensured that the mesh was representative in this area.

LiDAR elevation data at the point of the last surveyed cross-section on the Dunglow watercourse (0114M0002) was edited to equal the lowest bed level of this cross-section. This is the location where the Dunglow watercourse from the 1D domain discharges to the 2D domain, so aligning the bed levels of

these two model elements improves stability and continuity of flow. It should be noted that LiDAR data will consist of the elevation of the water in the channel at the time it was flown, so correcting data at this location based on bed levels in the channel and structure survey is considered appropriate.

LiDAR elevation data was also edited at the point in the model where Dunglow River flows out from Dunglow Lough. LiDAR levels were increased upstream of chainage 0 to ensure that water did not propagate backwards into the lough.

4.14.3 Hydraulic Model Construction

(1) 1D Structures (in-channel along modelled watercourses):	See Appendix A.2 Number of Bridges and Culverts: 4 Number of Weirs: 3

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 4.24.4. Details on modelled structures are also presented in Appendix A.1 and Appendix A.2.

On the Dunglow River, Weir 0114M00058W at chainage 1273.209m (refer to Figure 4.14.3), causes flow to back up and subsequent flooding during fluvial dominated events of 10% AEP or lower.

Figure 4.14.3: Weir 0114M00058W

On the Dunglow River, Bridge 0114M00030D at chainage 1570.665m (refer to Figure 4.14.) causes a restriction to flow during large fluvial dominated events for all AEPs considered. However the bridge does not cause flooding under normal conditions. This bridge collapsed during the flood event in September 1985, see Section 4.14.5(1)(c) causing a major restriction to flow and subsequently widespread flooding.

Figure 4.14.6: Bridge 0114M00030D

(2) 1D Structures in the 2D domain (beyond the modelled watercourses):	None
(3) 2D Model structures:	None

(4) Defences:

Type	**Watercourse**	**Bank**	**Model Start Chainage (approx.)**	**Model End Chainage (approx.)**
No Formal Defences				

(5) Model Boundaries - Inflows:

Full details of the fluvial flow estimates are provided in the Hydrology Report (IBE0700Rp0006_UoM01 Hydrology Report_F01 - Chapter 4.16 and Appendix D). The boundary conditions implemented in the model are in Table 4.16.1.

Table 4.16 1: Dunglow River Boundary Conditions

Boundary Description	Boundary Type	Branch Name	Chainage	Chainage	Gate ID	Boundary ID
Open	Inflow	DUNGLOW_RIVER	13.395	0		38_1154_1
Distributed Source	Inflow	DUNGLOW_RIVER	13.395	1375		Top-up flow between 38_1154_1 & 38006
Distributed Source	Inflow	DUNGLOW_RIVER	1375	1800		Top-up flow between 38006 & 38_1155_3
Open	Water Level	DUNGLOW_RIVER	1841.527	0		DS Q-h

Figure 4.14.7 shows the upstream hydrograph on the Dunglow River at HEP 38_1154_1 for the 1% AEP fluvial event.

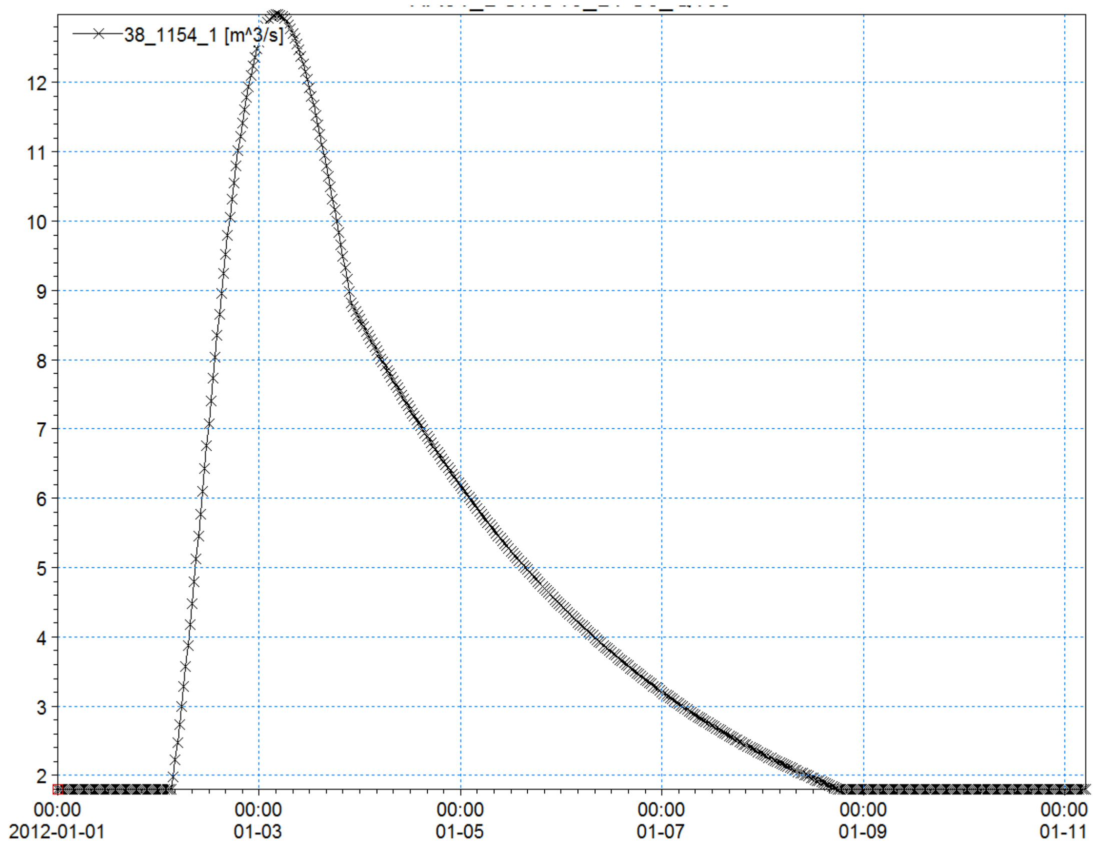

Figure 4.14.7: 1% AEP Inflow Hydrograph for Dunglow River

Boundary conditions for the MIKE21 open coastal boundary were generated by combining storm surge and tidal elevation data. Outputs from the Irish Coastal Protection Strategy Study (ICPSS) have resulted in extreme tidal and storm surge water levels being made available around the Irish Coast for a range of AEPs. The locations of the ICPSS nodes along with the relevant AFA locations are shown in Figure 4.14 4.14.8. The associated AEP water levels for each of the nodes are contained in Table 4.14.2. It should be noted that the water levels listed below are 'still' water levels, as this model does not account for wave run-up or overtopping.

The coastal boundary for this model is set across the entrance to Dunglow Bay; therefore the values for node NW24 were used for the still water inundation modelling in Dungloe.

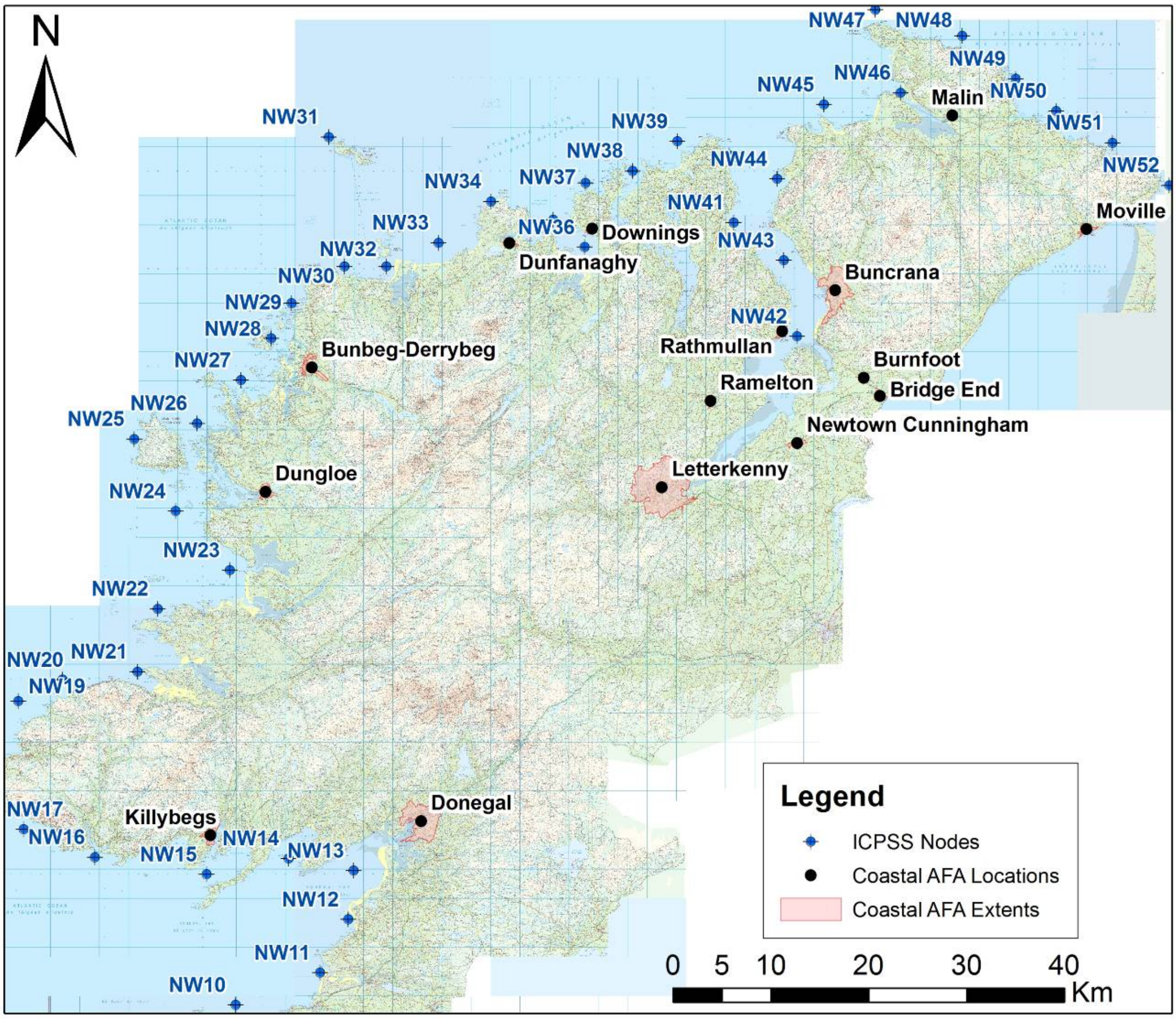

Figure 4.14.8: ICPSS Node Locations (IBE0700Rp0006_UoM01 Hydrology Report_D01)

Table 4.14.2: ICPSS AEP Total Water Levels for Relevant Model Nodes

AEP (%)	Elevation to OD Malin for a Range of AEPs								
	NW13	NW15	NW24	NW28	NW35	NW36	NW42	NW46	NW52
50	2.60	2.54	2.50	2.49	2.65	2.72	2.93	2.70	1.83
20	2.75	2.68	2.64	2.62	2.79	2.85	3.06	2.85	1.97
10	2.86	2.79	2.73	2.71	2.88	2.94	3.15	2.95	2.07
5	2.97	2.88	2.83	2.80	2.97	3.04	3.23	3.06	2.16
2	3.11	3.01	2.95	2.92	3.09	3.16	3.35	3.19	2.28
1	3.22	3.11	3.04	3.01	3.18	3.25	3.43	3.29	2.37
0.5	3.32	3.20	3.13	3.09	3.27	3.34	3.52	3.39	2.47
0.1	3.57	3.43	3.35	3.30	3.48	3.55	3.71	3.63	2.68

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

Using information from the Secondary Port of Burtonport in the Admiralty Tide Tables, a tidal water level approaching MHWS 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 total water level from Table 4.24.2. 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 4.14.9 illustrates the tidal profile, storm surge profile and resultant total water level profile for a 0.5% AEP design event. The total water profile was applied as a level boundary to the north eastern edge of the 2D domain.

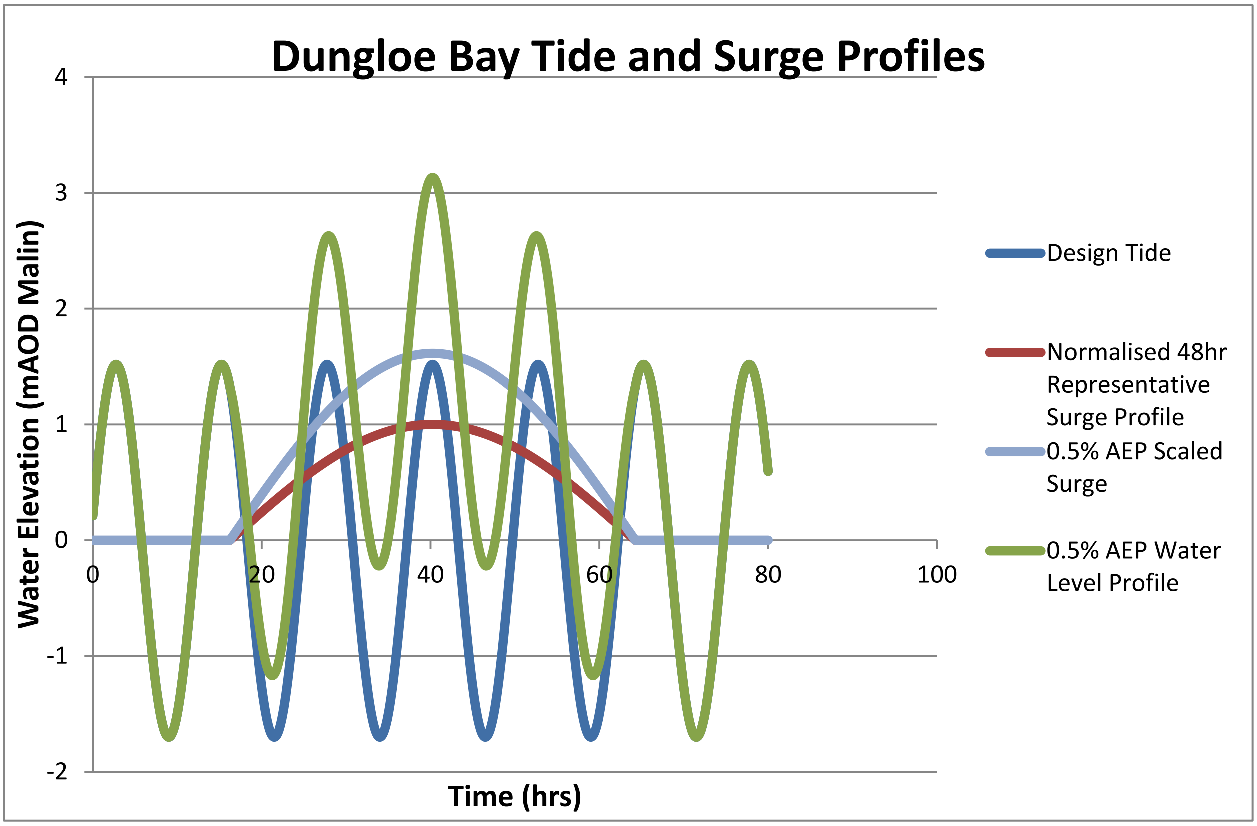

Figure 4.14.9: Dungloe Coastal Boundary

In order to determine joint probability flooding from both fluvial and coastal sources, where relevant, the timings of fluvial peaks were shifted relative to the timings of the coastal peaks. This established the worst case joint coastal and fluvial flooding at each localised area.

<table>
<tr><td>(6) Model Boundaries – Downstream Conditions:</td><td colspan="2">A water level boundary was applied at the downstream extent of the Dunglow River where it discharges to Dunglow Bay (chainage 1841.527). This enables the transfer of flow between the 1D and 2D domain. It should be noted that this boundary is given a 'dummy' water level value of 0.42 mOD Malin. However this value is ignored once the simulation commences as the level of this boundary varies in time based on dynamic calculations driven by the water levels informed by the 2D model.</td></tr>
<tr><td colspan="3">(7) Model Roughness: Refer to Chapter 3.5 for details on derivation of Manning's n.</td></tr>
<tr><td>(a) In-Bank (1D Domain)</td><td>Minimum 'n' value: 0.040</td><td>Maximum 'n' value: 0.050</td></tr>
<tr><td>(b) MPW Out-of-Bank (1D)</td><td>Minimum 'n' value: N/A</td><td>Maximum 'n' value: N/A</td></tr>
<tr><td>(c) MPW/HPW Out-of-Bank (2D)</td><td>Minimum 'n' value: 0.020
(Inverse of Manning's 'M')</td><td>Maximum 'n' value: 0.059
(Inverse of Manning's 'M')</td></tr>
</table>

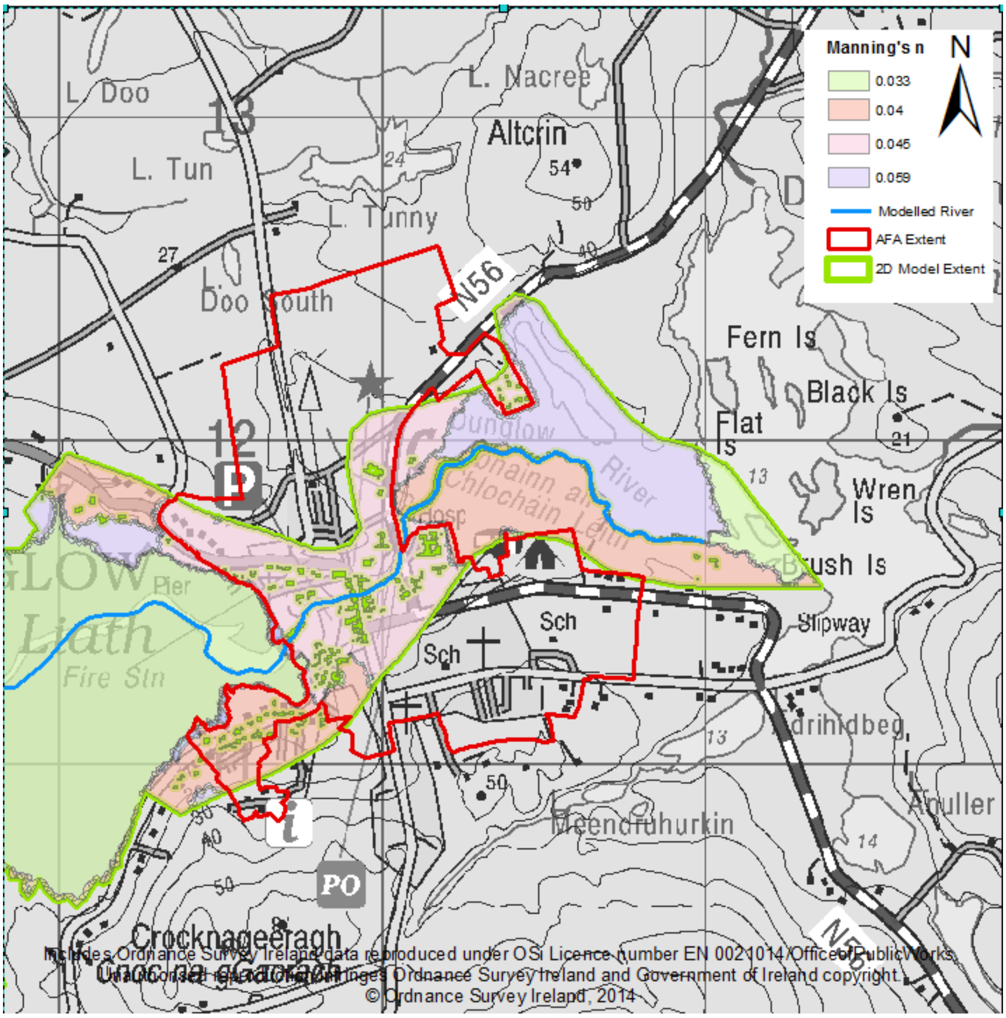

Figure 4.14.10: Map of 2D Roughness (Manning's n)

Figure 4.14.10 illustrates the roughness values applied within the 2D domain of the model. Any areas within the AFA zone not assigned a roughness are outside the 2D model domain. 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 mark were taken as 0.033 which is the default value set by the MIKE21 modelling software.

(c) Examples of In-Bank Roughness Coefficients	
	
Figure 4.14.11: *Dunglow River* 0114M00132_DN	**Figure 4.14.12: *Dunglow River* 0114M00083_UP**
Manning's n = 0.045 Natural stream - clean, winding, some weeds and stones.	Manning's n = 0.040 Natural stream - clean, winding, some pools and shoals.

4.14.4 Sensitivity Analysis

To be completed for final version of report.

4.14.5 Hydraulic Model Calibration and Verification

(1) Key Historical Floods (from IBE0700Rp0002_UoM 01 Inception Report unless otherwise specified):	
(a) **Dec 2011**	Flooding occurred in numerous areas including between Glenties and Dungloe on 14th December 2011 following heavy rain, which subsequently led to many roads becoming impassable. There are no hydrometric gauges within the model extent and rainfall data for this event was not available. Data at Aranmore tide gauge was analysed for this event, and shows that the highest water level recorded around this time was 1.9mOD Malin, although the quality of this data appears to be very poor. This water level is significantly less than a 50% AEP coastal event, so it is unlikely that this is a significant factor for this flood event. An investigation was carried out to find additional data for this event but there was none found to be available As there is no further information on source, flows, levels or return periods available, this event is not suitable to facilitate model calibration.
(b) **Oct 1989**	It was reported in the Donegal People's Press that roads in low lying areas were flooded due to heavy rainfall, with the main roads between Doochary and Dungloe

and between Lettermacaward and Dungloe being closed for a period. It was also reported that roads from Letterkenny to Dungloe and Glenties were closed for a period.

The daily rainfall at Derryhenny Doochary daily station for 27th October was recorded as 91.5mm. This equates to a 5% AEP rainfall event using the FSU Depth Duration Frequency model (FSU WP 1.2 'Estimation of Point Rainfall Frequencies'). This was the closest rainfall station (see Figure 4.14.13), and the best information available but should be treated with caution however as Derryhenny Doochary station is approximately 10km South-East of the Dungloe AFA. The closest tide gauge with data available for this event is Malin Head, approximately 80km from Dungloe and subject to very different conditions as it lies on the northern coast of Ireland. This data is therefore not suitable for quantifying the coastal flood event at Dungloe.

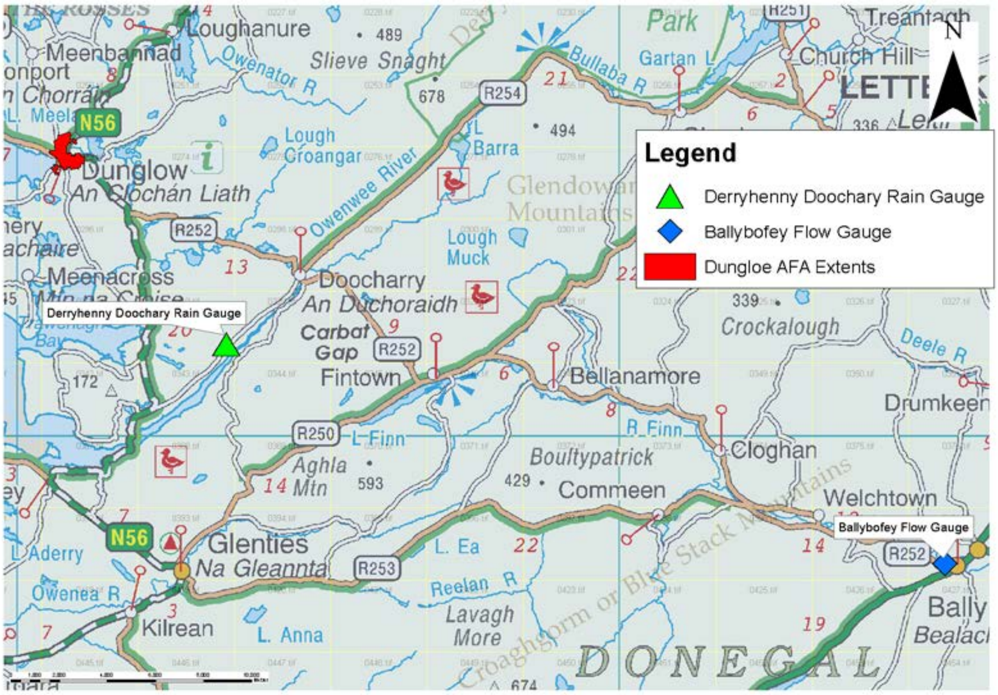

Figure 4.14.13: Location of Derryhenny Doochary rain gauge and Ballybofey flow gauge in relation to Dungloe AFA

It should be noted that the model extents only consider the town of Dungloe, so these reports may be outside the scope of the model as they refer to regional roads. In addition there is no further information available on source, flows, levels or return periods so this event is not suitable to facilitate model calibration.

(c) **Sep 1985**

Floods were reported as being worst in living memory by the Chief Fire Officer for Donegal County speaking to the Donegal Democrat newspaper. Streams overflowed their banks and the Finn, Foyle, Eske and Swilly rivers all overflowed their banks at high tide in many locations along their tidal stretches. It was estimated in this same

press article that millions of pounds worth of perishable goods were destroyed in the county as well as untold damage to the many premises affected.

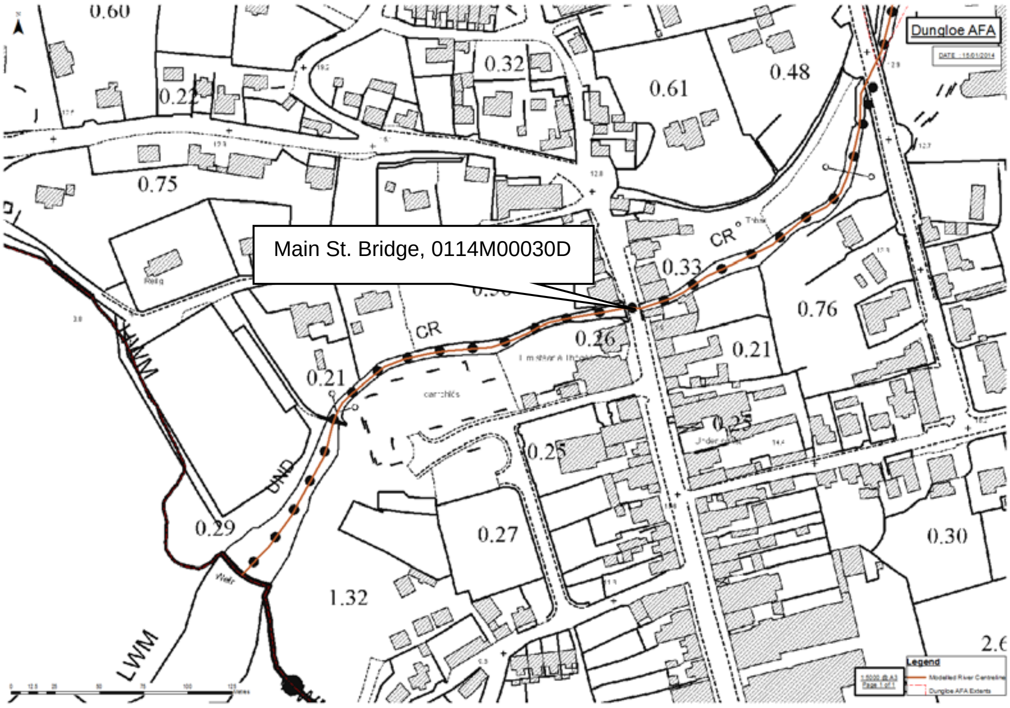

Figure 4.14.14: Lower reaches of Dunglow River, location of Main St. Bridge

In Dungloe, the Atlantic Bar and other premises adjacent to the river on Main Street (Figure 4.14.14) were flooded. Two ladies had to be rescued from their accommodation in Doochary. The floods caused damage to a bridge in Dungloe and emergency repairs had to be carried out. The flood was estimated to have an AEP of 3.77% at Ballybofey, see figure in Section 4.14.5(1) (b).

The daily rainfall at Derryhenny Doochary daily station for 20th September was recorded as 80.1mm, this equates to an 8% AEP rainfall event using the FSU DDF model. No hydrometric or tide gauge data is available.

Calibration using the information provided was found to be difficult as Main Street was not found to flood in the model for any of the fluvial scenarios considered when the bridge was operating normally. It was considered that the reported damage to the bridge may have been the cause of the flooding to Main Street, so this event was not used for model calibration.

Summary of Calibration

There are no hydrometric gauges within the Dungloe model extent and the only rainfall gauge within the AFA (Dungloe) did not have data available for any of the historic flood events highlighted above. Where possible, the rainfall event AEP was estimated using the FSU Depth Duration Frequency model from data available at Derryhenny Doochary daily rainfall station, located 10km south east of Dungloe.

Data from the tide gauge at Aranmore was used to estimate the coastal AEP of the flood event in December 2011; however the quality of this data is unknown. No other tide gauge data was available for these historic events. Data at Malin Head is not relevant to the tidal regime experienced at Dungloe.

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. For example at HEP 38006, the estimated flow during the 1% AEP event is 13.73m^3/s ((IBE0700Rp0006_UoM 01 Hydrology Report_D01, Appendix D) and the modelled flow is 13.87m^3/s. The flow at the downstream HEP 38_1155_3 could not be reliably measured during the final runs due to the tidal influence within this model; however flows were checked during development of the model before the tidal boundary was added. Full flow tables and discussion of comparison results are in Appendix A.3.

A mass balance check has been carried out on the model to make sure that the total volume of water entering and leaving the model at the upstream and downstream boundaries balances the quantity of water remaining in the model domain at the end of a simulation. Refer to Chapter 3.11 for details of acceptable limits. Table 4.14.3 summarises the mass errors of each model run:

Table 4.14.3: Mass Error for Dungloe design runs

Model	Mass Error
10% AEP Fluvial	0.00%
1% AEP Fluvial	0.00%
0.1% AEP Fluvial	-0.05%
10% AEP Coastal	0.00%
0.5% AEP Coastal	0.00%
0.1% AEP Coastal	-0.05%

Very low mass error is shown for all model design runs, so the Dungloe model is considered to be robust and stable.

Very little historical data relating to flooding in the Dungloe AFA is available and quantifying historical flood events is difficult due to the lack to hydrometric, rainfall and tide gauge data in the vicinity of the AFA. General information from the Glenties Area Engineer (Section 4.14.5(5)) was used in conjunction with historical data, but overall the model is poorly calibrated due to the lack of useable information.

(2) Post Public Consultation Updates:

Following informal public consultation and formal S.I public consultation periods in 2015, no model updates were required for Final issue.

(3) Standard of Protection of Existing Formal Defences:

Defence Reference	Type	Watercourse	Bank	Modelled Standard of Protection (AEP)
None				

(4) Gauging Stations:

There is one gauging station within the model extent, Dunglow (38006). This is a staff gauge station and is inactive. It could not be located during the channel and structure survey, and no data from this station is available for use. Therefore this gauge was not suitable for calibration.

(5) Other Information:

a) *Glenties Electoral Engineer Meeting - Minutes (2006)* - Notes low lying land near the pier which is liable to flood once or twice a year due to high tides. Road is liable to flood and properties may be affected. This is consistent with the model output as shown in Figure 4.14.15.

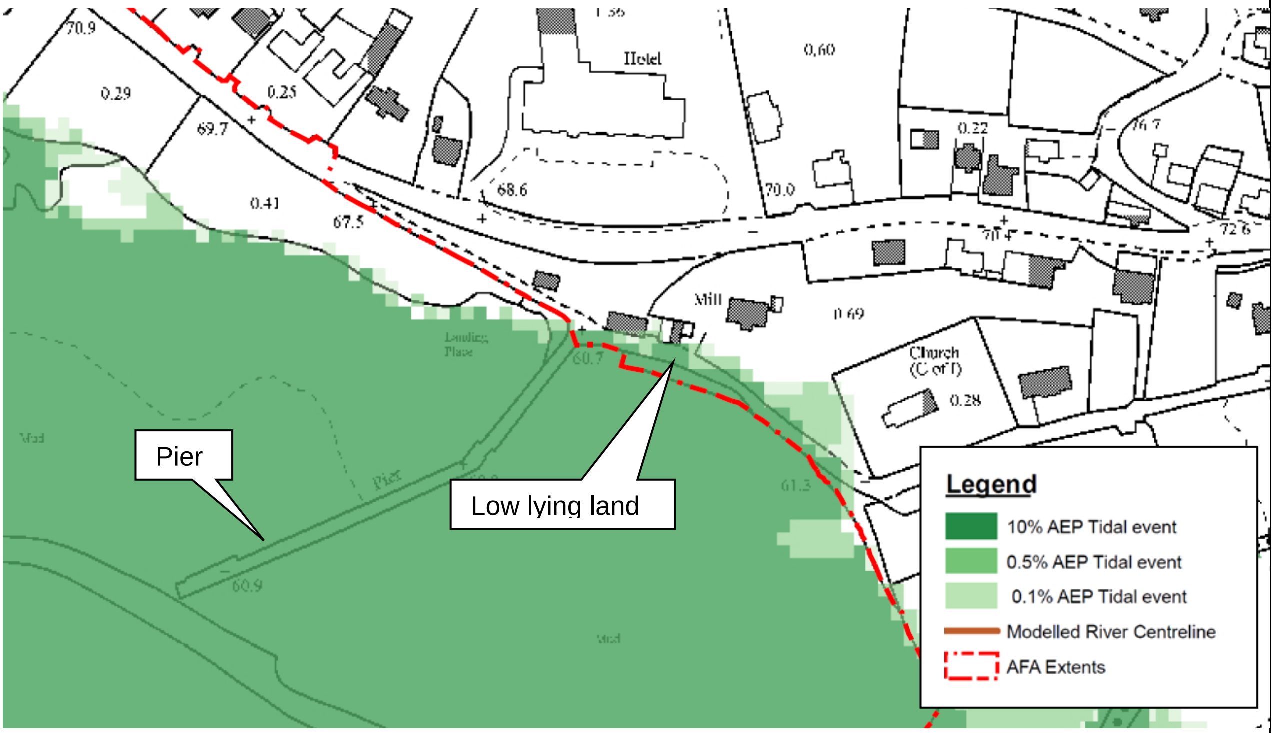

Figure 4.14.15 - Coastal flooding of low lying land adjacent to the pier

Another note in the Engineer's meeting describes the River Dunglow overflowing its banks after heavy rain every year near the weir structure adjacent to the hospital. The road is said to flood occasionally, although it is unclear if this refers to the main N56 or the minor road running parallel to the river. The model shows flooding of low land during the 10% AEP design run and some flooding of the minor road, but the N56 does not flood in the model even during the 0.1% AEP design run as shown in Figure 4.14.16.

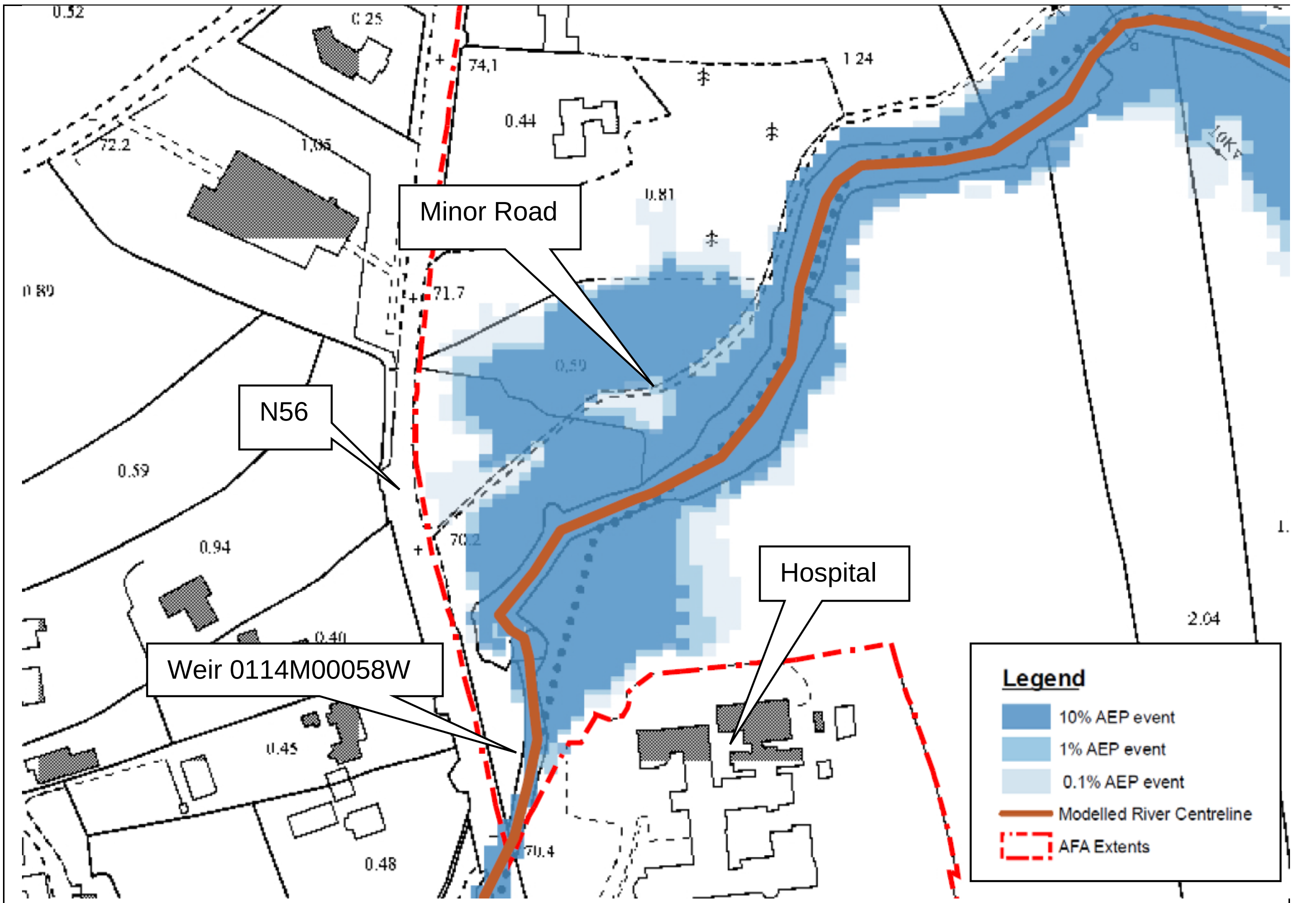

Figure 4.14.16 - Fluvial flooding upstream of the hospital

There are other notes referring to areas around Dungloe, but these were found to be relevant to areas outside the model extents and were therefore not considered.

4.14.6 Hydraulic Model Assumptions, Limitations and Handover Notes

(1) Hydraulic Model Assumptions:
(a) Delayed input hydrographs so that fluvial peak corresponds roughly with surge peak. This is to ensure the AFA was subjected to the highest volumes of water from both sources of flooding at the same time for each scenario. (b) Edited layout of double weir structure around chainage 1270 on Dunglow River to best represent feature in model. (c) Bridge at chainage 1570m on Dunglow River was modelled based on the downstream detail as the upstream survey only picked up the middle arch. The roughness coefficient for this bridge was increased due to a pipe crossing the arches. See Figure in Section 4.14.3(1) and Appendix A.2 for roughness coefficient values applied to structures. (d) The in-channel roughness coefficients were selected based on normal bounds using photos received from the channel and structure survey. Using CIRIA's (1997) Manning's n values for culverts as a

reference it is assumed that the final selected values are representative, refer to Chapter 3.6.1. (e) Increased the topographic level of Dunglow Lough at the upstream extent of the model to prevent water flowing back towards it. (f) Levels for the pier extending into Dunglow Bay were taken and interpolated from LiDAR data. (g) Bathymetry at the western model boundary of Dunglow Bay was edited and levels lowered to prevent adjacent cells drying and causing instabilities. This is standard modelling practice to minimise instabilities within the domain. These edits have no bearing on model results as they are an adequate distance from the area of interest.
(2) Hydraulic Model Limitations and Parameters:
Limitations (a) The model is poorly calibrated due to a lack of historical and hydrometric data. (b) The model is ungauged for the purposes of flow estimation, as detailed in IBE0700Rp0006_UoM01 Hydrology Report_D01, Chapter 4.16. (c) Coastal still water levels are modelled however flooding caused by wave run-up and overtopping is not taken account of. (d) The lateral links between chainages 13m-345m on the Dunglow River require an exponential smoothing factor of 0.8. (e) A maximum cell size of 25m^2 was used for all land adjacent to HPW.
Hydraulic Model Parameters:

MIKE 11	
Timestep (seconds)	2.5
Wave Approximation	High Order Fully Dynamic
Delta	0.6
Inter1Max factor	10
MIKE 21	
Timestep (seconds)	0.01-2.5
Drying / Flooding / Wetting depths (metres)	0.005 / 0.05 / 0.1
Eddy Viscosity (and type)	Constant eddy formulation varying in space based on equation $0.02\Delta x^2/\Delta t$.
MIKE FLOOD	
Link Exponential Smoothing Factor (where non-default value used)	Chainages 13-345: 0.8 All other links: default (1)

(3) Design Event Runs & Hydraulic Model Handover Notes:	
(a) The coastal boundary total water level is based on tide levels at Burtonport and ICPSS point NW24. (b) There are instabilities within the 1D model at chainages 1345 and 1752. The instability at chainage 1345 occurs only at low flows (<4.5m^3/s) for all scenarios. The instability at chainage 1752 occurs at three different times during the fluvial 10%AEP scenario, one at peak flow. However these instabilities at chainage 1752 smooth out to become insignificant at lower AEPs. None of these instabilities cause out of bank flooding therefore the instabilities were considered acceptable. (c) The design runs have a 0% Mass Balance Error. (d) The relatively flat land upstream of weir 0114M00058W adjacent to the hospital is prone to flooding as is seen during fluvial dominated flood events with 10% AEP and lower. This is due to the channel having relatively low banks along this section and water being held back by the weir, as shown in Figure 4.14.15. (e) The land downstream of weir 0114M00058W has quite a steep fall to its outlet into Dunglow Bay; see Long Section Profile in Appendix A.2. This section of the channel was generally found to have sufficient capacity to convey flows up to and including 0.1% AEP events. However it should be noted that the bridge on Main Street, 0114M00030D, is situated on this section and flooding may occur here if this bridge was to be blocked. (f) The coastal flood risk to the Dungloe area was found to be relatively low, mainly due to the fact that the land rises quite steeply. Low lying land near the pier and around where the Dunglow River discharges into the bay was found to be at risk however, as shown in Figure 4.15.16.	
(4) Hydraulic Model Deliverables:	
Please see Appendix A.4 for a list of all model files provided with this report.	
(5) Quality Assurance:	
Model Constructed by:	David Irwin
Model Reviewed by:	Stephen Patterson
Model Approved by:	Malcolm Brian

APPENDIX A.1

1D Structures modelled in the 1D domain

Structure Details - Bridges and Culverts:

RIVER BRANCH	CHAINAGE	ID**	LENGTH (m)	OPENING SHAPE	HEIGHT (m)	WIDTH (m)	SPRING HEIGHT FROM INVERT (m)	MANNINGS N
DUNGLOW_RIVER	1757.64	0114M00010D	1.2	Irregular	2.403	13.15	1.325	0.013
DUNGLOW_RIVER	1570.665	0114M00030D	10.41	Irregular X3	0.69, 1.27, 1.27	2.14, 3, 2.87	1.08, 1.07, 0.98	0.05
DUNGLOW_RIVER	1360.702	0114M00051I	21.34	Irregular	2.407	7.62	N/A	0.013
DUNGLOW_RIVER	324.037	0114M00155D	2.8	Irregular	2.097	6.51	N/A	0.013

Structure Details - Weirs

RIVER BRANCH	CHAINAGE	ID	MANNING'S N	TYPE
DUNGLOW_RIVER	1500	011M00039W	0.05	Broad Crested Weir
DUNGLOW_RIVER	1281.78	0114M00057X	0.013	Broad Crested Weir
DUNGLOW_RIVER	1273.209	0114M00058W	0.04	Broad Crested Weir

1D Structures modelled in the 2D domain

Structure Details - Bridges and Culverts:

None

Structure Details - Weirs:

None

** Denotes structures incorporated as closed cross-sections only (and therefore not included in the Network file).

** Structure ID Key:

D – Bridge Upstream Face

E – Bridge Downstream Face

I – Culvert Upstream Face

J – Culvert Downstream Face

NB: All other weirs in the Network file are over topping weirs which form part of a composite structure with the culvert/bridge at the corresponding chainage.

APPENDIX A.2

Long Section Profile Plots

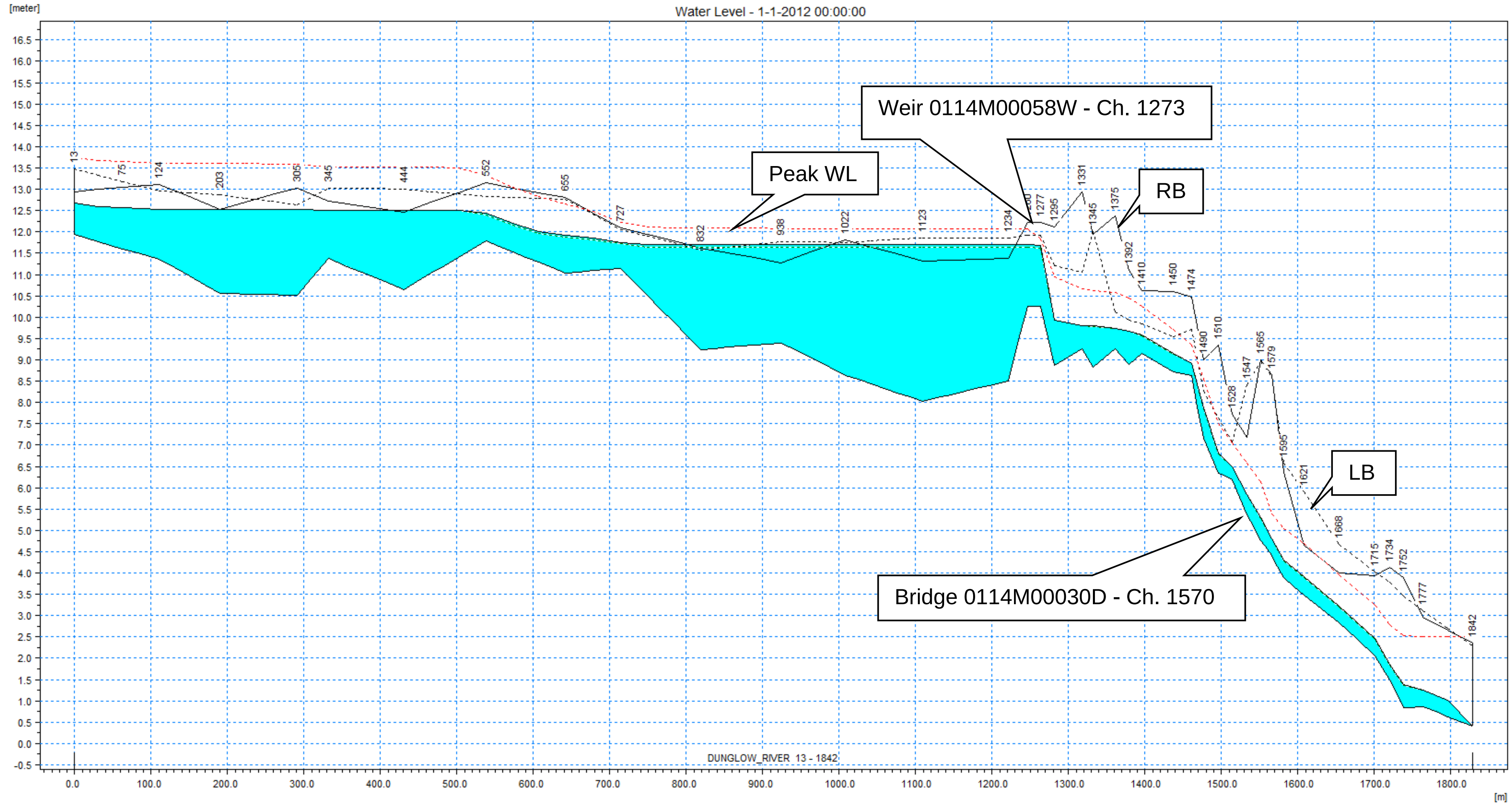

Figure A.4.14.4 - Dunglow River Fluvial 1% AEP Design Run

APPENDIX A.3

FLOW TABLES

	Peak Water Flows			
River Name & Chainage	**AEP**	**Check Flow (m3/s)**	**Model Flow (m3/s)**	**Diff (%)**
DUNGLOW_RIVER 1383.5	10%	8.94	9.24	+3.41
38006	1%	13.73	13.87	+0.98
	0.1%	21.27	20.73	-2.54
DUNGLOW_RIVER 1825.44	10%	9.08	9.76	+7.47
38_1155_3	1%	13.95	14.39	+3.15
	0.1%	21.60	21.61	+0.04

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

It can be seen from the table that the model flows generally correlate well with the check flows. The difference is less than 4% at the intermediate checkpoint HEP 38006.

The downstream HEP 38_1155_3 also shows good correlation, although there is a slightly higher difference of 7.47% during the 10% AEP design run. Flow measurements at the downstream HEP are less reliable due to the tidal influence at this point, so this difference was not considered to be significant, especially as the mass balance calculations do not indicate significant gains or losses of flow from the model.

APPENDIX A.4

MIKE FLOOD	MIKE 21	MIKE 21 - DFS0 FILE	MIKE 21 RESULTS
HA01_DUNG16_MF_DES_1_Q10F HA01_DUNG16_MF_DES_1_Q100F HA01_DUNG16_MF_DES_1_Q1000F HA01_DUNG16_MF_DES_1_Q10S HA01_DUNG16_MF_DES_1_Q200S HA01_DUNG16_MF_DES_1_Q1000S	HA01_DUNG16_M21_DES_1_Q10F HA01_DUNG16_M21_DES_1_Q100F HA01_DUNG16_M21_DES_1_Q1000F HA01_DUNG16_M21_DES_1_Q10S HA01_DUNG16_M21_DES_1_Q200S HA01_DUNG16_M21_DES_1_Q1000S HA01_DUNG16_MESH_19 HA01_DUNG16_mesh_19_bedresistance HA01_DUNG16_MESH_19_EDDY	HA01_DUNG16_DFS0_SURGE	HA01_DUNG16_M21_DES_1_Q10F.dfs2 HA01_DUNG16_M21_DES_1_Q100F.dfs2 HA01_DUNG16_M21_DES_1_Q1000F.dfs2 HA01_DUNG16_M21_DES_1_Q10S.dfs2 HA01_DUNG16_M21_DES_1_Q200S.dfs2 HA01_DUNG16_M21_DES_1_Q1000S.dfs2

MIKE 11 - SIM FILE & RESULTS FILE	MIKE 11 - NETWORK FILE	MIKE 11 - CROSS-SECTION FILE	MIKE 11 - BOUNDARY FILE
HA01_DUNG16_M11_DES_1_Q10F HA01_DUNG16_M11_DES_1_Q10F.res11 HA01_DUNG16_M11_DES_1_Q100F HA01_DUNG16_M11_DES_1_Q100F.res11 HA01_DUNG16_M11_DES_1_Q1000F HA01_DUNG16_M11_DES_1_Q1000F.res11 HA01_DUNG16_M11_DES_1_Q10S HA01_DUNG16_M11_DES_1_Q10S.res11 HA01_DUNG16_M11_DES_1_Q200S HA01_DUNG16_M11_DES_1_Q200S.res11 HA01_DUNG16_M11_DES_1_Q1000S HA01_DUNG16_M11_DES_1_Q1000S.res11	HA01_DUNG16_NWK_DES_1	HA01_DUNG16_XNS_DES_1	HA01_DUNG16_BND_DES_1_Q10F HA01_DUNG16_BND_DES_1_Q100F HA01_DUNG16_BND_DES_1_Q1000F HA01_DUNG16_BND_DES_1_Q10S HA01_DUNG16_BND_DES_1_Q200S HA01_DUNG16_BND_DES_1_Q1000S
MIKE 11 - DFS0 FILE		**MIKE 11 - HD FILE & RESULTS FILE**	
HA01_DUNG16_DFS0_Q2 HA01_DUNG16_DFS0_Q10 HA01_DUNG16_DFS0_Q100 HA01_DUNG16_DFS0_Q1000		HA01_DUNG16_HD_DES_1_Q10F HA01_DUNG16_HDMaps_DES_1_Q10F.dfs2 HA01_DUNG16_HD_DES_1_Q100F HA01_DUNG16_HDMaps_DES_1_Q100F.dfs2 HA01_DUNG16_HD_DES_1_Q1000F HA01_DUNG16_HDMaps_DES_1_Q1000F.dfs2 HA01_DUNG16_HD_DES_1_Q10S HA01_DUNG16_HDMaps_DES_1_Q10S.dfs2 HA01_DUNG16_HD_DES_1_Q200S HA01_DUNG16_HDMaps_DES_1_Q200S.dfs2 HA01_DUNG16_HD_DES_1_Q1000S HA01_DUNG16_HDMaps_DES_1_Q1000S.dfs2	

GIS Deliverables - Hazard		
Flood Extent Files (Shapefiles)	**Flood Depth Files (Raster)**	**Water Level and Flows (Shapefiles)**
Fluvial N01DUE_EXFCD001_010_100_F0 N01DUE_EXFCD001_010_100_F0_page 1 of 2 N01DUE_EXFCD001_010_100_F0_page 2 of 2	Fluvial N01DUE_DPFCD100_F0 N01DUE_DPFCD100_F0_page 1 of 2 N01DUE_DPFCD100_F0_page 2 of 2 N01DUE_DPFCD010_F0 N01DUE_DPFCD010_F0_page 1 of 2 N01DUE_DPFCD010_F0_page 2 of 2 N01DUE_DPFCD001_F0 N01DUE_DPFCD001_F0_page 1 of 2 N01DUE_DPFCD001_F0_page 2 of 2	Fluvial N16NDFCDF0
Coastal N01DUE_EXCCD001_010_100_F0 N01DUE_EXCCD001_010_100_F0_page 1 of 1	Coastal N01DUE_DPCCD100_F0 N01DUE_DPCCD100_F0_page 1 of 1 N01DUE_DPCCD005_F0 N01DUE_DPCCD005_F0_page 1 of 1 N01DUE_DPCCD001_F0 N01DUE_DPCCD001_F0_page 1 of 1	Coastal N16NDCCDF0

Flood Zone Files (Shapefiles)	**Flood Velocity Files (Raster)**	**Flood Defence Files (Shapefiles)**
N24ZNA_MCDC1 N24ZNB_MCDC1	<u>Fluvial</u> N01DUE_VLFCD100_F0 N01DUE_VLFCD100_F0_page 1 of 2 N01DUE_VLFCD100_F0_page 2 of 2 N01DUE_VLFCD010_F0 N01DUE_VLFCD010_F0_page 1 of 2 N01DUE_VLFCD010_F0_page 2 of 2 N01DUE_VLFCD001_F0 N01DUE_VLFCD001_F0_page 1 of 2 N01DUE_VLFCD001_F0_page 2 of 2 <u>Coastal</u> N01DUE_VLCCD100_F0 N01DUE_VLCCD100_F0_page 1 of 1 N01DUE_VLCCD005_F0 N01DUE_VLCCD005_F0_page 1 of 1 N01DUE_VLCCD001_F0 N01DUE_VLCCD001_F0_page 1 of 1	N/A
GIS Deliverables - Risk		
Specific Risk - Inhabitants (Raster)	**General Risk - Economic (Shapefiles)**	**General Risk-Environmental (Shapefiles)**
N/A		