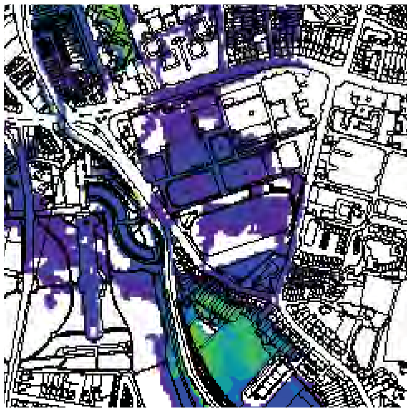
RPS

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

North Western - Neagh Bann CFRAM Study

UoM 01 Hydraulics Report
4.10 Convoy

IBE0700Rp0011



OPW
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Photographs of flooding on cover provided by Rivers Agency

NWNB CFRAM Study

HA01 Hydraulics Report

Convoy Model

DOCUMENT CONTROL SHEET

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

Rev.	Status	Author(s)	Modeller	Reviewed by	Approved By	Office of Origin	Issue Date
D01	Draft	T. Carberry J. Murdy	I. Bentley	S. Patterson	G. Glasgow	Limerick/Belfast	30/06/2014
F01	Draft Final	Various	I. Bentley	L. Arbuckle	G. Glasgow	Belfast	19/03/2015
F02	Draft Final	Various	I. Bentley	L. Arbuckle	G. Glasgow	Belfast	13/08/2015
F03	Draft Final	Various	I. Bentley	S. Patterson	G. Glasgow	Belfast	11/07/2016

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	**Table 4.1**
North Western Neagh Bann CFRAM Study UoM01 Inception	**February 2013**	IBE0700Rp0002_UoM 01 Inception Report_F02	**4.3.2**
North Western Neagh Bann CFRAM Study Hydrology Report	**July 2013**	IBE0700Rp0006_UoM 01 Hydrology Report_D01	**4.23**
North Western Neagh Bann CFRAM HA01_06_36 Survey	**October 2013**	IBE0700Rp0007_HA01_06_36 NWNB_CFRAM_Survey Contract Report F01	**1.6.4**

4 HYDRAULIC MODEL DETAILS

4.10 CONVOY MODEL

4.10.1 General Hydraulic Model Information

(1) Introduction:	
The NWNB CFRAM Flood Risk Review (2011s5232 NW&NB CFRAM FRR Report_Final_v2.0) highlighted Convoy as an AFA for fluvial flooding based on a review of historic flooding and the extents of flood risk determined during the PFRA. The Convoy model represents the River Deele catchment, a tributary of the Foyle. The catchment is a medium sized catchment (134km^2) originating in the hilly area to the west of the village of Convoy. The catchment is largely agricultural land (68% pastures) with some peat (22%) and forest (14%) land coverage also. The modelled reaches of the Deele are fairly flat (S1085 ranging from 5 to 10m/km). For reporting purposes the Deele River as it flows through the AFA is referred to as the Cloghroe River in this report. The Tullydonnell Upper watercourse (Reach 0160M also called Milltown watercourse) also flows through the AFA extents representing a catchment area of less than 5km^2. This catchment is also largely agricultural land (87%) but is fairly steep. The Sandy Mills gauging station (01041 – OPW) is located along the modelled reach of the Deele approximately 10km downstream of the AFA. This station was given a B rating classification under FSU indicating there is confidence in the rating at Q_{med}. This station was used as a pivotal site to adjust initial Q_{med} estimations based on catchment descriptors within the Convoy model. For full details of hydrological analysis, refer to UoM 01 Hydrology Report (IBE0700_Rp0006_F02). Two sections of the Cloghroe River (Deele) are MPW; chainage 0m to 6502m and 9917m to 16400m. The remaining sections of this watercourse are designated as HPW, along with its tributaries and the Milltown River. All watercourses were modelled as 1D-2D using ISIS 2D to determine fluvial flooding extents and accurately identify flooding in the 2D domain in areas where HPW and MPWs meet. Discussion has been added to Section 4.10.1(1). Refer to Chapter 3 and Section 4.10.2 for further details. The approach to overtopping of structures is discussed in Section 3.3.4.	
(2) Model Reference:	HA01_CONV23
(3) AFAs included in the model:	CONVOY
(4) Primary Watercourses / Water Bodies (including local names):	
Reach ID / **Name** 0159M CLOGHROE RIVER (also better known as the Deele River) 0159A CLOGHROE RIVER TRIB 1	

0159B CLOGHROE RIVER TRIB 2 0160M MILLTOWN		
(5) Software Type (and version):		
(a) 1D Domain: ISIS v3.7.1	**(b) 2D Domain:** ISIS 2D v3.7.1	**(c) Other model elements:** N/A

4.10.2 Hydraulic Model Schematisation

(1) Map of Model Extents:

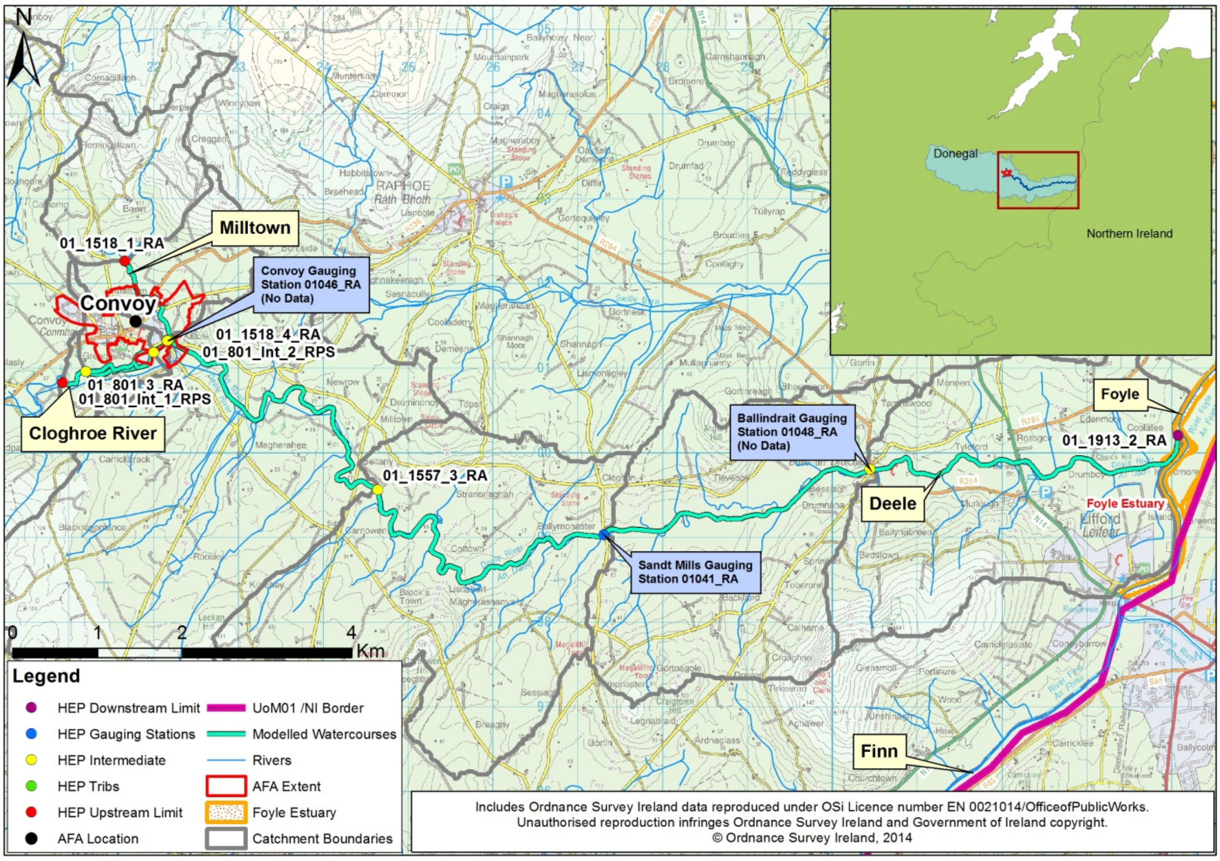


Figure 4.10.1: Overview Map of Model Extents

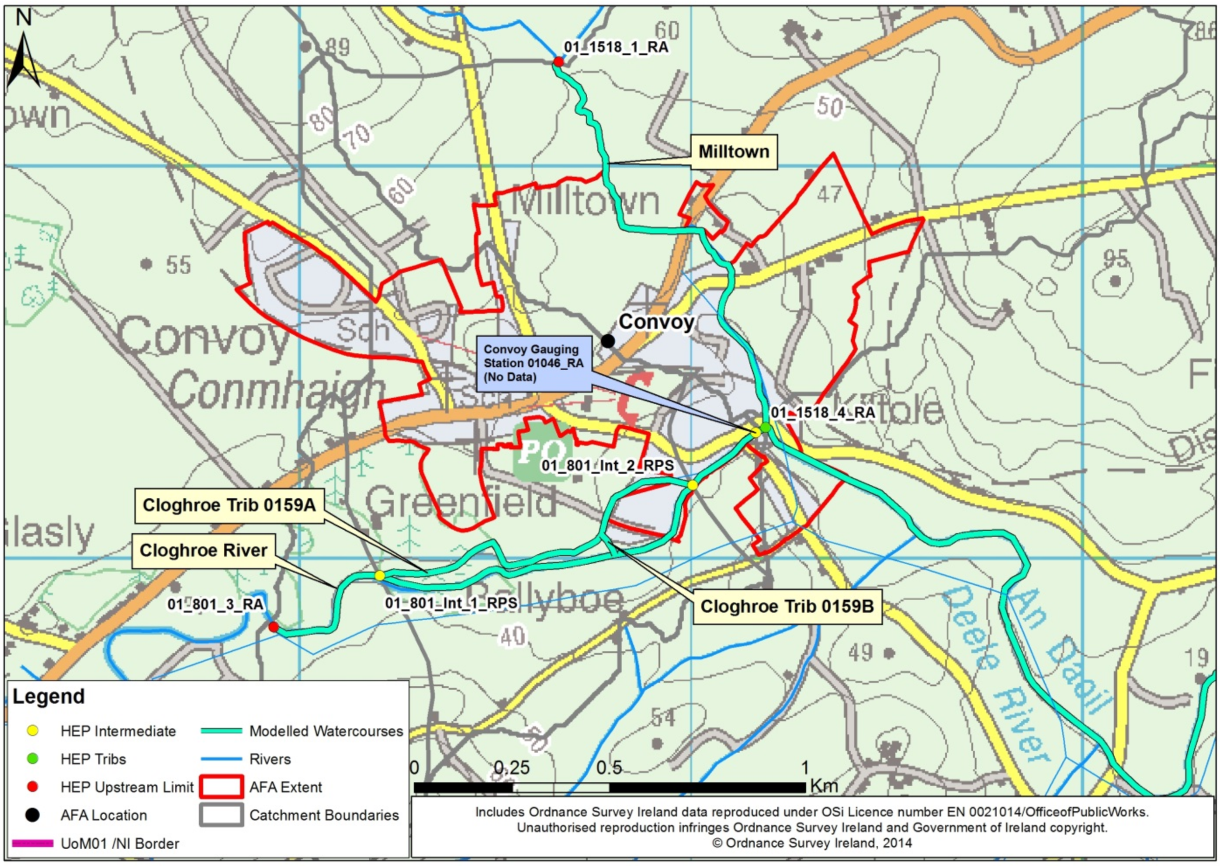


Figure 4.10.2: Overview Map of Model Extents (Zoomed to AFA Extents)

Figure 4.10.1 and Figure 4.10.2 illustrate the extent of the Convoy model, the river centre line, HEP locations and AFA extent. The Convoy model contains 2no. Upstream Limit HEPs, located to the north and west of the AFA boundary, representing the Milltown watercourse and the Cloghroe River (Deele) respectively. There is 1no. Tributary HEP representing the Cloghroe Tributary. There are 4 no. Intermediate HEPs and 1no. HEP Gauging Station (Sandy Mills, Stn no. 01041) located on the River Deele downstream of the AFA. The Convoy and Ballindrait Gauging Stations have no data available and so were redefined as Intermediate HEPs (refer to Appendix A.3 for details on anchoring the model to Gauging Station and Intermediate HEPs).

In channel flow was 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 modelled watercourses 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
0159M	CLOGHROE RIVER	220931	1008826
0159A	CLOGHROE RIVER TRIB 1	221202	400959
0159B	CLOGHROE RIVER TRIB 2	221800	401012
0160M	MILLTOWN	221656	402270

(3) Total Modelled Watercourse Length:		20km (approx)	
(4) 1D Domain only Watercourse Length:	0km	**(5) 1D-2D Domain Watercourse Length:**	20km
(6) 2D Domain Mesh Type / Resolution / Area:		Rectangular / 5m cells / 2.2 km^2	

(7) 2D Domain Model Extent:

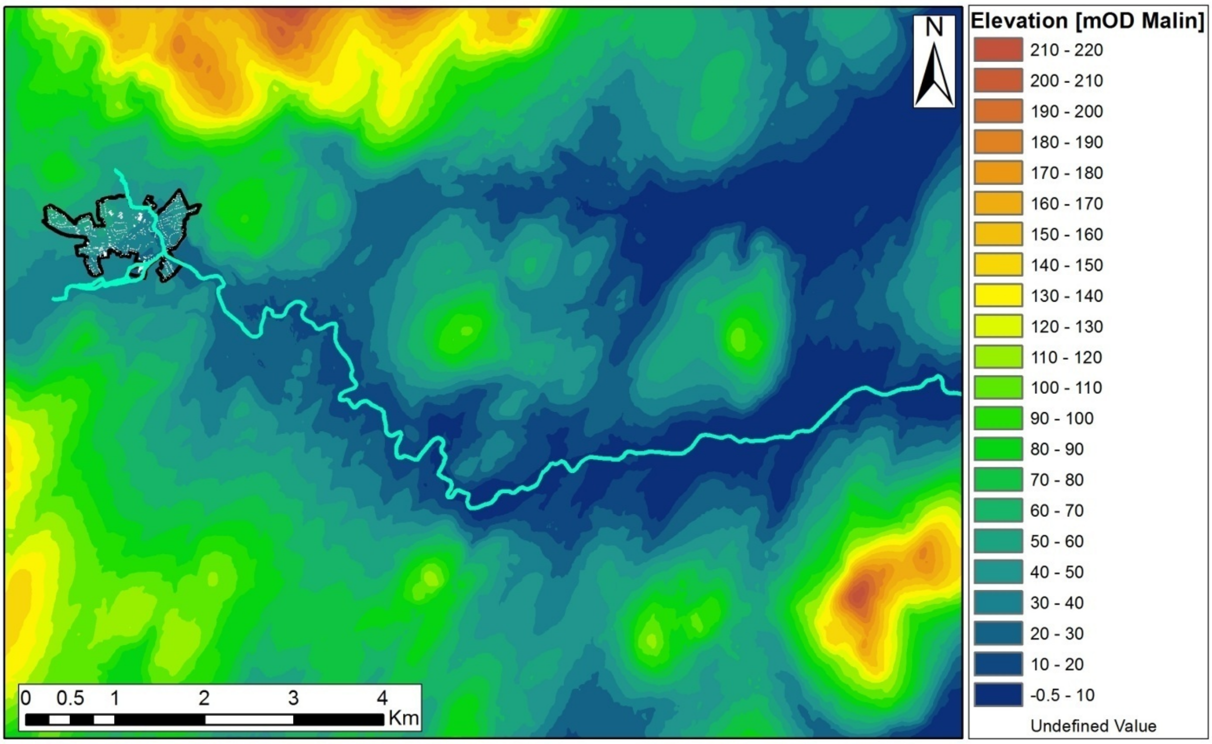


Figure 4.10.3: 2D Model Domain - Convoy

Figure 4.10.3 illustrates the modelled extents and general topography. The spatial extent of the AFA boundary is outlined in black. The reach centre-line is 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 3.3.2 for details on representation of buildings in the model.

Figure 4.10.4 shows an overview drawing of the model schematisation. Figure 4.10.5 to Figure 4.10.7

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 structure as discussed in section 4.10.3(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.

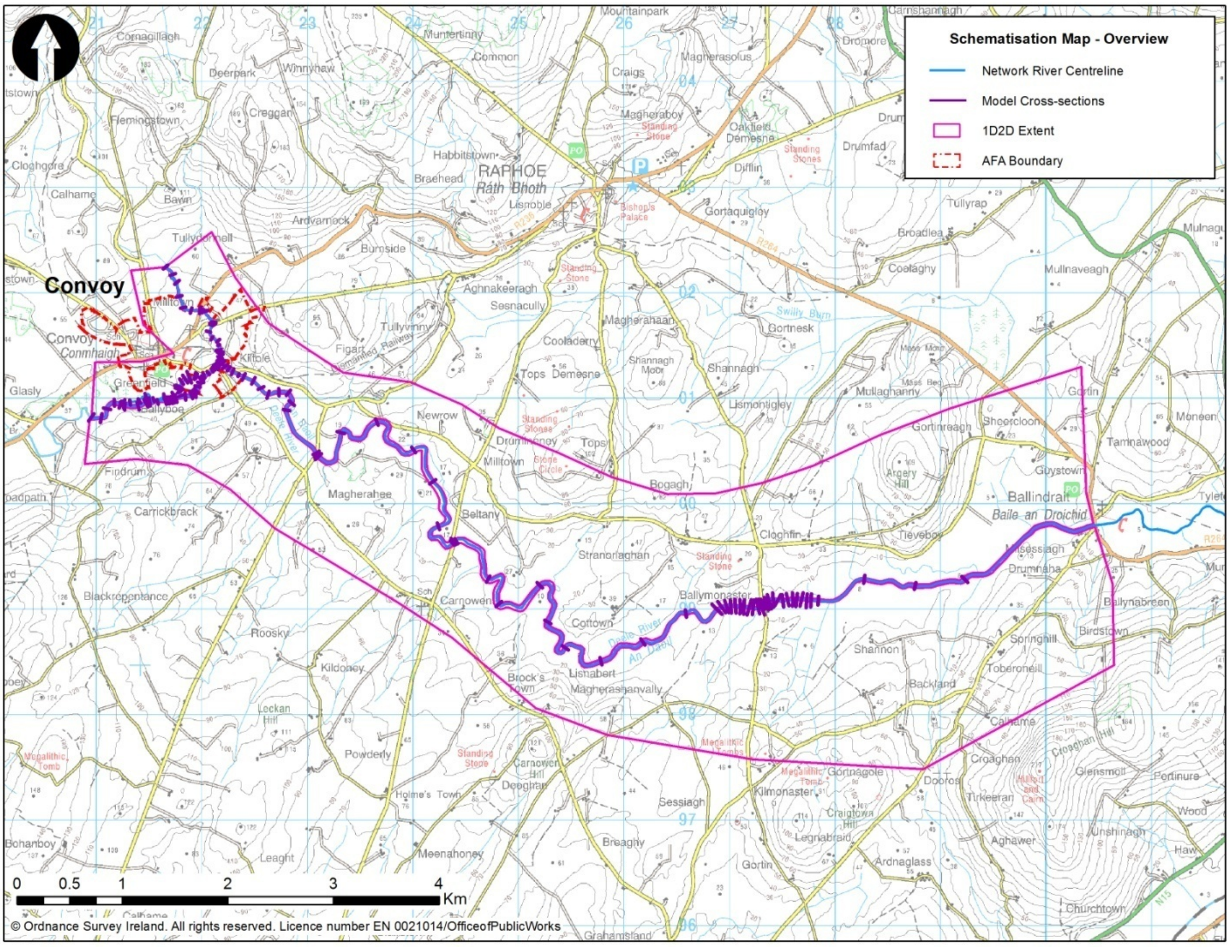


Figure 4.10.4: Model Schematisation Overview

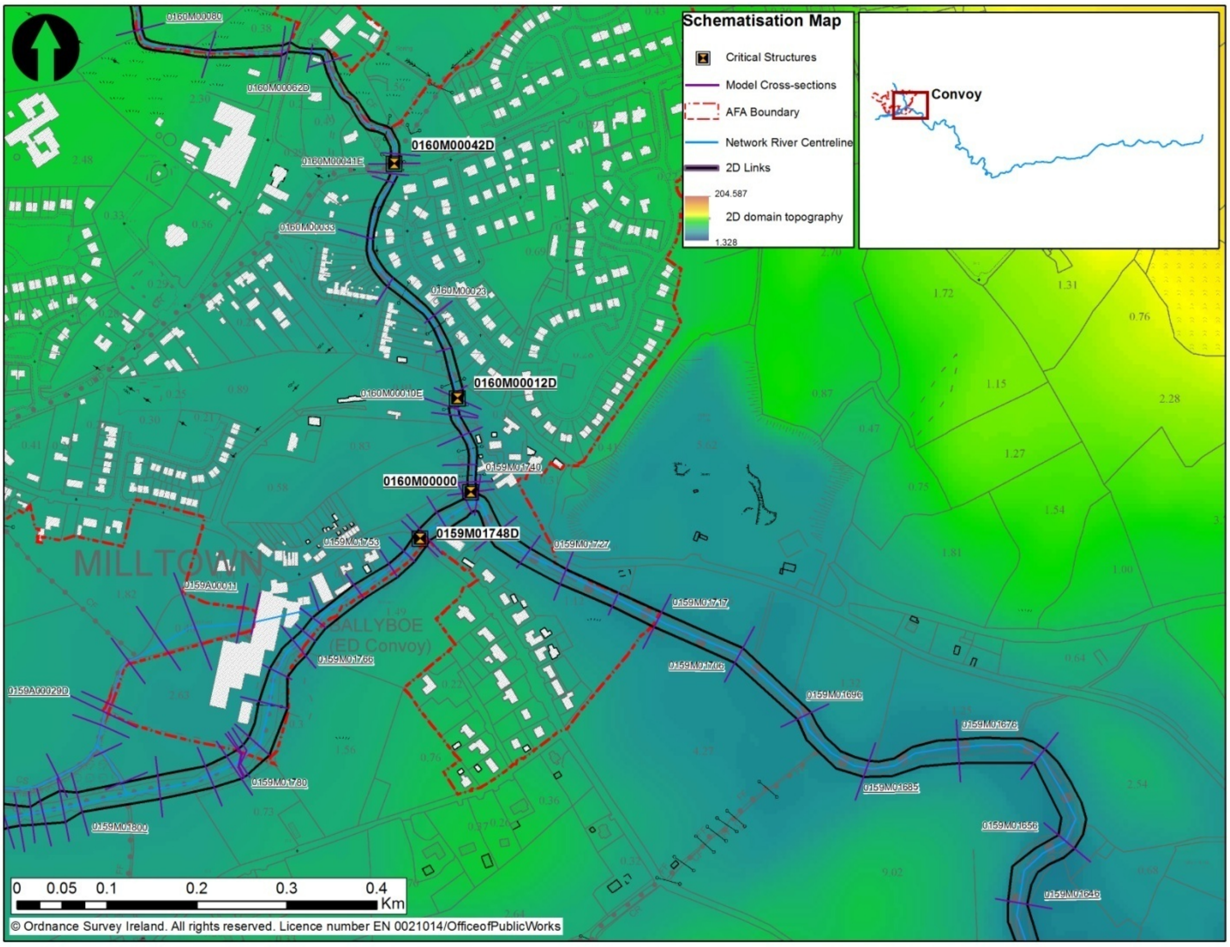


Figure 4.10.5: Detailed Area 1 of Model Schematisation showing Critical Structures

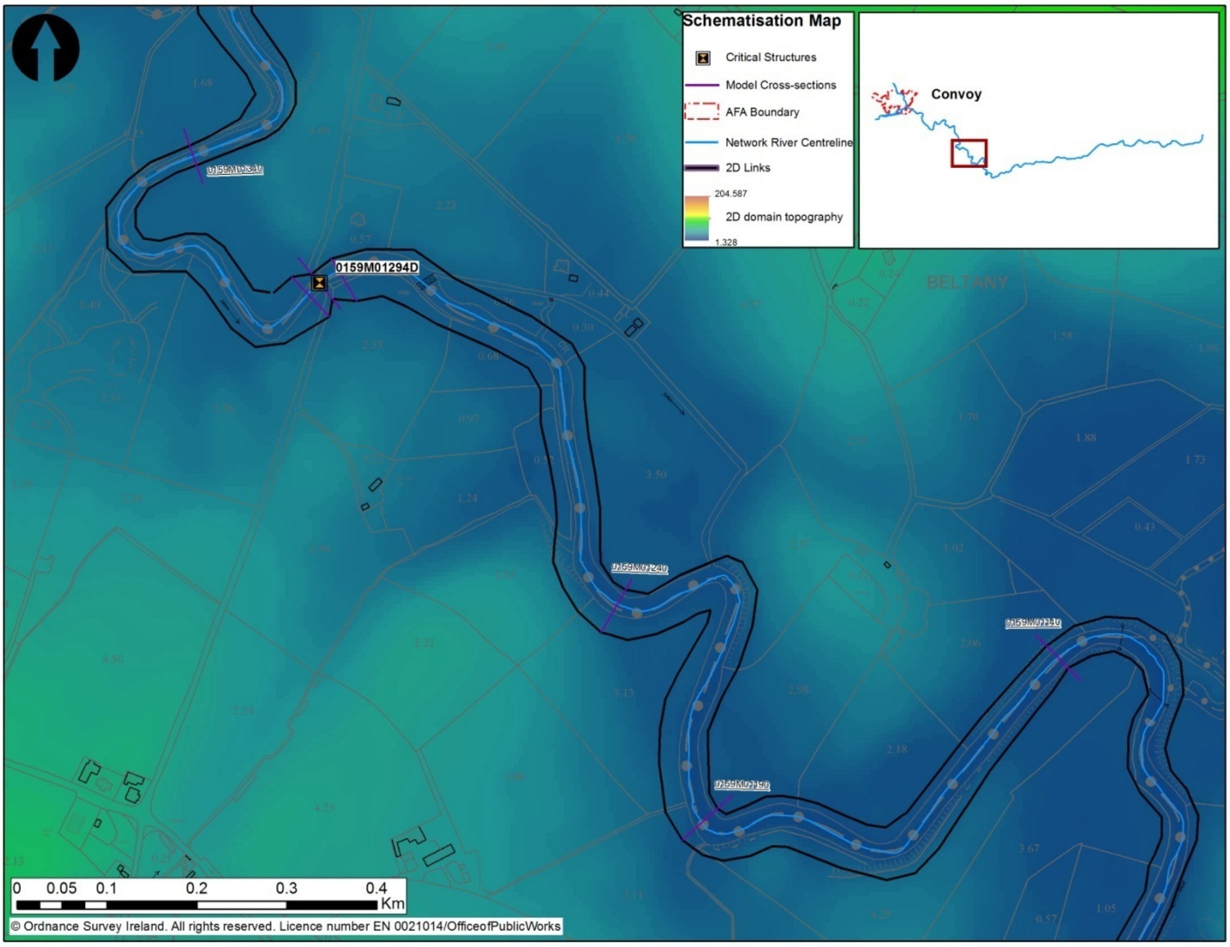


Figure 4.10.6: Detailed Area 2 of Model Schematisation showing Critical Structures

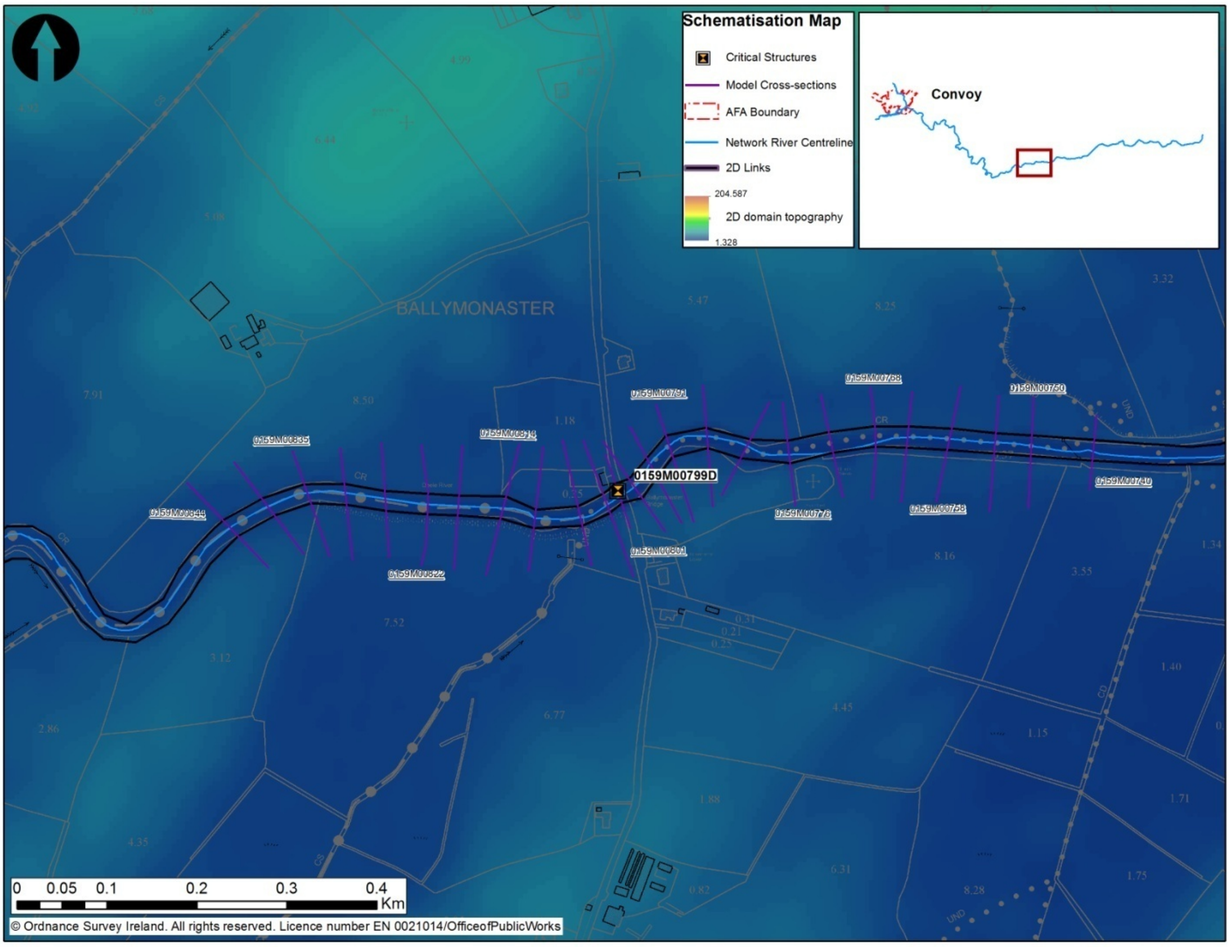


Figure 4.10.7: Detailed Area 3 of Model Schematisation showing Critical Structures

(8) Survey Information

(a) Survey Folder Structure:

First Level Folder	**Second Level Folder**	**Third Level Folder**
Murphy_NW1_M23_WP4_0159M_A_V1_130410 Convoy Murphy: Surveyor Name NW1: North Western CFRAM Study Area, Hydrometric Area 1 M23: Model Number 23 0159M: River Reference WP4: Work Package 4 Version: V1 *130410:* Date Issued (10 APR 2013)	V0_20130329_Ascii	
	V0_20130329_GIS	Flood_Plain_Photos_and_Shapefile
		Structure_Register
		Surveyed_Cross_Section_Lines
		Watercourse_Register
	V0_20130329_Photos	0159M01646_DN
	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**
0159M	CLOGHROE RIVER	Murphy_NW1_M23_WP4_0159M_A_V1_130410 Murphy_NW1_M23_WP4_0159M_V1_130329 Murphy_NW1_M23_WP4A14_0159M_EXTRA_V1_130410
0159A	CLOGHROE RIVER TRIB 1	Murphy_NW1_M23_WP4_0159A_V1_130315
0159B	CLOGHROE RIVER TRIB 2	Murphy_NW1_M23_WP4_0159B_V1_130315
0160M	MILLTOWN	Murphy_NW1_M23_WP4_0160M_V1_130313

(9) Survey Issues:

None

4.10.3 Hydraulic Model Construction

(1) 1D Structures (in-channel along modelled watercourses):	17 Bridges 1 Culvert 8 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 locations of critical structures included in the model are presented in Figure 4.10.4 to Figure 4.10.7. Details of these structures are also 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 in ISIS is included in Chapter 3.4.3. Figure 4.10.8 to Figure 4.10.11 highlight the critical structures in the Convoy model.

The road bridge shown on Figure 4.10.8 (0159M01748D, Ch 1466m) on the Cloghroe River becomes surcharged during the 1% and 0.1% AEP design events, causing increased flooding upstream. Flood waters bypass the structure, flooding a road on the left bank during both these events. Properties on the left bank, upstream of this bridge are affected.

Figure 4.10.8: Bridge 0159M01748D.

The road bridge on Cloghroe River shown in Figure 4.10.9 (0159M00799D) becomes surcharged during the 0.1% AEP design event, causing increased flooding upstream. Flood waters bypass the structure, flooding a road on both banks during both this event. Properties on the right bank downstream of this bridge are affected.

Figure 4.10.9: Arched Bridge 0159M00799D on Cloghroe River

A road bridge shown on Figure 4.10.10 (0160M00042D, Ch 868m) at Townsparks/Carrick Court causes significant afflux and increases upstream flood extents, particularly for the 0.1% AEP design event. As the area and shape of the bridge change, approximately half way along its length, this causes great disturbance to the flow and causes backing up.

Figure 4.10.10: Culvert under Road Bridge 0160M00042D on Milltown River

The bridge shown on Figure 4.10.11 (0160M00012D, Ch 1168m) causes high afflux during all modelled scenarios and increases flood risk immediately upstream. This afflux is due to the reduction in size of the watercourse at this location and causes a bottleneck situation. Although the flow is disturbed by this structure, flooding shown upstream of cross section 0160M00018 does not appear to be significantly influenced.

Figure 4.10.11: Culvert 0160M00012D on Milltown River

(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.)**
Embankment	Cloghroe	Left	6010m (0159M01292)	10960m (0159M00799D)
Embankment	Cloghroe	Left	10960m (0159M00799D)	14480m (A5_BR1)
Embankment	Cloghroe	Right	6010m (0159M01292)	10960m (0159M00799D)
Embankment	Cloghroe	Right	10960m (0159M00799D)	14480m (A5_BR1)

These embankments are provided with the intention of protecting areas of agricultural land that may be considered to be functional floodplain. Much of the embanked reach is MPW and the model resolution is therefore relatively coarse, which may lead to inaccuracy in the modelled standard of protection (<10% AEP). However, the main purpose of these structures is the protection of farmland from low magnitude, high frequency flooding. These structures are considered to be ineffective informal defences as their condition and construction is of uncertain status; therefore undefended modelling is not required. See Figure 4.10.12 for location of these embankments.

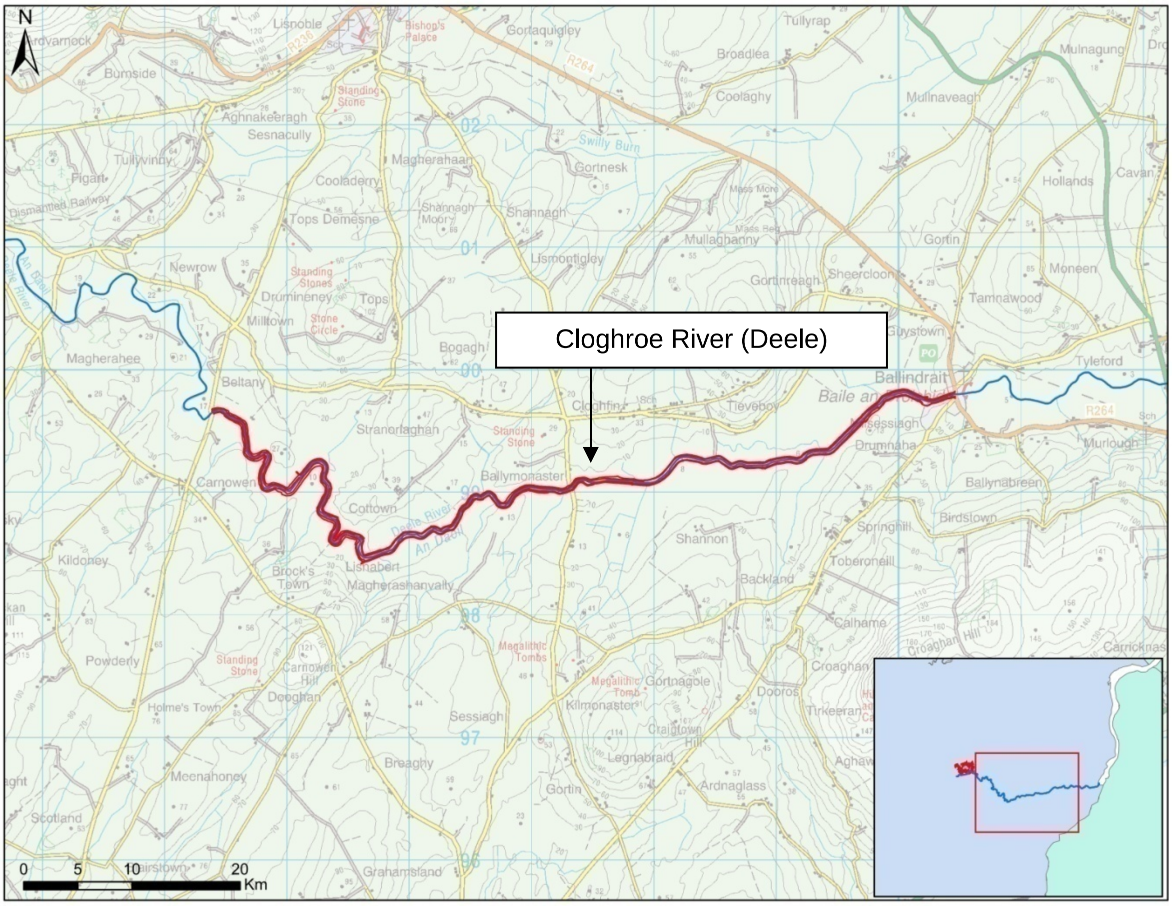


Figure 4.10.12: Approximate Location of Informal Ineffective Defences Along the Cloghroe (Deele)

River.

(5) Model Boundaries - Inflows:

Full details of the flow estimates are provided in the Hydrology Report (IBE0700Rp0006_UoM01 Hydrology Report_D01 - Section 4.23 and Appendix D). The boundary conditions implemented in the model are shown in Table 4.10.1 below.

Table 4.10.1: Model Boundary Conditions

	Boundary Type	Branch Name	Boundary HEP
1	Upstream	Cloghroe	01046_RA
2	Upstream	Milltown	01_1518_1_RA
3	Lateral	Cloghroe	01046_RA and 01_1913_2_RA
4	Lateral	Milltown	01_1518_1_RA and 01_1518_4_RA

Figure 4.10.13 shows the model inflow hydrographs for the 0.1% AEP design event. These are the upstream Limits of the Cloghroe (0159M) and Milltown Rivers (0160M), HEPs 01046_RA and 01_1518_1_RA respectively.

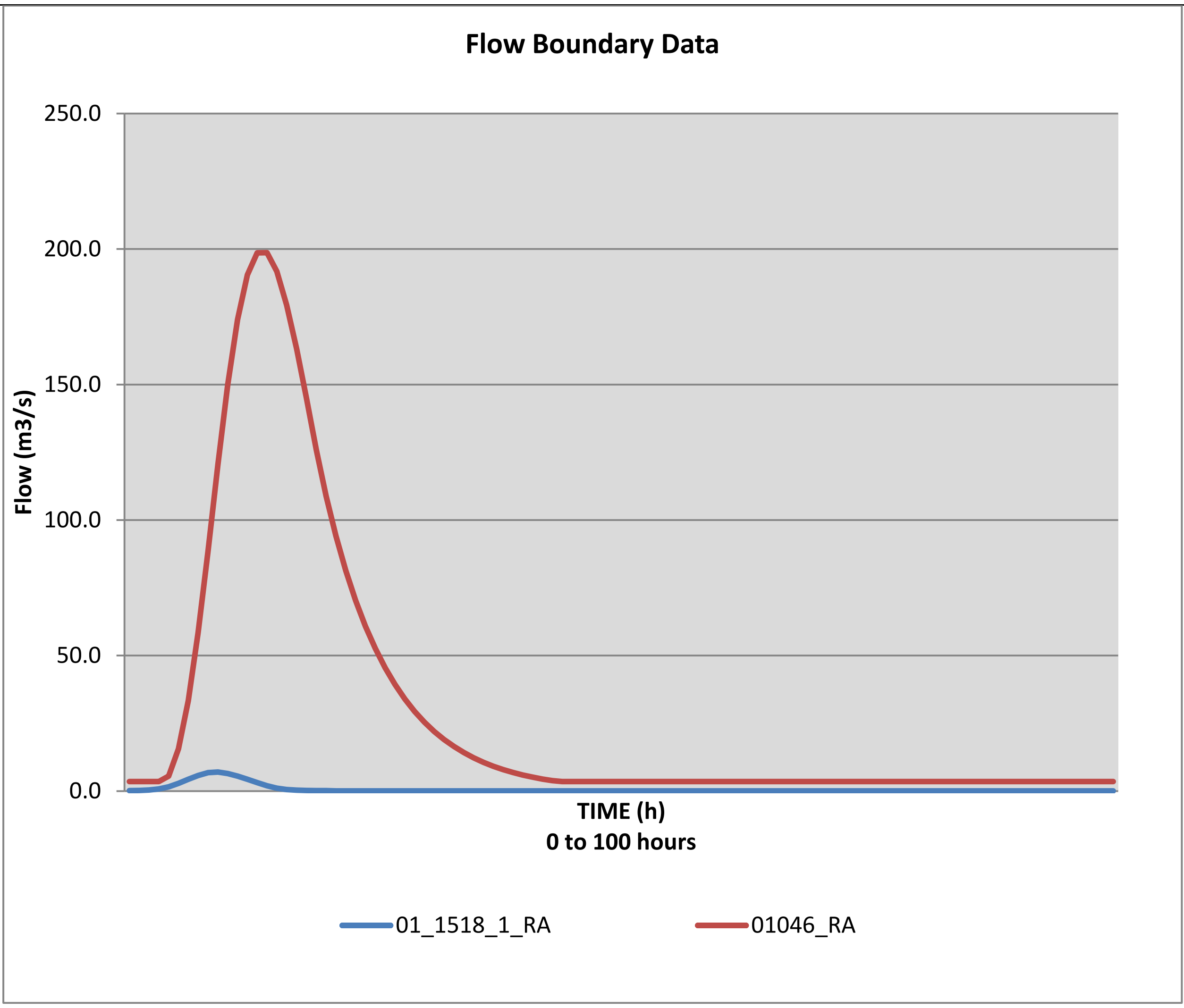


Figure 4.10.13: Upstream Input Hydrographs, 0.1% AEP design event

(6) Model Boundaries – Downstream Conditions:

The modelled reach was extended using additional cross sections that were extracted from an existing MIKE11 Foyle River model, to a point 1480m downstream of the R264 Road bridge. The reach downstream of the R264 is modelled as 1D but was not used for flood extent mapping.

A Flow-Head boundary (QHBDY) was generated using the ISIS QH boundary generator tool, based on the downstream cross section and average channel gradient at this location. This boundary type is essentially equivalent to the ISIS Normal Depth boundary (NCBDY) but was used in this case due to occurrence of model instability associated with the Normal Depth boundary unit. The derived boundary is plotted in Figure 4.10.14.

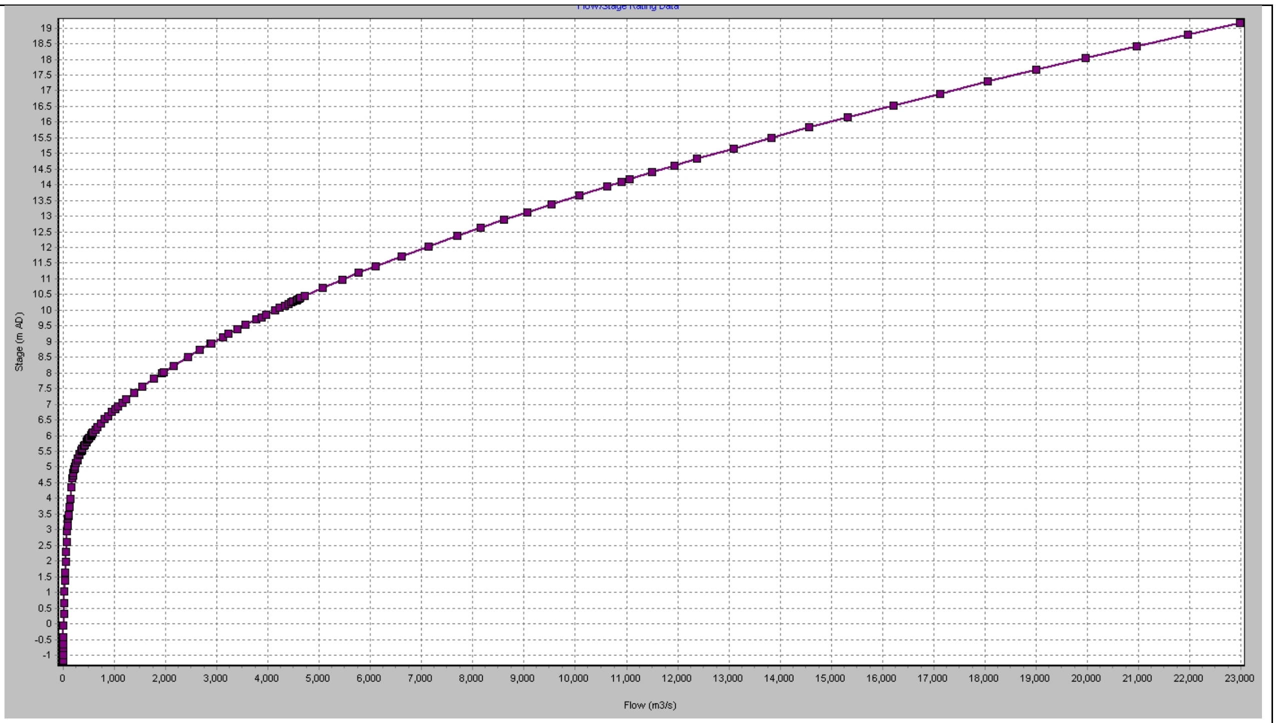


Figure 4.10.14: Downstream boundary

(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: 0.030 (Inverse of Manning's 'M')	Maximum 'n' value: 0.050 (Inverse of Manning's 'M')

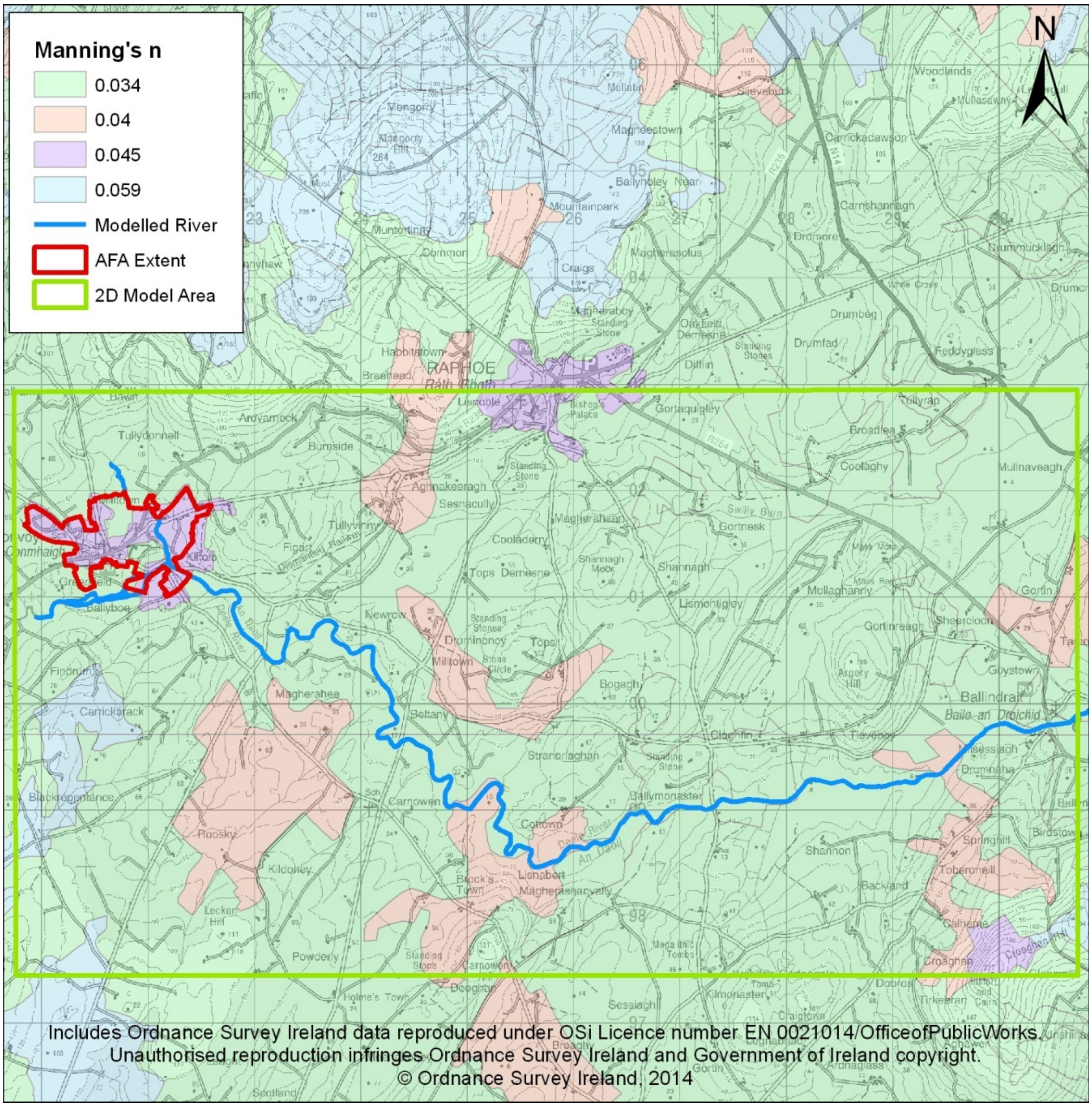


Figure 4.10.15: Map of 2D Roughness (Manning's n)

Figure 4.10.15 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. Null Manning's M values on inland water bodies were corrected to Manning's n of 0.033.

(d) Examples of In-Bank Roughness Coefficients

Figure 4.10.16: 0159M00890

Manning's n = 0.040

Clean, winding, occasional weed along channel edges

Figure 4.10.17: 0159M01740

Manning's n = 0.040

Clean, winding, stones in channel and vegetation on banks

Figure 4.10.18: 0159M01595

Manning's n = 0.040

Clean and straight, with vegetation on banks

Figure 4.10.19: 0159M1883_UP

Manning's n = 0.040

Clean, winding, light vegetation along banks.

<table>
<tr>
<td>
Figure 4.10.20: 0160M00003D
Manning's n = 0.050
Clean and straight with stones and dense vegetation on banks</td>
<td>
Figure 4.10.21: 0160M00126_UP
Manning's n = 0.050
Clean, winding. Narrow channel with dense vegetation on banks.</td>
</tr>
</table>

4.10.4 Sensitivity Analysis

To be completed for F02 version of report.

4.10.5 Hydraulic Model Calibration and Verification

<table>
<tr><td colspan="2">(1) Key Historical Floods (From IBE0700Rp0002_UoM 01 Inception Report_F02 unless otherwise specified):</td></tr>
<tr><td>(a) DEC 2011</td><td>Information was found during the internet search detailing how flooding occurred in Convoy, on 14th December 2011 following heavy rain. As a consequence many roads became impassable.

The closest gauge with rainfall data for this date is the Malin Head hourly gauge, situated around 60Km NNE from the AFA. On this date, 9.3mm of rainfall was recorded over 15 hours. Using the FSU DDF model to estimate rainfall frequency this does not indicate a significant event, with an AEP exceeding 100%. Without rainfall data in proximity to the AFA of suitable temporal resolution it is not possible to accurately derive a design rainfall frequency for this event.</td></tr>
</table>

The modelled flood extents have illustrated that only minor roads in Convoy are affected by fluvial flooding. The road that is situated between Kiltole and Carrickbrack has been shown to flood during a 10% AEP fluvial event. Within the urbanised area of Convoy, the Milltown area, particularly the road close to Convoy Enterprise Park and Fountain Terrace floods during the 1% and 0.1% AEP fluvial events. Approximately 200m to the east of this point, especially where the road that passes the Quarry, the model indicates flooding following a 10% AEP fluvial event.

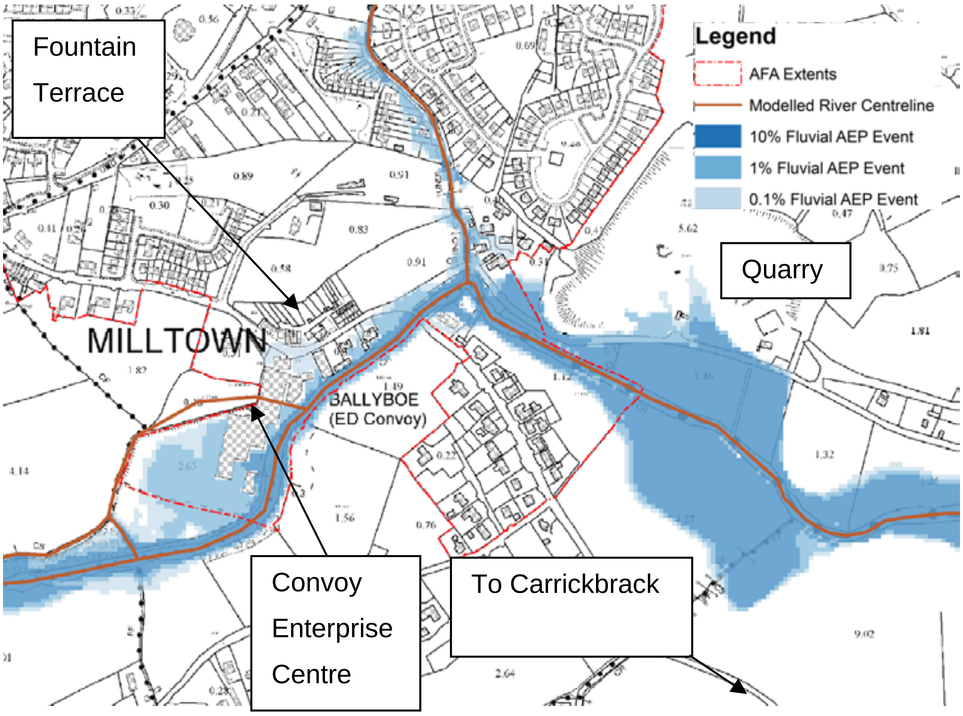


Figure 4.10.22: Model Fluvial Flooding in the Milltown area

(b) SEP 1985

Press articles from the Donegal Democrat were found on www.floodmaps.ie during the historical review process which indicated that flooding occurred in Convoy, on 20th September 1985. It was reported that the fire brigade assisted with flooding; however no further details are available.

The closest rain gauge with data relating to this event is the Stranorlar (Cavan Lower) gauge, situated around 7Km to the south west of the AFA. This gauge measured 45.1mm of rainfall on this date. Using the FSU DDF model and an assumed duration of 24 hours (since higher resolution temporal data is not available) this relates to a 38.5% AEP event.

This report is also regarded as particularly limited for model calibration. It can only be deduced that this flooding event probably occurred somewhere around the urbanised area, whereby residential and commercial properties were affected. The model has illustrated flooding in the Milltown area, particularly close to the river around the Convoy Enterprise Centre, River View Terrace and Kiltole Lower.

Summary of Calibration

Due to the lack of quantitative data on previous flood events it has not been possible to calibrate the model with historical reports. With the limited information available it has been not possible is to compare specific areas that have been identified to have been affected in the past, although model results do suggest that roads become flooded in fluvial flood events in this AFA, which agrees with the December 2011 report. As such, there has not been any information presented in previous flood events that suggest that any of the model parameters should be changed.

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 38_3389_2_RPS, the estimated flow during the 0.1% AEP event was 4.51 m^3/s (IBE0700Rp0006_UoM 01 Hydrology Report_F01, Appendix D) and the modelled flow was 4.59 m^3/s. Flow comparison tables and discussion are presented in Appendix A.3. Differences between the estimated and modelled flows are thought to be mainly due to storage attenuation effects within the MPW reach of the Cloghroe River

Checks have been carried out on the ISIS mass balance model outputs which may give an indication as to the robustness and stability of the model and makes sure that significant volumes of water are not being created or lost in the modelling process. These methods are discussed in Chapter 3.12. The average mass error in the model was calculated as a percentage of the total model flow for each scenario. Table 4.10.2 summarises the mass errors of each model run. It should be noted that due to the relatively small volume of water within this model, the mass balance calculation is very sensitive, thus larger errors are produced.

Table 4.10.2: Mass Error of Model

Model	1D Mass Error
10% AEP Fluvial	2.75%
1% AEP Fluvial	4.39%
0.1% AEP Fluvial	6.74%

(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) Standard of Protection of Existing Formal Defences:

None – agricultural embankments are considered to be ineffective

(4) Gauging Stations:

Sandy Mills (01041) is an OPW operated gauge, located close to Ballymonaster Bridge (0159M00799D) on the Cloghroe River (Deele). This station was given a B rating classification under FSU indicating there is confidence in the rating at Q_{med}. This station was taken forward as a pivotal site under FSU and

indicates the observed Q_{med} (derived from the AMAX series) is higher than the Q_{med} which is derived from catchment descriptors by a factor of 1.58 at the gauging station. Considering the confidence in the rating at Q_{med} and the long period of record (1973 – 2009) it was considered prudent that all of the Q_{med} values derived from catchment descriptors on this model are adjusted upwards in line with the adjustment factor at the gauging station.

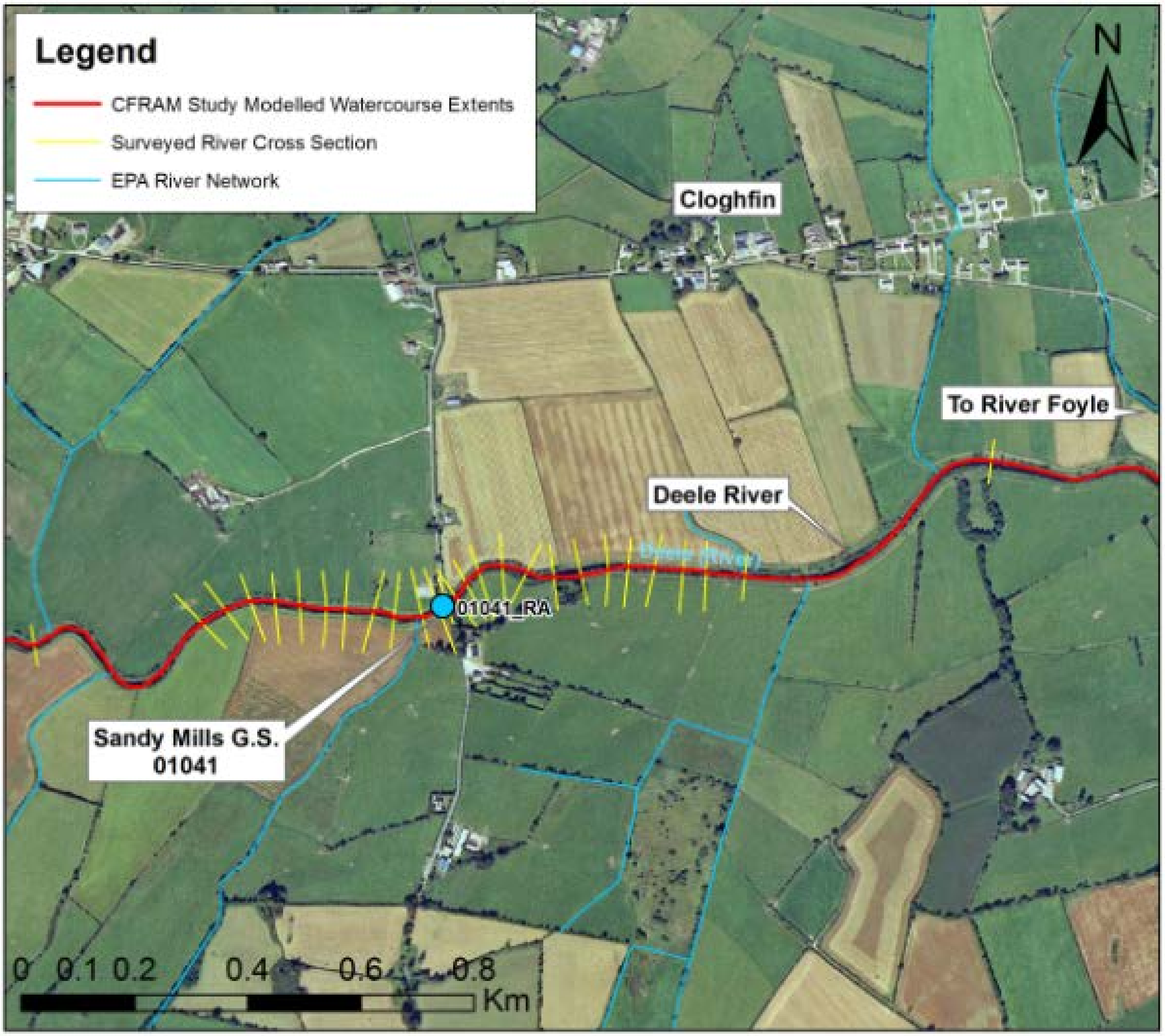


Figure 4.10.23: Location of Sandy Mills Gauging Station

This gauging station was subject to rating review to ascertain the confidence in the Q_{med} value (and hence adjustment factor), improve the flow estimates at the gauging station and in order to support calibration of the model. It was only possible to model the gauging station reach in 1D within the rating review model and due to the flat nature of the floodplain behind earthen embankments the reliable limit of the modelled Q-h relationship was set by the top of embankment level.

The modelled Q-h, existing rating and spot gaugings are shown in the figure below.

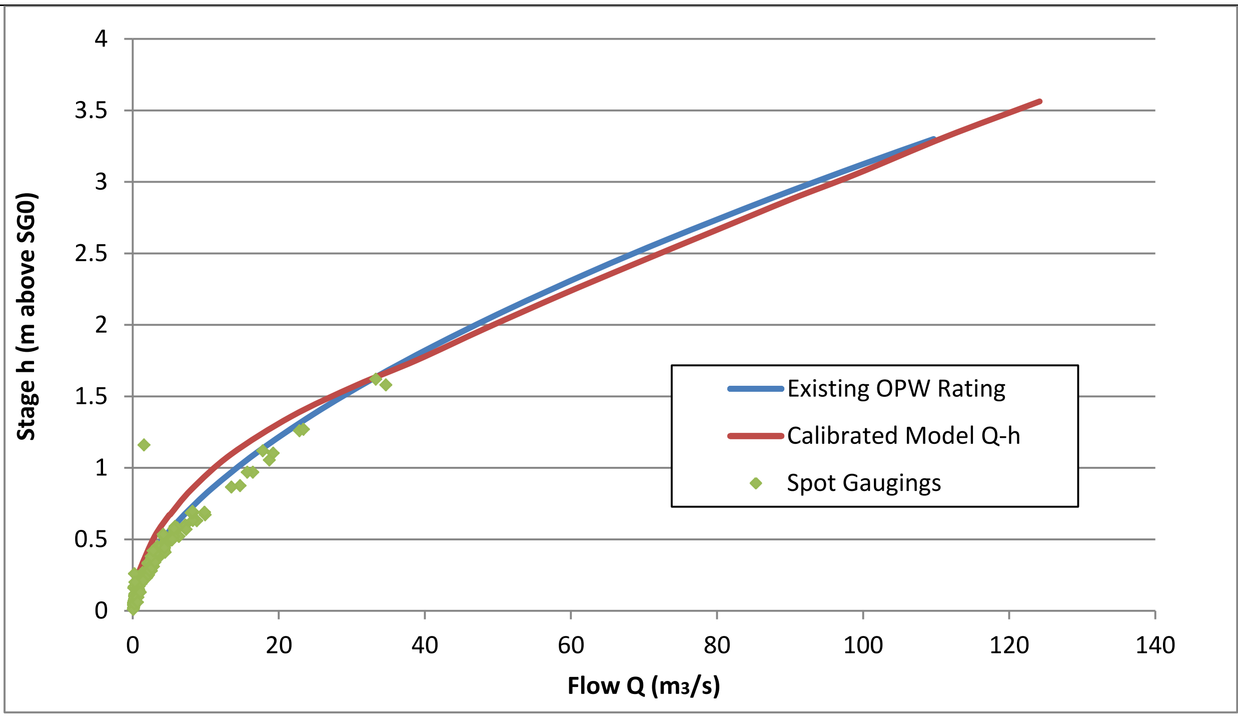


Figure 4.10.24: Sandy Mills, modelled Q-h relationship, existing rating and spot gaugings

Figure 4.10.24 shows that the model fairly represents the OPW rating curve based on the flow gaugings up to the limit of the OPW rating at 110 m^3/s. Calibration at lower flows was found to be poor although the model provides a good fit to the highest spot flow gaugings. The best fit rating curve was achieved with a Manning's n value of 0.035. This is consistent with a clean, straight channel which best describes this reach of the Deele River. Analysis of the results show that floodwaters remain in bank at the gauged section until river flow exceeds 124 m^3/s or 7.2m (OD Malin). As the model was unable to represent out of bank flows accurately it has not been possible to extend the rating curve significantly. The modelled rating curve does not suggest uncertainty in the rating at the median flood flow.

(5) Other Information:

It was reported (www.donegaldaily.com) that flooding occurred in Convoy on the 29th January 2012, following 24 hours of non-stop rain. Minor flooding was described to have occurred in Convoy. There are no details of flooding extents or flows available. This report was not used for model calibration since there were insufficient geographical references associated with this report.

4.10.6 Hydraulic Model Assumptions, Limitations and Handover Notes

(1) Hydraulic Model Assumptions:	
a) Reaches 0159A and 0159B are shown dry in the survey photos and reach 0159A is blocked at both ends by closed sluice gates. These reaches were not included in the 1D model and it was assumed that they would be adequately represented within the 2D model domain. b) The culvert at cross section 0160M00042D has different cross section profiles at its upstream and downstream ends. It has been assumed that a transition occurs at approximately midway between the two ends.	
(2) Hydraulic Model Limitations and Parameters:	
a) The DFlood and MaxItr parameters were increased to 5 and 17 respectively, to improve model stability / convergence. b) A 0.5 second timestep was used for both the 1D and 2D components for all scenarios. c) Theta has been increased to 0.99 to increase the stability of the model. d) A cell size of 5m was chosen for the 2D grid in order to represent the floodplain. e) There is only a small amount of historic data on which to verify the model outputs. The calibration and verification of the Convoy model is therefore somewhat limited.	
Hydraulic Model Parameters:	
ISIS 1D	
Timestep (seconds)	0.5
dflood	5
ISIS 2D	
Timestep (seconds)	0.5
Drying / Wetting depths (metres)	0.01 / 0.1
Eddy Viscosity (and type)	1 - Constant eddy formulation based on equation $k*x^2/t$, where k=0.02
(3) Design Event Runs & Hydraulic Model Handover Notes:	
a) Details of critical structures are provided in Section 4.10.3 with accompanying photographs. b) Model results have indicated flooding within the AFA at the Convoy Enterprise Centre and to roads near the Cloghroe River, as discussed in Section 4.10.5 above. Other areas of flood risk within the AFA are indicated on the right bank of the Milltown watercourse, affecting the rear gardens of properties in the Townsparks area, and upstream of the Townsparks/Carrick Court culvert. c) Extensive, frequent flooding of farmland is indicated in areas outside the AFA, particularly from the	

Cloghroe River downstream of the Convoy AFA. These areas can be considered functional floodplain and provide attenuation and storage of floodwater, reducing peak flows and flood risk further downstream.	
(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:	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)	MANNING'S n
Bridges								
CLOGHROE RIVER	1465	0159M01748D	6.36	ARCH x 2	3.53/5.87	2.53 / 7.35	0.24 / 3.1	0.04
CLOGHROE RIVER	3013	0159M01593D	6.2	ARCH x 2	3.84/3.56	5.76 / 5.72	2.64 / 2.41	0.04
CLOGHROE RIVER	5992	0159M01294D	6.4	ARCH x 3	4.58/5.24.65	4.52 / 6.12 / 4.8	3.1 / 3.25 / 3.21	0.04
CLOGHROE RIVER	10955	0159M00799D	6.7	RECTANGULAR x2	4.60/4.56	6.14 / 6.18	2.50 / 3.4	0.04
CLOGHROE RIVER TRIB	40	0159A00093D	2	RECTAMGULAR	0.98	1.95	0.98	0.04
CLOGHROE RIVER TRIB	43	0159A00092E	2	ARCH	1.39	2.15	0.73	0.04
CLOGHROE RIVER TRIB	396	0159A00056	0.5	RECTANGULAR	0.92	1.62	0.92	0.04
CLOGHROE RIVER TRIB	684	0159A00029D	3.5	RECTANGULAR	1.18	3.7	1.18	0.04
MILLTOWN	667	0160M00062D	9.1	ARCH	3.37	4.53	2.04	0.05
MILLTOWN	1264	0160M00003D	7.56	ARCH	2.42	3.22	1.17	0.05

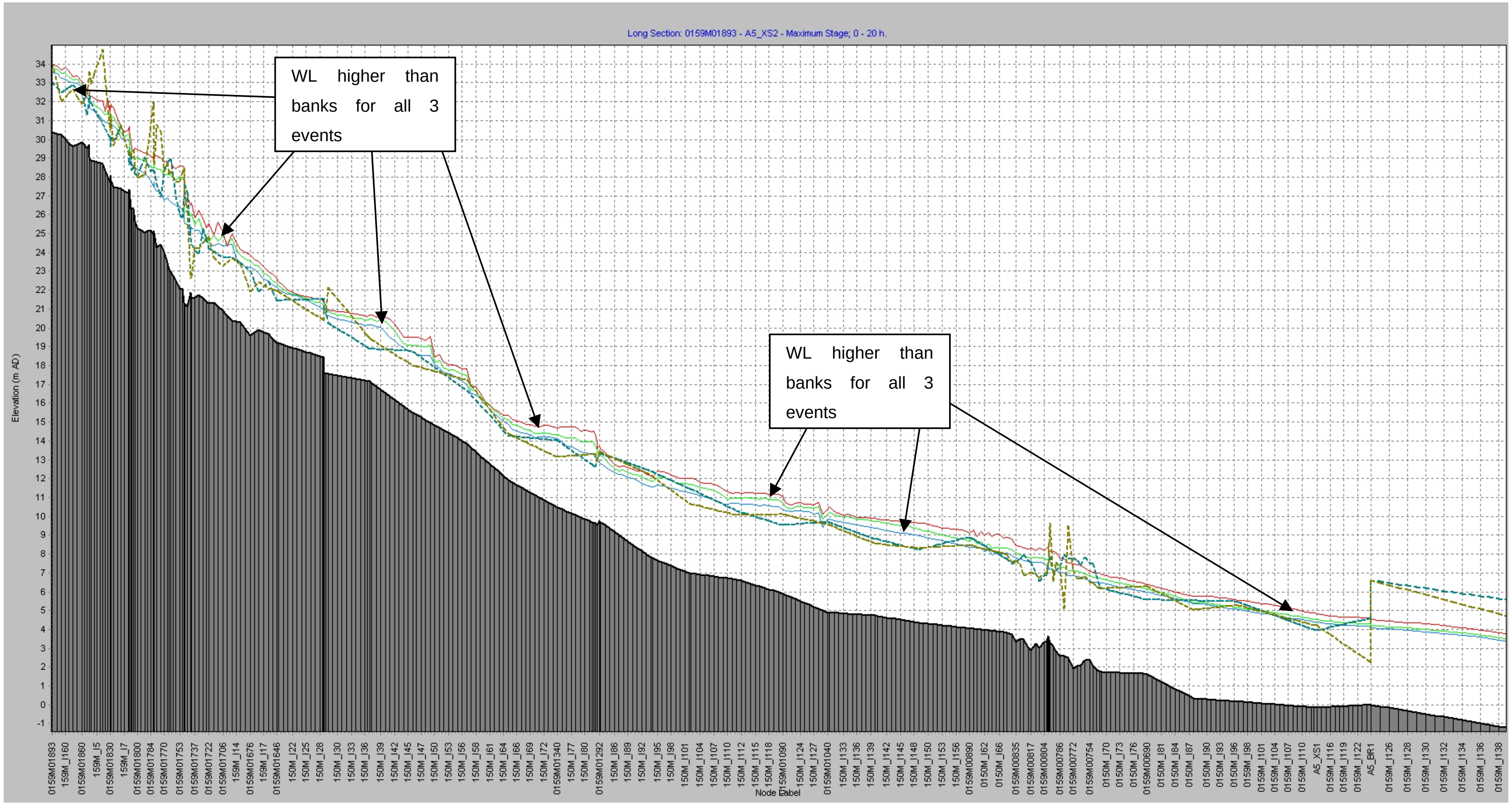
Structure Details – Bridges & Culverts								
RIVER BRANCH	**CHAINAGE**	**ID****	**LENGTH (m)**	**OPENING SHAPE**	**HEIGHT (m)**	**WIDTH (m)**	**SPRING HEIGHT FROM INVERT (m)**	**MANNING'S n**
MILLTOWN	420	0160M00042D	10.5	RECTANGULAR	2	3.47	2	0.03'
MILLTOWN	1167	0160M00012D	10.5	ARCH	3.22	3.69	3.22	0.02
CLOGHROE RIVER	1465	0159M01748D	6.36	ARCH x 2	3.53 / 5.87	2.53/7.35	0.24/3.1	0.04
CLOGHROE RIVER	3013	0159M01593D	6.2	ARCH x 2	3.84 / 3.56	5.76/5.72	2.64/2.41	0.04
CLOGHROE RIVER	5992	0159M01294D	6.4	ARCH x 3	4.58 / 5.20 / 4.65	4.52 / 6.12 / 4.8	3.1 / 3.25 / 3.21	0.04
CLOGHROE RIVER	10955	0159M00799D	6.7	RECTANGULAR x2	4.60 / 4.56	6.14 / 6.18	2.50 / 3.4	0.04
CLOGHROE RIVER TRIB	40	0159A00093D	2	RECTAMGULAR	0.98	1.95	0.98	0.04
Culverts								
CLOGHROE RIVER TRIB	896	0159A00006I	73	RECTANGULAR x2	0.9 / 0.94	0.72 / 0.72	0.9 / 0.94	0.04

Structure Details - Weirs			
RIVER BRANCH	**CHAINAGE**	**ID****	**Type**
CLOGHROE RIVER	420	0159M01852W	RN BROAD CRESTED
CLOGHROE RIVER	662	0159M01828W	RN BROAD CRESTED
CLOGHROE RIVER	863	0159M01808W	RN BROAD CRESTED
CLOGHROE RIVER	906	0159M01803W	RN BROAD CRESTED
CLOGHROE RIVER	1133	0159M01779W	RN BROAD CRESTED
MILLTOWN	1178	0160M00011W	RN BROAD CRESTED
CLOGHROE RIVER	420	0159M01852W	RN BROAD CRESTED
CLOGHROE RIVER	662	0159M01828W	RN BROAD CRESTED

** Structure ID Key:

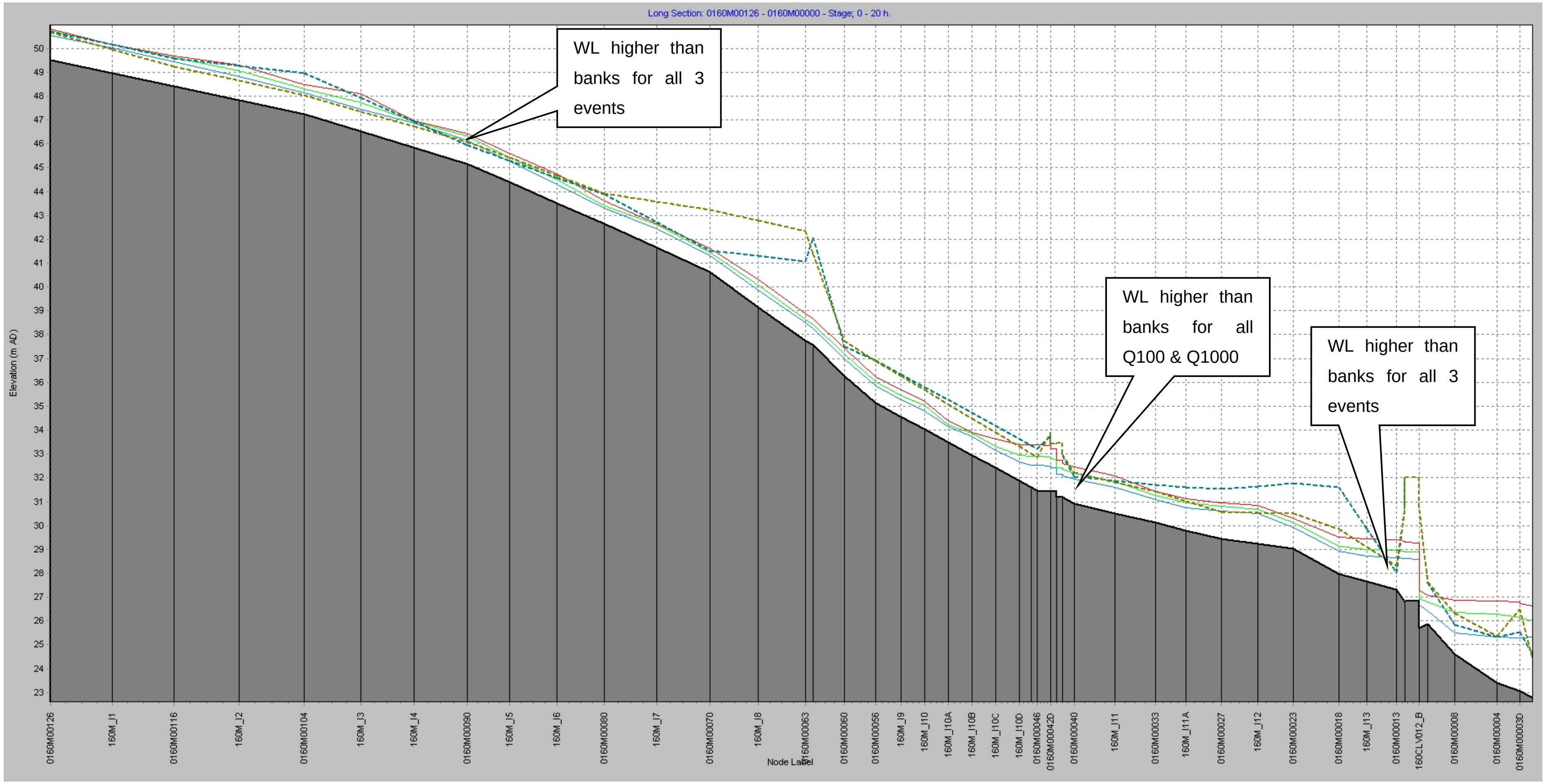
D – Bridge Upstream Face; **E** – Bridge Downstream Face; **I** – Culvert Upstream Face; **J** – Culvert Downstream Face; **W** - Weir

APPENDIX A.2



Reach 0159M: Cloghroe River.

The long section shown above is for the watercourse reach 0159m. The dashed blue line and brown lines shown on the plot are the left and right banks respectively. Included in the plot are peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP events. Location where out of bank flow have occurred have also been noted.



Reach 0160M: Milltown watercourse.

The long section shown above is for the watercourse reach 0160m. The dashed blue line and brown lines shown on the plot are the left and right banks respectively. Included in the plot are peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP events. Location where out of bank flow have occurred have also been noted.

APPENDIX A.3

Flow Comparison at HEP Check Points

Watercourse	HEP	AEP	Check Flow (m^3/s)	Model Flow (m^3/s)	Difference (%)
CLOGHROE RIVER	**01_801_Int_1_RPS**	10%	107.64	107.91	+0.25
		1%	148.33	149.50	+0.78
		0.1%	199.43	200.50	+0.54
CLOGHROE RIVER	**01_801_Int_2_RPS**	10%	107.73	109.54	+1.68
		1%	148.45	152.85	+2.96
		0.1%	199.60	206.08	+3.25
CLOGHROE RIVER	**01046_RA**	10%	107.73	109.33	+1.49
		1%	148.45	151.37	+1.96
		0.1%	199.60	197.35	-1.12
MILLTOWN	**01_1518_4_RA**	10%	4.27	4.35	+1.92
		1%	6.94	6.68	-3.66
		0.1%	11.30	9.97	-11.79
CLOGHROE RIVER	**01_1557_3_RA**	10%	110.76	116.41	+5.09
		1%	152.63	167.48	+9.72
		0.1%	205.22	221.48	+7.93
CLOGHROE RIVER	**01041_RA**	10%	115.49	113.09	-2.08
		1%	159.15	161.66	+1.58
		0.1%	213.98	223.69	+4.54
CLOGHROE RIVER	**01048_RA**	10%	117.95	112.42	-4.68
		1%	162.53	152.64	-6.08
		0.1%	218.52	194.03	-11.21

The table above is used to make a comparison between the estimated flow details and model flow at every HEP inflow, check point and modelled tributaries. These flows have been compared with the hydrology flow estimation and a percentage difference provided to ensure the model is well anchored to the hydrological estimates.

Flows in the Cloghroe River (Deele) are influenced by storage-attenuation effects due to areas of active floodplain on this river reach. That said the model flows and estimated flows are well anchored at locations along the Cloghroe River HEPs.

The HEP 01_1518_4_RA is located at the confluence of the Milltown watercourse and the much larger Cloghroe River (Deele) within the AFA. There is very close agreement between the estimated and model flows for all three modelled design events.

APPENDIX A.4

Model Files provided with this report

ISIS 2D .xml Files	ISIS 1D .ief Files	Sub-Folders
UOM01_CONV23_2D_DES_Q10F.xml UOM01_CONV23_2D_DES_Q100F.xml UOM01_CONV23_2D_DES_Q1000F.xml	UOM01_CONV23_1D_DES_Q10F.ief UOM01_CONV23_1D_DES_Q100F.ief UOM01_CONV23_1D_DES_Q1000F.ief	ISIS 1D ISIS 2D Results

1st Level Sub-Folder	2nd Level Sub-Folder	Files
ISIS 1D	Bredagh_0154M	UOM01_CONV23_1D_DES.DAT UOM01_CONV23_1D_DES.zzs UOM01_CONV23_1D_DES_Q10F.IED UOM01_CONV23_1D_DES_Q100F.IED UOM01_CONV23_1D_DES_Q100F_.IED
ISIS 2D	Active Area	UOM01_CONV23_2D_DES_ACTVA.dbf UOM01_CONV23_2D_DES_ACTVA.shp UOM01_CONV23_2D_DES_ACTVA.shx
	` Links	UOM01_CONV23_2D_DES_0159M.dbf UOM01_CONV23_2D_DES_0160M.dbf UOM01_CONV23_2D_DES_0159M.shx UOM01_CONV23_2D_DES_0160M.shx UOM01_CONV23_2D_DES_0159M.shp UOM01_CONV23_2D_DES_0160M.shp
	DTM	UOM01_CONV23_2D_DES_2M_LID1.asc UOM01_CONV23_2D_DES_2M_LID2.asc UOM01_CONV23_2D_DES_5M_NDTM.asc UOM01_CONV23_2D_DES_BLD.dbf UOM01_CONV23_2D_DES_BLD.shp UOM01_CONV23_2D_DES_BLD.shx
	2D Roughness	UOM01_CONV23_2D_DES_MANN.asc

1st Level Sub-Folder	2nd Level Sub-Folder	Files
Results	ISIS 1D MIN-MAX	UOM01_CONV23_1D_DES_Q10F.csv UOM01_CONV23_1D_DES_Q100F.csv UOM01_CONV23_1D_DES_Q1000F.csv
	ISIS 1D UNSTEADY RESULTS	UOM01_CONV23_1D_DES_Q10F.zzl UOM01_CONV23_1D_DES_Q100F.zzn UOM01_CONV23_1D_DES_Q1000F.zzl UOM01_CONV23_1D_DES_Q10F.zzn UOM01_CONV23_1D_DES_Q100F.zzl UOM01_CONV23_1D_DES_Q1000F.zzn
	ISIS 2D MAX DEPTH	UOM01_CONV23_2D_DES_Q10F.asc UOM01_CONV23_2D_DES_Q100F.asc UOM01_CONV23_2D_DES_Q1000F.asc
	Check Files	UOM01_CONV23_1D_DES_Q10F_1DMB.csv UOM01_CONV23_1D_DES_Q100F_1DMB.csv UOM01_CONV23_1D_DES_Q1000F_1DMB.csv UOM01_CONV23_2D_DES_Q10F_2DMB.csv UOM01_CONV23_2D_DES_Q100F_2DMB.csv UOM01_CONV23_2D_DES_Q1000F_2DMB.csv

GIS Deliverables - Hazard

Flood Extent Files (Shapefiles)	**Flood Depth Files (Raster)**	**Water Level and Flows (Shapefiles)**
Fluvial N19EXFCD001F0 N19EXFCD010F0 N19EXFCD100F0 Coastal N19EXCCD001F0 N19EXCCD005F0 N19EXCCD100F0	Fluvial N19DPFCD001F0 N19DPFCD010F0 N19DPFCD100F0 Coastal N19DPCCD001F0 N19DPCCD005F0 N19DPCCD100F0	Fluvial N19NFCDF0 Coastal N19NCCDF0
Flood Zone Files (Shapefiles)	**Flood Velocity Files (Raster)**	**Flood Defence Files (Shapefiles)**
N19ZNA_MCDF0 N19ZNB_MCDF0	Fluvial N19VLFCD001F0 N19VLFCD010F0 N19VLFCD100F0 Coastal N19VLCCD001F0 N19VLCCD005F0 N19VLCCD100F0	N/A

GIS Deliverables - Risk

Specific Risk - Inhabitants (Raster)	**General Risk - Economic (Shapefiles)**	**General Risk-Environmental (Shapefiles)**
Fluvial N19RIFCD100F0 N19RIFCD010F0 N19RIFCD001F0 Coastal N19RICCD100F0 N19RICCD005F0 N19RICCD001F0		