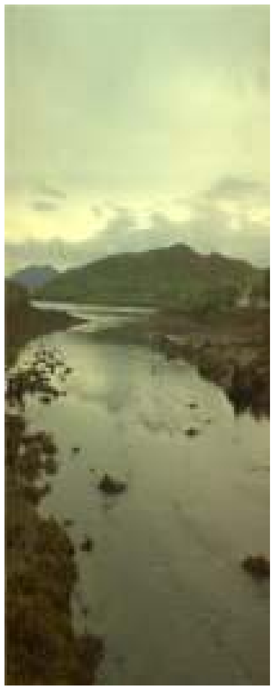

South Western CFRAM Study

Hydraulics and Flood Mapping Appendices,
Unit of Management 21

August 2014

The Office of Public Works

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description	Standard
A	Nov 2013	M Piggott	R Gamble	R Gamble	Draft	
B	May 2014	M Piggott	R Gamble	R Gamble	Draft Final	
C	Aug 2014	M Piggott	R Gamble	R Gamble	Draft Final Revision Minor amendments to text	

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Appendices

Appendix A. Durrus AFA

A.1 Model Build Proforma

UOM	**21**		
AFA/ MPW Reach	**Durrus**		
Model ID	**I29DS**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourse	**Four Mile Water North**	**FLUVIAL RISK**	Yes
Length Modelled (km)	**4.3**	**COASTAL RISK**	No
Area Modelled (km^2)	**2.2**	**VULNERABLE TO WAVES**	No

Input Data	
River Channel Topographic Data	River channel survey was undertaken by Murphy Surveys Limited as part of the CFRAM Study surveyed between October 2012 and March 2013 Alterations to survey for modelling purposes: 21FMWS00008H, 21FMWN00202H, 21FMWN00168H - lowered bed slightly to stabilise against the downstream spill/weir 21NAGH00000H, 21NAGH00017E - copied from 21NAGH00017D to provide channel downstream of bridge 21FMWN00210X - inserted notch in the channel bed to stabilise at low flow 21FMWN00196H - raised bed levels to remove scour hole from confluence with FWMS Where steep sections were modelled with a spill unit (See Schedule 2), the surveyed chainage was added to the downstream open channel section to maintain river length.
Floodplain Topographic Data	Filtered LiDAR (Durrus2mdtm.asc) 2m grid resolution with +/- 0.1m RMSE captured in April 2012.All of the geometric survey data captured by the surveyor was reviewed with checks carried out on 10% of the cross sections. Levels from the river channel cross sections were checked against the Digital Terrain Model (DTM) as described in Section 2.3. The average difference between the levels of the surveyed cross sections and the DTM was found to be 0.184mm. The LiDAR was used for the area covered by the AFA. IFSAR was used to supplement the LiDAR over the Four Mile Water Estuary which is outside of the AFA. The LiDAR and IFSAR levels were checked against surveyed levels and no significant inaccuracies were noted.
Map data	OSI 5000 raster tiles 6709 used for mapping. 6709-A.dwg, 6709-B.dwg and 6709_dwg.txt used to provide material file data. The OSI mapping was found to include all current developments and was consistent with site observations, the river channel survey and aerial photography.

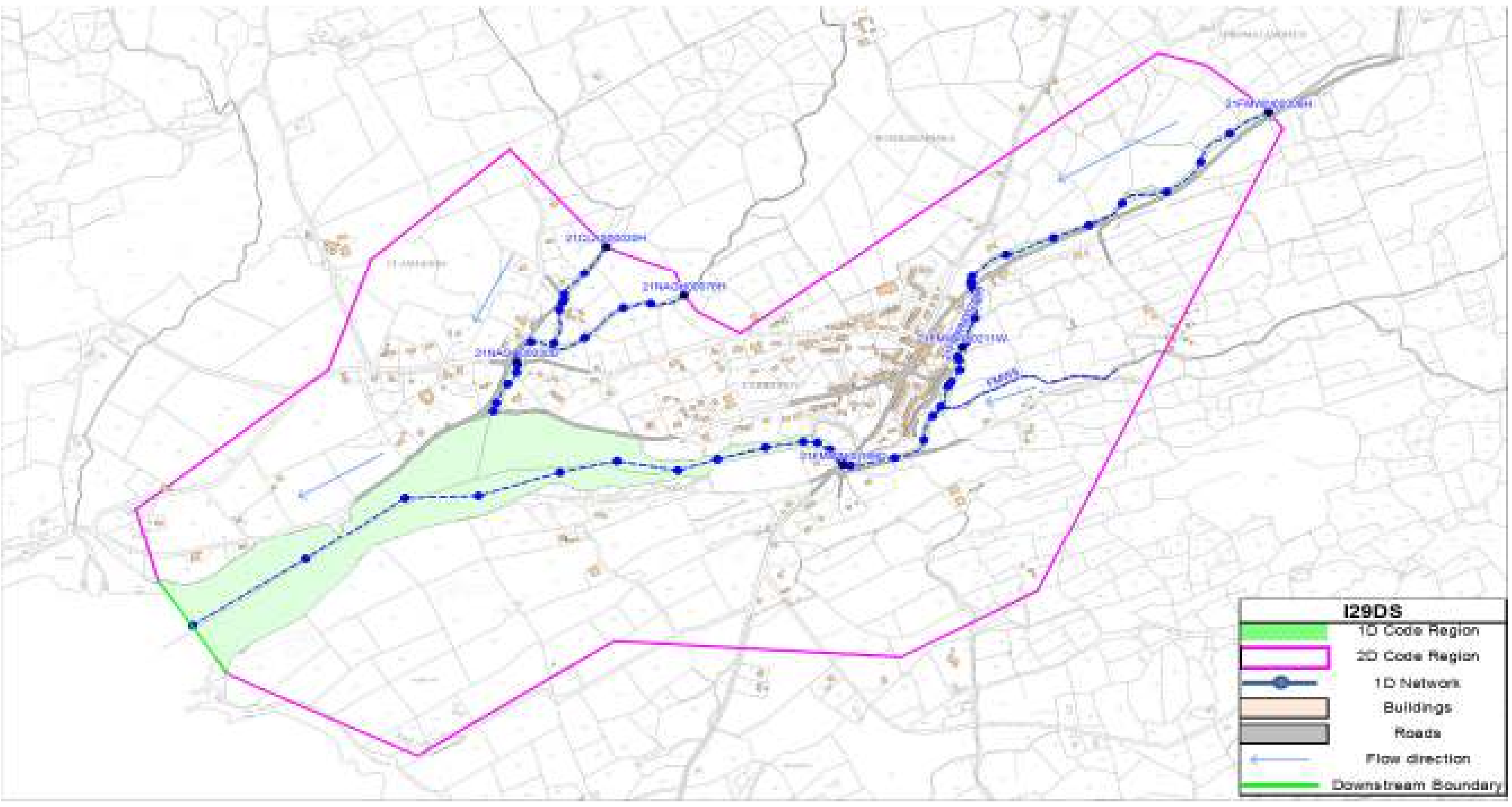
Model Build	
General Schematisation	A 1D/2D ISIS/TUFLOW approach was taken for Durrus to model flow along the main watercourses and head loss through hydraulic structures whilst enabling mutlidirectional flow across the urban and floodplain areas. The 1D model considers the Clashadoo, Ahanegavanagh and Four Mile Water North as the main watercourses. The design hydrographs were input using inflows connected to the upstream end of the watercourse, and as lateral inflows between confluences. The 2D model was extended upstream of the AFA region to capture floodplain flow from further up Four Mile Water North. The downstream boundary of the model has been extended to include the Four Mile Water estuary. Four Mile Water South has not been connected to the 2D domain because the river channel is well constrained to its confluence with Four Mile Water North. A loop channel that runs parallel to the right side of Four Mile Water North has been modelled as an orifice to represent the flow constriction at the upstream end of the channel. The 0.1% AEP peak flow along the loop channel is in the order of 1m³/s while the peak flow in the Four Mile Water North channel is approximately 45m³/s. The direction of slope of the ground between the loop channel and Four Mile Water North would draw any flood water back into the main channel. The 2D model grid size was set to 5m to represent the urban area without compromising model run time. River banks were enforced using the breaklines in the 2D domain based on survey spot levels. Buildings were raised above the floodplain by 0.15m to represent their threshold levels, and then a high Manning's 'n' value of 0.2 was also applied to represent the storage of the building. This approach means flood depths can be extracted at buildings for flood damage analysis.
Software Versions Used	ISIS version 6.6.0.81, TUFLOW 2012-05-AE-iDP-w64
Total No of 1D nodes	**102**
Open channel (H)	73
Bridges (D)	4
Culverts (I)	1
Weirs (W)	4 (3 represent waterfalls or steep sections)

Model Extent	Reach/Feature	Upstream Limit (ING)	Downstream Limit (ING)
	Clashadoo	93950, 42300	93840, 42070
	Aganegavannagh	94130, 42190	93700, 41910
	Four Mile Water South	95160, 42000	94700, 41910
	Four Mile Water North	95420, 42630	93040, 41390

Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Clashadoo	0.04	0.06	0.06	Schedule 1: Photographs
	Aganegavannagh	0.04	0.06	0.06	Schedule 1: Photographs
	Four Mile Water South	0.04	0.06	0.06	Schedule 1: Photographs
	Four Mile Water North	0.04	0.06	0.06	Schedule 1: Photographs
	Open pasture	N/A	N/A	0.06	Schedule 1: Photographs
	Dense vegetation	N/A	N/A	None	Schedule 1: Photographs
	Buildings	N/A	N/A	0.2	Schedule 1: Photographs
	Roads	N/A	N/A	0.033	Schedule 1: Photographs

Structures	See Schedule 2 for Hydraulic Structure Parameters
Upstream boundary	All direct inflows have been applied at the upstream end of the surveyed extent and are located where water is constrained to a narrow valley and is well upstream of the AFA.
Lateral inflows	Four Mile Water North: 21FMWN00278 - inflow for hydrological catchment 21_7736_IC. Equally weighted between nodes 21FMWN00278H, 21FMWN00268H and 21FMWN00248H where there are low points in the bankside survey.
Downstream boundary	The downstream boundary of the 1D was located at the outfall of the Finninhy into the estuary (Kenmare River) at node 21 FINN0000H. The design tidal conditions were applied directly to the 1D node. The design tidal conditions and wave overtopping 2D downstream boundary was located along the quayside/coastline of the estuary/Kenmare River. The tide plus total surge levels were applied as level-time(HT) boundary. The wave overotpping discharges were applied as a discharge-time (QT) on the landward side of the coastaline crest and a separate HT boundary with the associated tidal plus surge levels located in the seaward cell to enable excess wave dischareg to flow back out of sea when water level on the floodplain was above defence crest. The design astronomical tide plus total surge (still water) levels were applied as a level-time (HT) boundary to 1D node 21FMWN00008H at the downstream extent of Four Mile North Water. Wave overtopping and tidal still water modelling have not been undertaken in the 2D domain.
Run Settings	Unsteady simulation of the full 15 hour hydrograph. The 1D timestep has been set to 1s. The 2D timestep has been set to 2s. The 1D timestep divides into the 2D timestep, and the 2D timestep is less than half the grid cell size as recommended. Minimum flows of 1m³/s on Clashadoo, 3.0m³/s on Ahanegavanagh, 0.5m³/s on Four Mile Water South and 5m³/s on Four Mile Water North. These minimum flows are less than 10% of the channel capacity and a representative of baseflow. Therefore the minimum flows do not affect the storage available during flood events. All other parameters are set to default.

Model Geoschematic



SCHEDULE 1 : PHOTOGRAPHS

Photo 1: Clashadoo Active Channel

ING 093840, 042070 - captured on 28/09/2012

Photo 2: Clashadoo Vegetated River Banks

ING 093860,042190 - captured on 28/09/12

Photo 3: Aganegavannagh Active River Channel

ING 093760,042050 - captured on 18/09/12

Photo 4: Aganegavannagh River Banks

ING 093990,042160 - captured on 18/09/2012

Photo 6: Four Mile Water South River Banks

ING 095010,041990 - captured on 15/03/2013

Photo 7: Four Mile Water North Active River Channel

ING 094680,041900 - captured on 15/03/13

Photo 8: Four Mile Water North River Banks

ING 094680,041900 - captured on 15/03/13

Photo 9: Open pasture

ING 093010,041530# - captured on 14/03/13

SCHEDULE 2: Structures

Data file P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I29DS_Durrus\DESIGN\model\ISIS\DAT\I29DS_ISIS_001_296_01.dat

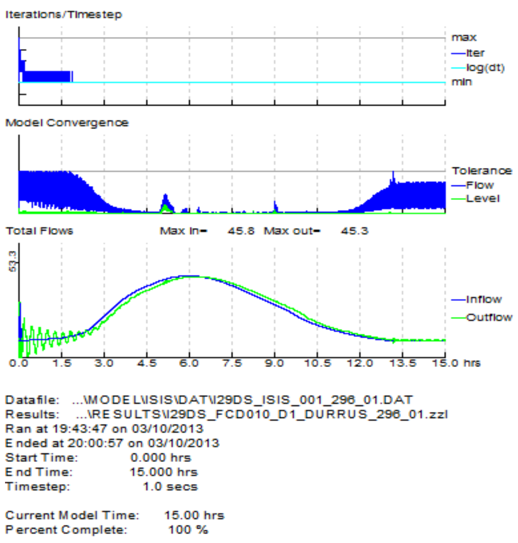
Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Comments/ Justification
				Soffit Elevation	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation	Length	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation	Modular Limit	Weir Coeff.	
CLAS00012I	93860	42175	Concrete pipe with rectangular outlet CULVERT	2.69	1	0	1	N/A	N/A	N/A	N/A	3.564	0.9	1	Private road culvert constricting flow above 3.6mODM. Spill representing flow over road and parapet.
NAGH00030D	93760	42020	Masonary arch bridge ARCH BRIDGE	1.93	2	17	1	N/A	N/A	N/A	N/A	2.5	0.9	1	Carrigbui Bridge
NAGH00017D	93700	41900	Masonary arch bridge ARCH BRIDGE	2.29	1	33	1	N/A	N/A	N/A	N/A	3.02	0.9	1	L4704 Bridge - Masonry Arch
21FMWS00008H	94500	41900	Confluence SPILL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.955	0.9	1.5	Spill to stabilise drop downstream into FMWN channel
21FMWN00227W	94730	42450	Weir SPILL	N/A	N/A	N/A	N/A	9.2	32	0.9	N/A	N/A	N/A	1.5	Weir - angled crest on plan, modelled so that all flow returns to FMWN. Low flow notch at 9.2mODM, main crest at 9.45mODM.
FMWN00226D	94760	42210	Steel and masonry bridge with flat soffits USBPR BRIDGE	10.36	3	0	1	N/A	N/A	N/A	N/A	11.56	0.9	1	School Road Bridge - section from 33.45m truncated and represented in parallel channel leading to 21LOOP. Spill for parapets and bridge deck.
21FMWN00211W	94740	42060	Waterfall SPILL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.2	0.9	1.5	Waterfall with scour hole immediately d/s. Irregular rock constriction with central notch modelled by a spill.
21FMWN00202H	94710	41970	Waterfall SPILL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.6	0.9	1.5	Irregular rock crest modelled by a spill.
21FMWN00168H	94490	41780	Irregular rocky bed SPILL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		0.9	1.5	Spill to model steep slope towards bridge
FMWN00166D	94480	41790	Steel and masonry bridge with flat soffits USBPR BRIDGE	2.63	2	0	1	N/A	N/A	N/A	N/A	3.5	0.9	1	Carrigboy Bridge. Spill for the bridge parapet has been truncated to in-bank width.

A.2 Model Performance Proforma

Durrus Model Performance

1D Convergence

Convergence Plot 1% AEP Fluvial Event

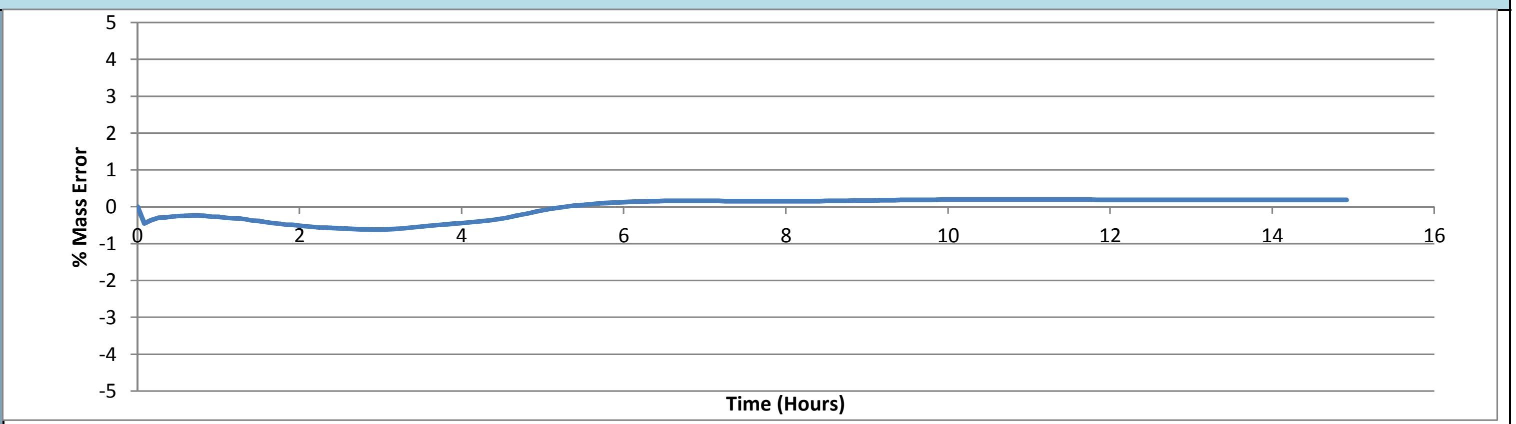


Comments

The 1D model components were convergent and within the recommended tolerances for the entire of the event.
Version I29DS_ISIS_001_296_01.dat was used for all fluvial design runs.

2D Convergence

Mass Balance Plot 1%AEP Fluvial Event



Comments

The overall 2D mass balance error was +0.2% or 10421 m^3.
The 2D model remains within the recommended tolerance of ±1% cumulative mass error throughout the 1%AEP event. The period of higher mass error between 2 and 4 hours is due to the initial wetting of the 2D cells that represent fields on the right bank between 21FMWN00238H and 21FMWN00268H. However, the mass error is within the recommended tolerance and the results are deemed to be reliable.

Hydrological Performance

HEP ID	Location	Model Node	10% AEP Design (m^3/s)	10% AEP Modelled (m^3/s)	10% AEP % Difference	1%AEP Design (m^3/s)	1%AEP Modelled (m^3/s)	1%AEP % Difference	0.1%AEP Design (m^3/s)	0.1%AEP Modelled (m^3/s)	0.1%AEP % Difference
21_6225_1	Ahanegava	21NAGH00046H	8.6	8.8	2%	12.7	13.3	5%	18.8	18.9	0%
21_6225_2	Ahanegava	21NAGH00018H	8.7	8.9	2%	12.9	13.5	5%	19.1	20.2	6%
21_7736_5	Four Mile	21FMWN00211W	20.5	20.2	-2%	30.7	30.1	-2%	46	45.0	-2%
21_8044_2	Four Mile	21FMWN00147H	24.2	22.0	-9%	36.3	32.9	-9%	54.3	49.1	-10%

Comments

The HEPs within the AFA are within 6% of the design peak flow.
For the purposes of the CFRAMS, the river flow and peak tide have been phased to coincide. Therefore, the tidal interaction combines with attenuation from structures and floodplain flow to reduce the peak flow at HEP 21_8044_2 which is less than the target design hydrology peak which assumes no backwater (highlighted yellow). however this does not affect the HEPs within the AFA and extreme sea levels are well below the bed elevations and natural bed drops within the AFA.

Calibration Event 1

Model Run ID	No calibration events were available for Durrus AFA.
Period Modelled	
Hydraulic Modification to Design Model	
Hydrological inflows	
Calibration Plot	
Comments	

Sensitivity Test 1: Increased Flow

Model Run ID: I29DS_FHD010_D1_DURRUS

Hydraulic Modification to Design Model: No hydraulic modifications were made to the design model.

Hydrological inflows: All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the QMED 7-variable equation, the pooling growth curves and the pivotal site selected based on the hydrological sensitivity tests in the Unit of Management 21 Draft Final Hydrology Report, Chapter 6 (October 2013).
This is broadly equivalent to the HEFS 1%AEP as the increase in urban extent has less the 1% impact on peak flow. Therefore, the HEFS 1%AEP results (FHD010) have been used as the sensitivity test results.

Sensitivity Plot: See Schedule 3 - Calibration and Sensitivity

Comments: A 30% increase in flows resulted does not significantly increase the areas at flood risk because the design 1%AEP is already out of bank and the floodplain is narrow, thereby limiting the extent. The largest change to flood risk was located upstream of the Sruth Mhuileann waterfall but even this was relatively minor.

Hence, the Durrus model is not significantly sensitive to increases in flow.

Sensitivity Test 2: Increased Manning's 'n'

Model Run ID: I29DS_ISIS_incN

Hydraulic Modification to Design Model: The Manning's 'n' values were increased to the upper limit of the recommended ranges in Chow 1959.
- All active channels 0.040 to 0.045
- All river banks 0.060 to 0.080
- Pasture / parkland / garden 0.060 to 0.080
- Buildings 0.200 to 0.300
- Roads 0.033 to 0.040

Hydrological inflows: No modifications were made to the design inflows.

Sensitivity Plot: See Schedule 3 - Calibration and Sensitivity

Comments: An increase in roughness values, both inbank and out-of-bank resulted in a small increase of the flood extent. The largest increase in flood extent was at the Sruth Mhuileann waterfall and along School Road further upstream. The increases in flooding extent are generally accompanied by a reduction in flow velocities and a consequent reduction in flood hazard, except in areas a deep (>1m) flooding.

Flood risk at Durrus was found to be sensitive to the uncertainties in the Manning's 'n' values use to represent vegetative and land use roughness.
An allowance should be made when interpreting the design flood outlines and the in the maintenance of any flood risk management option due to this uncertainty in Manning's 'n' values selected.

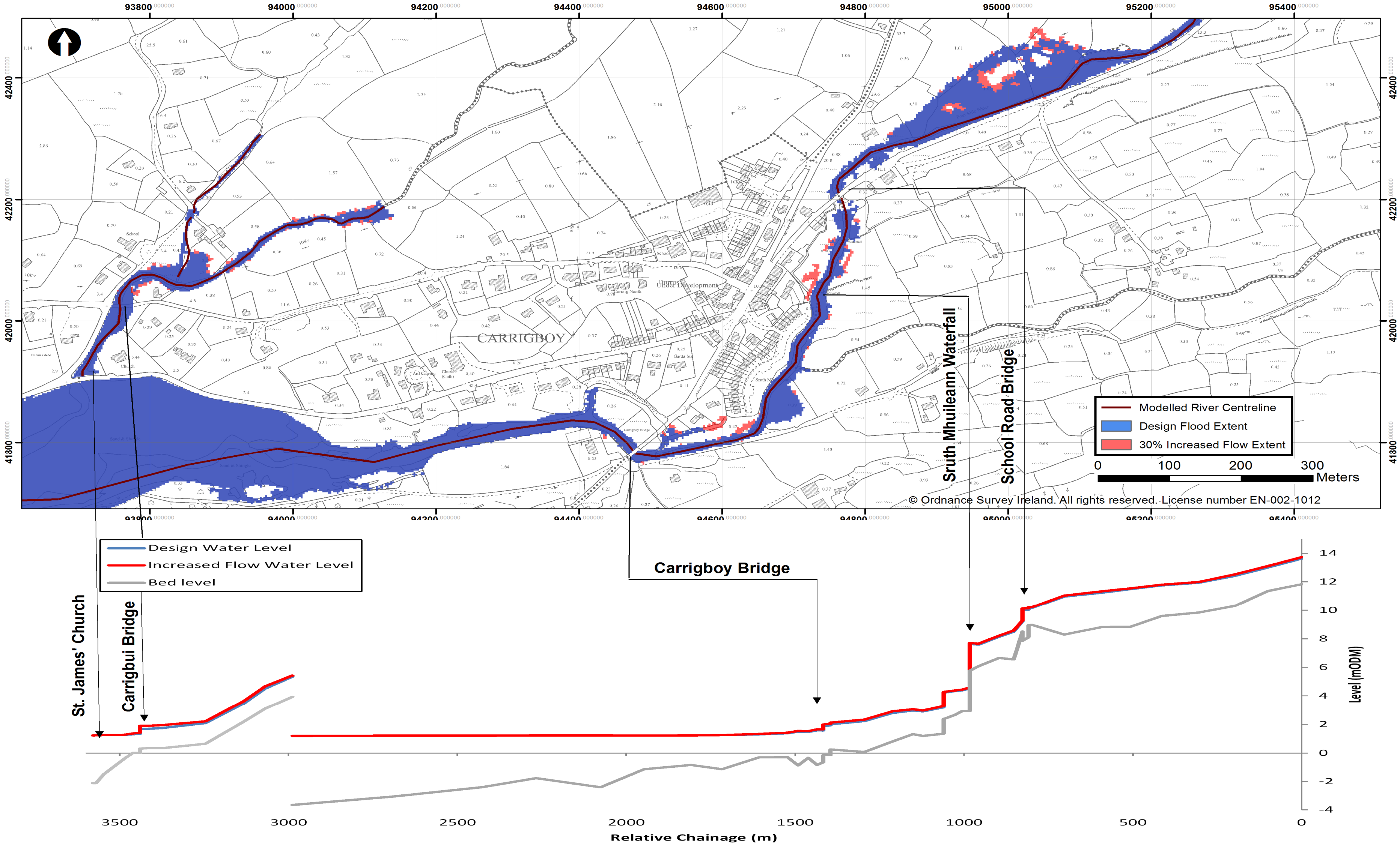
The design Manning's 'n' values were applied as a best estimate for Durrus as they best reproduced the frequency of flooding as reported by the local engineers.

Sensitivity Test 3: Increased Downstream Water Level Boundary. Not applicable as the extreme sea levels are well below the channel bed elevations within Durrus and below the the natural waterfalls which limit tidal progression.

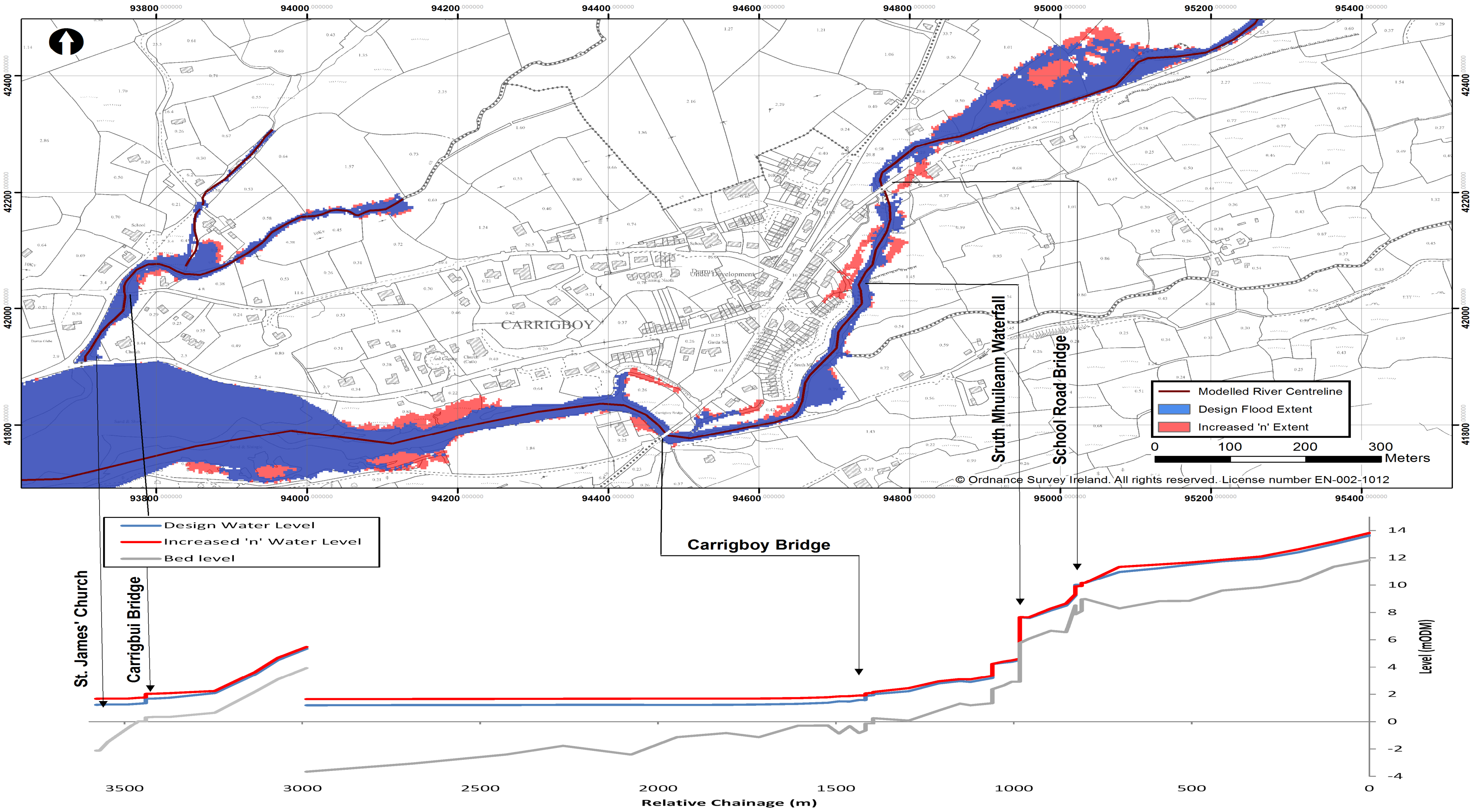
Model Run ID	
Hydraulic Modification to Design Model	
Hydrological inflows	
Sensitivity Plot	
Comments	

Mott MacDonald

Map A.1: Sensitivity to 30% Increased Flow



Map A.2: Sensitivity to Increased Manning's 'n'



A.3 Model Outputs

Durrus Model Outputs

Threshold of Property Flooding	0.1%AEP Fluvial current at Sruth Mhuileann
Critical Structures for Flood Risk	The loop channel on Four Mile Water North between 21FMWN00226D and 21FMWN00211W and the Sruth Mhuileann waterfall. Carrigbui Bridge.
Areas affected by flooding	Fluvial dominated events: Right bank upstream of the AFA at 21FMWN00248H, Sruth Mhuileann, confluence of Clashadoo and Ahanegavanagh.
Risk to people	The risk to life at the Sruth Mhuilean estate is low to moderate due to the shallow depth of flooding. However, flood hazard is significant to extreme for the riverside fields upstream of School road.
Consideration for Flood Risk Management Options	The time to peak is less than 4 hours which limits the time available for flood warning. Increased conveyance measures should be considered for the area affected by the Sruth Mhuileann waterfall. There is limited storage available on the right bank upstream of 21FMWN00238H to enable storage and attenuation measures. The Carrigbui Bridge is the only structural constriction of note.

Flood Map Outputs

The following table outlines the print-ready flood mapping deliverables provided in Schedule 4.

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Map	Flood Zone Map	Flood Depth Map	Flood Velocity Map	Flood Hazard Map
I29DS_FCD200	Design	10	MHWS	I21HDS29_EXFCDEXF_D2		I21HDS29_DPFCD200_D2	I21HDS29_VLFCD200_D2	I21HDS29_HZFCD200_D2
I29DS_FCD010	Design	1	MHWS	I21HDS29_EXFCDEXF_D2	I21HDS29_ZNFCDFZF_D2	I21HDS29_DPFCD010_D2	I21HDS29_VLFCD010_D2	I21HDS29_HZFCD010_D2
I29DS_FCD001	Design	0.1	MHWS	I21HDS29_EXFCDEXF_D2	I21HDS29_ZNFCDFZF_D2	I21HDS29_DPFCD001_D2	I21HDS29_VLFCD001_D2	I21HDS29_HZFCD001_D2
I29DS_FMD200	Design	10	MHWS	I21HDS29_EXFMDEXF_D2				
I29DS_FMD010	Design	1	MHWS	I21HDS29_EXFMDEXF_D2				
I29DS_FMD001	Design	0.1	MHWS	I21HDS29_EXFMDEXF_D2				

GIS Outputs

Print Ready Maps are denoted by the highlighted cells and provided in Schedule 4

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Polygon and Nodes	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
I29DS_FCD500	Design	50	MHWS	I29EXFCD500D2		I29DPFCD500D2	I29VLFCD500D2	I29HZFCD500D2
I29DS_FCD200	Design	20	MHWS	I29EXFCD200D2		I29DPFCD200D2	I29VLFCD200D2	I29HZFCD200D2
I29DS_FCD200	Design	10	MHWS	I29EXFCD200D2		I29DPFCD200D2	I29VLFCD200D2	I29HZFCD200D2
I29DS_FCD050	Design	5	MHWS	I29EXFCD050D2		I29DPFCD050D2	I29VLFCD050D2	I29HZFCD050D2
I29DS_FCD020	Design	2	MHWS	I29EXFCD020D2		I29DPFCD020D2	I29VLFCD020D2	I29HZFCD020D2
I29DS_FCD010	Design	1	MHWS	I29EXFCD010D2	I29ZNFCD010D2	I29DPFCD010D2	I29VLFCD010D2	I29HZFCD010D2
I29DS_FCD005	Design	0.5	MHWS	I29EXFCD005D2		I29DPFCD005D2	I29VLFCD005D2	I29HZFCD005D2
I29DS_FCD001	Design	0.1	MHWS	I29EXFCD001D2	I29ZNFCD001D2	I29DPFCD001D2	I29VLFCD001D2	I29HZFCD001D2
I29DS_FMD500	Design	50	MHWS	I29EXFMD500D2		I29DPFMD500D2	I29VLFMD500D2	I29HZFMD500D2
I29DS_FMD200	Design	20	MHWS	I29EXFMD200D2		I29DPFMD200D2	I29VLFMD200D2	I29HZFMD200D2
I29DS_FMD200	Design	10	MHWS	I29EXFMD200D2		I29DPFMD200D2	I29VLFMD200D2	I29HZFMD200D2
I29DS_FMD050	Design	5	MHWS	I29EXFMD050D2		I29DPFMD050D2	I29VLFMD050D2	I29HZFMD050D2
I29DS_FMD020	Design	2	MHWS	I29EXFMD020D2		I29DPFMD020D2	I29VLFMD020D2	I29HZFMD020D2
I29DS_FMD010	Design	1	MHWS	I29EXFMD010D2		I29DPFMD010D2	I29VLFMD010D2	I29HZFMD010D2
I29DS_FMD005	Design	0.5	MHWS	I29EXFMD005D2		I29DPFMD005D2	I29VLFMD005D2	I29HZFMD005D2
I29DS_FMD001	Design	0.1	MHWS	I29EXFMD001D2		I29DPFMD001D2	I29VLFMD001D2	I29HZFMD001D2
I29DS_FHD200	Design	10	MHWS	I29EXFHD200D2		I29DPFHD200D2	I29VLFHD200D2	I29HZFHD200D2
I29DS_FHD010	Design	1	MHWS	I29EXFHD010D2		I29DPFHD010D2	I29VLFHD010D2	I29HZFHD010D2
I29DS_FHD001	Design	0.1	MHWS	I29EXFHD001D2		I29DPFHD001D2	I29VLFHD001D2	I29HZFHD001D2

Appendix B. Bantry AFA

B.1 Model Build Proforma

UOM	**21**		
AFA/ MPW Reach	**Bantry**		
Model ID	**I30BY**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourse	**Bantry, Mealagh and Dromacoosane**	**FLUVIAL RISK**	Yes
Length Modelled (km)	**14.2km**	**COASTAL RISK**	Yes
Area Modelled (km^2)	**10km²**	**VULNERABLE TO WAVES**	No

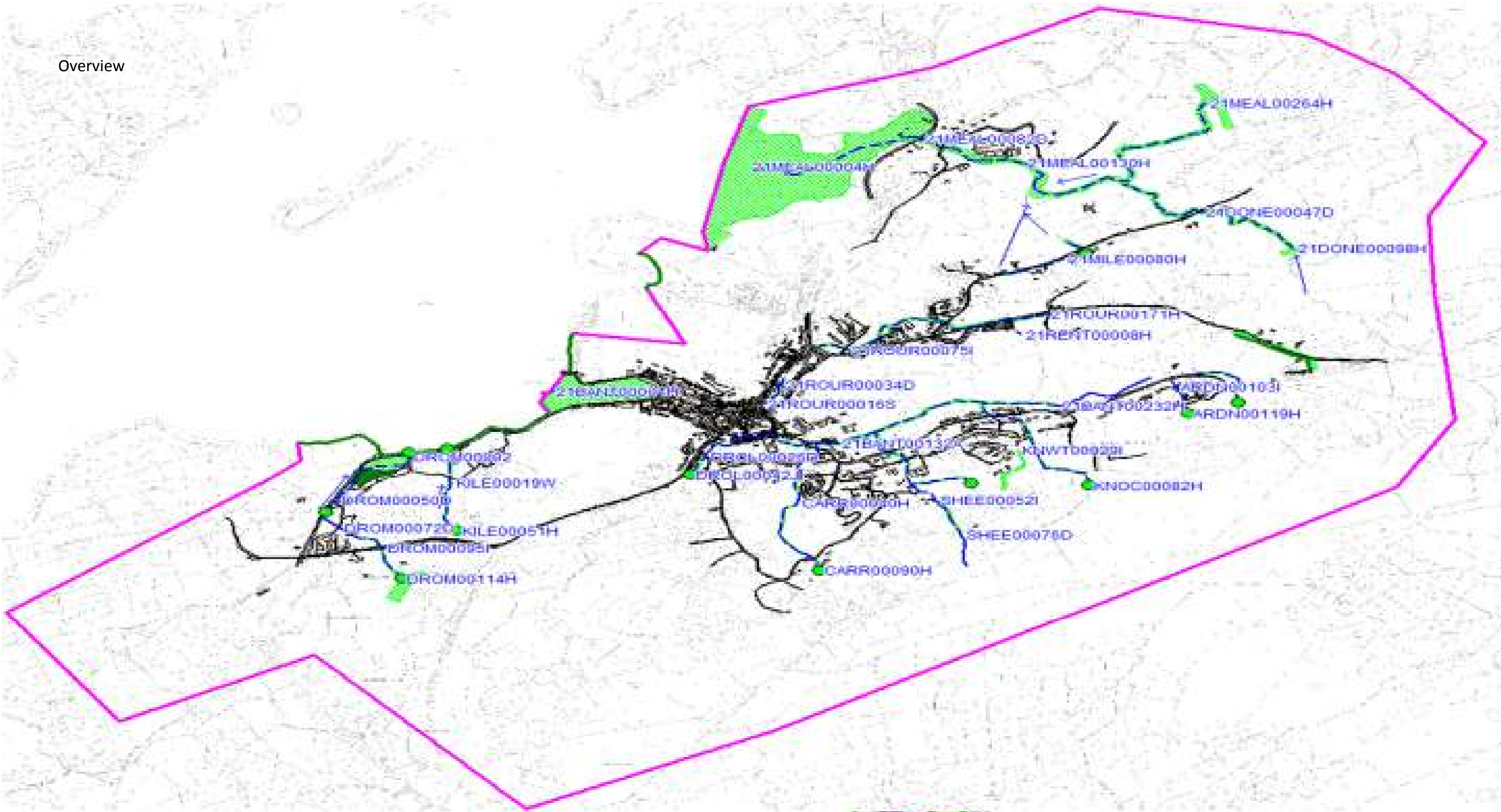
Input Data	
River Channel Topographic Data	River channel survey was undertaken by Murphy Surveys Limited as part of the CFRAM Study. 21RENT_Reenrour_V0.dwg (surveyed Sep 2012) - Minor tributary to Reenrour - nodes 21RENT00008I to 21RENT00008H. 21ROUR_Reenrour Trib_V0.dwg (surveyed Sep 2012) - Reenrour - nodes 21ROUR00000C to 21ROUR00171H 21BANT_Bantry_V1.dwg (surveyed Sep 2012) - Bantry - nodes 21BANT00001H to 21BANT00232H 21MILE_Milleencolla East_V1.dwg (surveyed Sep 2012) - Milleencolla East - nodes 21MILE00051I to 21MILE00080H 21RBEG_Raheen Beg_V1.dwg (surveyed Sep 2012) - Raheen Beg - nodes 21RBEG00029I to 21RBEG00074H 21DONE_Derryginagh_V1.dwg (surveyed Sep 2012) - Doneelagh Stream - nodes 21DONE00000H to 21DONE00098H 21MEAL_Mealagh River _V1.dwg (surveyed Apr 2013) - Mealagh - nodes 21MEAL00004H to 21MEAL00264H 21ARDN_Ardnageehy_V0.dwg (surveyed Sep 2012) - Ardnageehy - nodes ARDN00072H to ARDN00119H 21ARET_Ardnageehy East Trib_V0.dwg (surveyed Sep 2012) - Ardnageehy East Tributary - nodes ARET00002I to ARET00015H 21CARR_Carrignagat_V0.dwg (surveyed Sep 2012) - Carrignagat - nodes CARR00000H to CAR00083W 21DROL_Dromleigh_V0.dwg (surveyed Sep 2012) - Dromleigh - nodes DROL00000H to DROL00042J 21DROM_Dromacoosane_V0.dwg (surveyed Sep 2012) - Dromacoosane - nodes DROM00002 to DROM00114H 21KILE_Kilnarune_V0.dwg (surveyed Sep 2012) - Kilnaruane - nodes KILE00005I to KILE00051H 21KNOC_Knocknaveagh Area_V1.dwg (surveyed Sep 2012) - Knocknaveagh Area - nodes KNOC00000H to KNOC00082H 21MILW_Milleencolla West_V1.dwg (surveyed Sep 2012) - Milleencolla West - nodes MILW00029H to MILW00035H 21SHEE_Sheskin East_V0.dwg (surveyed Sep 2012) - Sheskin East - nodes SHEE00001H to SHEE00076D 21SHET_Sheskin East Trib_V1.dwg (surveyed Sep 2012) - Sheskin East Tributary - nodes SHET00008H to SHET00028H Alterations to survey for modelling purposes: 21ROUR00157H - In the absence of any survey data it was assumed that the culvert under the road at 21ROUR00157J would be of the same dimensions as the next culvert downstream at 21ROUR00126O. The head loss through the 21ROUR00126O culvert is 0.1m for the 0.1%AEP event. The Reenrour bed slope at the 21ROUR00126O culvert is much shallower than the bed slope at 21ROUR00157J and the head loss at 21ROUR00157J is expected to be smaller as a consequence. The 0.1% AEP event maximum water level at 21ROUR00157J is more than 0.2m below the bank top and it is therefore unlikely that the un-surveyed culvert would increase flood risk upstream of the road. 21ROUR00141H - Area called "Slip" on the right bank is very low and floods at low stage causing 1D2D instabilities at higher stage. Raised right bank levels downstream of 21ROUR00141H to reduce circulation. This allows flood water to inundate the floodplain correctly giving the correct flood extent. 21ROUR00114H - steep reach modelled using spill 21ROUR00016C - no surveying available for inlet to culvert (or junction with 21BANT). Assumed culvert dimensions to be similar to u/s Boy's Club Bridge Road Bridge. 21BANT00202H - Survey photographs show a concrete bridge with a very low soffit. Estimated deck level and flow opening area. Modelled using a vertical sluice to capture weir, orifice and over-deck flow. 21BANT00105W - added weir downstream of bridge to manage different bed level of downstream section 21BANT00091W to 21BANT00091H - very steep reach modelled by sharp crested weir. The surveyed chainage for this reach was added to the downstream section to maintain river length. 21BANT00091I - no surveying inside the culvert under Bantry. Assumed culvert shape doesn't change from the inlet shape until it is joined by the Reenrour culvert. Downstream of the Reenrour culvert joint, the Bantry culvert shape is enlarged to the same size as the surveyed outlet. 21MILE00063C - Culvert outlet section shape not surveyed - downstream section used at outlet, with bed levels adjusted to outlet invert 21DONE00032H, 21DONE00025H, 21DONE00015H, 21DONE00000H - a series of spills has been added to represent a very steep section ARDN00103I - The culvert at the downstream end of ARDN is not thoroughly surveyed, and the outlet was not identified. The culvert has been assumed to outfall on the far side of the road downstream of the ARDN reach. 21DROM00072W - Steep section modelled using weir instead of a steep channel upstream of Westlodge Hotel bridge. The surveyed chainage for this reach was added to the downstream section to maintain river length. 21KILE00019W - notched weir treated as flat crested because the survey did not pick up the notch and flat is more conservative. 21KNOC00008H - channel sections to the confluence with 21BANT have been estimated from the DTM.
Floodplain Topographic Data	Filtered LiDAR (Bantry2mdtm.asc) 2m grid resolution with +/- 0.2m RMSE captured in April 2012. All of the geometric survey data captured by the surveyor was reviewed with checks carried out on 10% of the cross sections. Levels from the river channel cross sections were checked against the Digital Terrain Model (DTM) as described in Section 2.3. The average difference between the levels of the surveyed cross sections and the DTM was found to be 0.184mm. The LiDAR was used for the majority of the area covered by the AFA. IFSAR was used to supplement the LiDAR over the areas covered by Kilnarune, Dromacoosane. The LiDAR and IFSAR levels were checked against surveyed levels and no adjustment was made for the final DTM.
Map data	OSI Raster and vector maps tiles 6624, 6624-C,D, 6625, 6654, 6654-05,10, 6654-A,B,D, 6655 6655-A were used to provide background map and material file data. The OSI mapping was found to include all current developments and was consistent with site observations, the river channel survey and aerial photography.

Model Build	
General Schematisation	A 1D/2D ISIS/TUFLOW approach was taken for Bantry to model flow along the main watercourses and head loss through hydraulic structures whilst enabling multidirectional flow across the urban and floodplain areas. The 1D model considers the Bantry and the Mealagh as the main watercourses. The design hydrographs were input using inflows connected to the upstream end of the watercourse, and as lateral inflows between confluences. The 2D model was extended upstream of the AFA region to capture floodplain flow that flows into the AFA, such as from the upstream end of the Sheskin, the Cappanaloha, and upstream of the Mealagh. The downstream boundaries of the model have been extended to include Bantry Harbour and the Mealagh estuary at Dunmark. The upper reaches of the Milleencolla East and Milleencolla West that are inside the AFA have been modelled in detail, with downstream boundaries leading into the 2D domain where it flows over the floodplain to join the Mealagh at 21MEAL00155H. The ditch to the west of Knocknaveagh Tributary has not been considered as the catchment area is less than 1km2 and the local engineers did not identify a watercourse in this area. The flow interactions between Ardnageehy and Ardnageehy East are modelled in 1D2D with downstream boundaries leading into the 2D domain. Overbank flow from Ardnageehy East flows out of the AFA into the Derryginagh and a 2D boundary has been placed across the floodplain to intercept the flow from the Ardnageehy East. This avoids duplication of hydrological inflows into the Derryginagh which has its own upstream direct inflow. The flow from the downstream boundaries of the Ardnageehy and Ardnageehy East flows out of the Mealagh catchment into the Bantry catchment along the Caherdaniel road. Hand calculations showed that the culverts on the Raheen Beg stream have capacity for flows up to the HEFS 0.1%AEP design event with very little surcharging . The channel is steep with a well defined v-shape. Any residual flow would stay close to the Raheen Beg channel. There is no risk of flooding to properties from the out-of-bank flows. The Raheen Beg was modelled in 1D only to provide flow routing to the confluence with the Mealagh. The 2D model grid size was set to 5m to represent the urban area without compromising model run time. River banks were enforced using the breaklines in the 2D domain based on survey spot levels. Buildings were raised above the floodplain by 0.15m to represent their threshold levels, and then a high Manning's 'n' value of 0.2 was also applied to represent the storage of the building. This approach means flood depths can be extracted at buildings for flood damage analysis.
Software Versions Used	ISIS version 6.6.0.81, TUFLOW 2012-05-AE-iDP-w64
Total No of 1D nodes	**344**
Open channel (H)	277
Bridges (D)	33
Culverts (I)	24
Weirs (W)	10

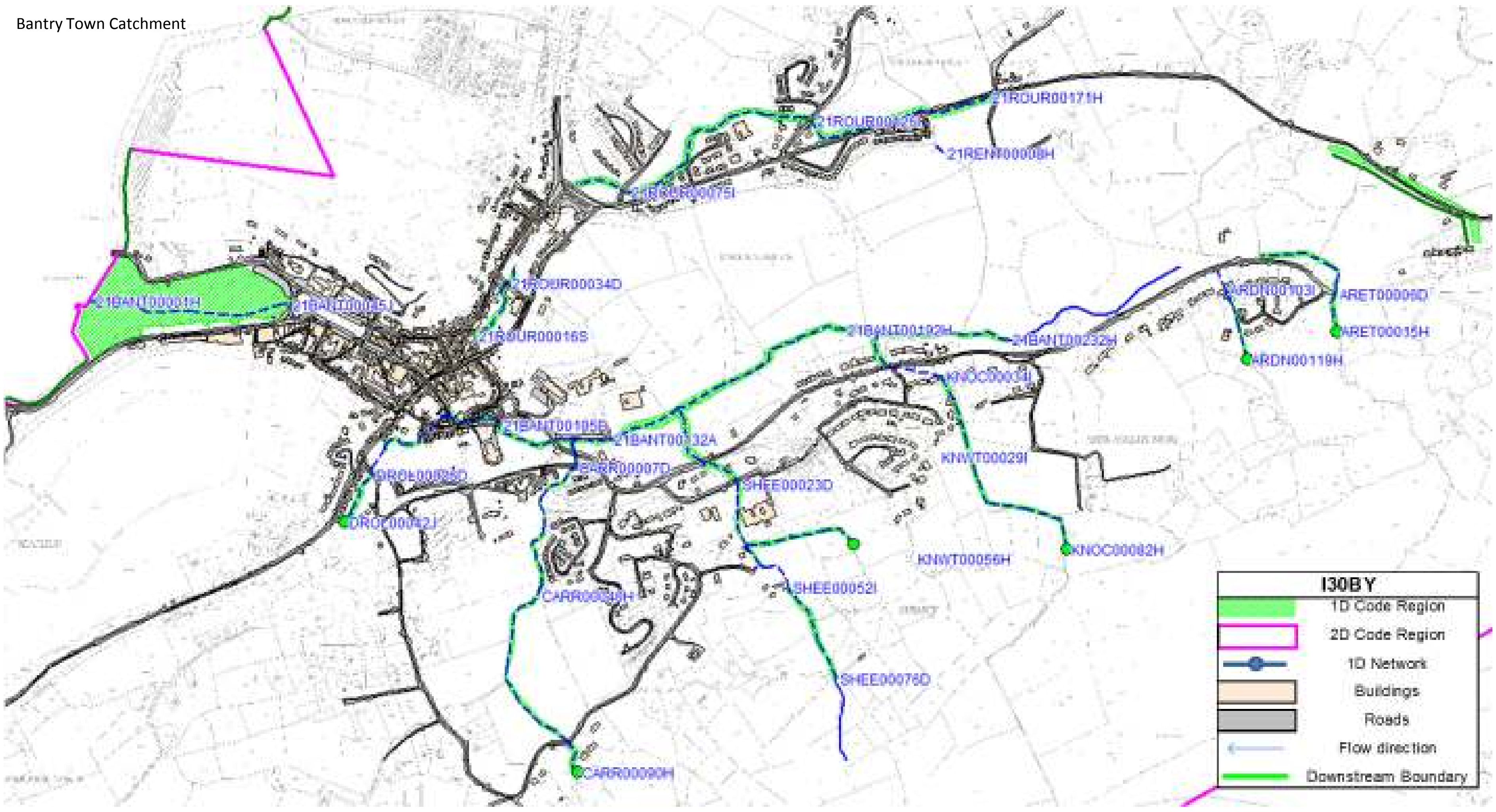
Model Extent	Reach/Feature	Upstream Limit (ING)	Downstream Limit (ING)
	Reenrour	100900, 048870	100860, 048970
	Reenrour Trib	100860, 048970	099600, 048420
	Bantry	101050, 048450	098960, 048540
	Milleencolla East	101080, 049330	100830, 049270
	Raheen Beg	101950, 049820	101350, 049860
	Derryginagh	102030, 049390	101270, 049820
	Mealagh River	101660, 050270	099760, 049880
	Ardnageehy	101600, 048400	101540, 048610
	Ardnageehy East	101810, 048470	101620, 048640
	Carrignagat	100080, 047480	100040, 048230
	Dromleigh	099540, 048040	099780, 048290
	Dromacoosane	098360, 047420	098380, 048170
	Kilnarune	098580, 047700	098530, 048190
	Knocknaveagh	101190, 047980	100730, 048470
	Milleencolla West	101170, 049370	101080, 049460
	Sheskin East	100680, 047500	100300, 048290
	Sheskin East Trib	100700, 047990	100440, 047990

Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Bantry Stream and urban reaches	0.04	0.06 as these are urban stone walls	N/A	Schedule 1: Photographs
	Reenrour and rural reaches	0.045	0.08	N/A	Schedule 1: Photographs
	Open pasture	N/A	N/A	0.06	Schedule 1: Photographs
	Dense vegetation	N/A	N/A	None	Schedule 1: Photographs
	Buildings	N/A	N/A	0.2	Schedule 1: Photographs

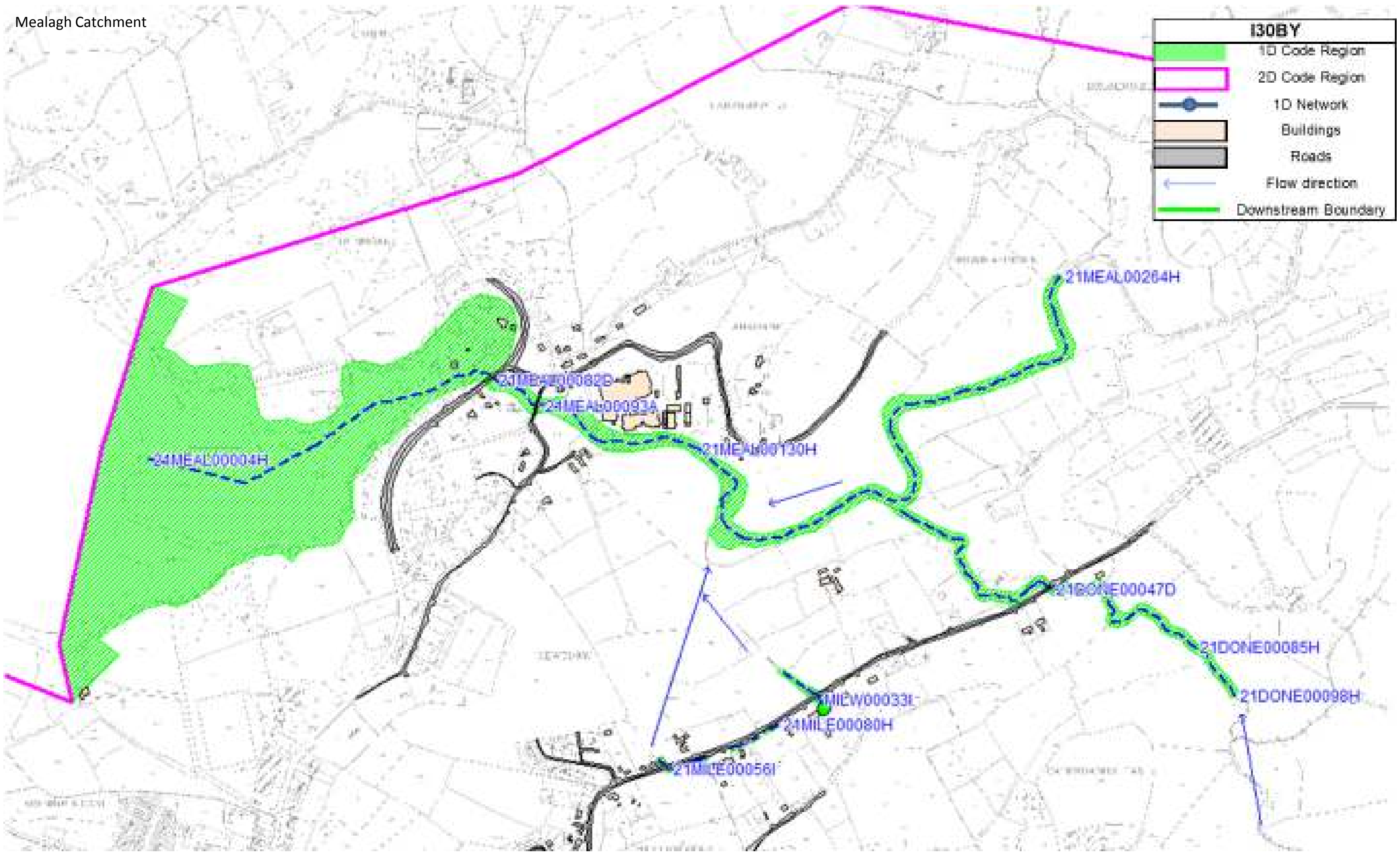
	Roads	N/A	N/A	0.033	Schedule 1: Photographs
	Concrete culvert	0.015	N/A	N/A	
	Masonry culvert	0.035	N/A	N/A	
Structures	See Schedule 2 for Hydraulic Structure Parameters				
Upstream boundary	All direct inflows have been applied at the upstream end of the surveyed extent and are located where water is constrained to a narrow valley and is upstream of the AFA where flooding would occur before the reach enters the AFA.				
Lateral inflows	Direct inflow to the numerous tributaries have been modelled in preference to lateral inflows due to the topographical nature of the catchment.				
Downstream boundary	The downstream boundaries of the Bantry, Mealagh, Dromacoosane and Kilnarune are located at Bantry Harbour, the Mealagh estuary and the coastline near Bantry House respectively. The design tidal conditions were applied directly to the 1D nodes. The design tidal conditions and wave overtopping 2D downstream boundary was located along the quayside/coastline between Mealagh estuary and Bantry House . The tide plus total surge levels were applied as level-time(HT) boundary. The wave overtopping discharges were applied as a discharge-time (QT) on the landward side of the coastline crest and a separate HT boundary with the associated tidal plus surge levels located in the seaward cell to enable excess wave discharge to flow back out of sea when water level on the floodplain was above defence crest. 1D channels that terminate in the 2D domain such as Milleencolla West are connected to the 2D domain by an SX line. The culvert at node 21MILE00051I on the Milleencolla East stream is the flow control for the stream. The downstream boundary to Milleencolla East has been defined as an flow-level (QH) boundary to reproduce the flow-level relationship associated with the culvert at 21MILE00051I. The peak flow in Milleencolla East is very small compared to the floodplain flow from the Mealagh and it has not been injected into the 2D domain following the culvert at 21MILE00051I. The 2D flow-level (HQ) boundary that captures the out-of-bank flow from the Ardnageehy East tributary has been attributed a 1 in 125 normal depth gradient to represent flow towards the Raheen Beg.				
Run Settings	Unsteady simulation of the full 25 hour hydrograph. The 1D timestep has been set to 1s. The 2D timestep has been set to 2s. The 1D timestep divides into the 2D timestep, and the 2D timestep is less than half the grid cell size as recommended. The following minimum flows have been used to represent baseflow conditions and ensure stability over the steep gradients: 0.5m³/s - Reenrour 0.4m³/s - Reenrour Trib 1.6m³/s - Bantry 0.1m³/s - Milleencolla East 0.3m³/s - Raheen Beg 1.0m³/s - Derryginagh 10m³/s - Mealagh These minimum flows account for less than 15% of the channel capacity and are representative of baseflow conditions therefore, the minimum flows do not reduce the volume available to store flood waters. The orifice linearization run parameter was set to 0.1m to stabilise and improve the transition to orifice mode at the steep culverts. All other run parameters were set to default.				
Model Geoschematics					



Bantry Town Catchment



Mealagh Catchment



SCHEDULE 1 : PHOTOGRAPHS

Photo 1: Bantry Active Channel

ING 100050, 048230 - captured on 19/10/2012

Photo 5: Bantry Vegetated Floodplain

Photo 2: Mealagh Active Channel

ING 100700, 049920 - captured on 28/02/2013

Photo 3: Dromacoosane Active Channel

ING 098250, 047640 - captured on 02/10/2012

Photo 4: Reenrour Active Channel

ING 099900, 048570 - captured on 25/09/2012

SCHEDULE 2: Structures

Data file P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I30BY_Bantry\DESIGN\model\ISIS\DAT\I30BY_ISIS_base_001_409.dat

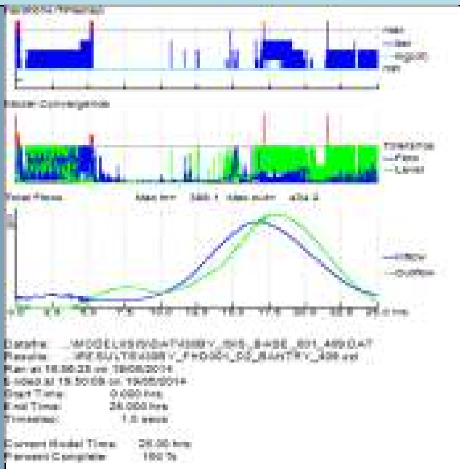
Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters													Comments/ Justification
				Soffit Elevation	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation	Breadth	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation	Modular Limit	Weir Coeff.	Soffit level (mAOD)	No of Openings	Invert u/s (mAOD)	Invert d/s (mAOD)	Area (m²)	Nominal Width (m)	Length (m)	K	Ki	M	Trash Screen	Trash Screen coefficient	Flapped	
21RENT00008I	100870	048970	Concrete pipe ORIFICE												37.28	1	36.68	36.68	0.283	0.60					NO		NO	Short culvert (<20m) modelled as orifice for stability. Outlet not surveyed.
21ROUR00157H	100880	048970	Open channel																									The channel does not cross under the road. It remains on the north side for the entire upstream reach. Therefore no structure was modelled.
21ROUR00126O	100610	048960	2 x 0.6m plastic pipes ORIFICE									23.46	0.9	1	21.547	2	20.947	20.947	0.565	0.60					NO		NO	2 x 0.6m diam pipes under road bridge. Short culvert modelled as an orifice. Spill represents a brick parapet.
21ROUR00075O	100170	048790	Single 0.9m diam concrete pipe under road ORIFICE									14.56	0.9	1	10.59	1	9.69	9.69	0.636	0.90					NO		NO	Single 0.9m diam concrete pipe under road
ROUR00062C01	100060	048800	Arched culvert under Glengarriff Road CONDUIT SPRUNG												10.55	1	8.8	6.45	3.2	2.13	244	0.9 * Bernoulli Loss	0.5		NO		NO	Arched culvert under Glengarriff Road - estimated invert level and assumed relatively straight with no manhole losses. The culvert has a circular pipe inlet which has been modelled as extending under the road before changing to a sprung arch as surveyed at downstream end. A Bernoulli loss has been used to model during weir, orifice and pipe flow modes at the culvert inlet due to stability problems with the standard culvert inlet unit.
21ROUR00034D	099910	048580	Concrete flat soffit road bridge ARCH BRIDGE	7.85	1	0	1																					Boy's Club Road Bridge - u/s and d/s ~0.1m diam pipe crossings at 7.6mAOD not included. Spill modelled in 2D.
21ROUR00016C	099860	048480	Culvert CONDUIT SPRUNG												5.425	1	3.675	0.41	1.37	0.75	200	1* Orifice	0.5	0.439	NO		NO	No surveying available for inlet to culvert. Modelled with dimensions similar to u/s Boy's Club Bridge Road Bridge.Orifice unit used to stabilise steep bed into culvert and transition from backwater to orifice mode.
21BANT00198D	100710	048480	Concrete bridge SLUICE	36.55	1	0	1	37.55	6.3	0.7	1	37.45	0.9	0.7														Surveying photo showed concrete bridge with very low soffit - estimated deck depth and flow opening area.
21BANT00132D	100140	048220	Masonry arch bridge ARCH BRIDGE	20.1	1	0	1					21.71	0.9	1														Temporary trash screen noted by surveyors not modelled.
21BANT00124D	100050	048220	Concrete bridge with flat soffit ARCH BRIDGE	18.67	1	0	1					18.92	0.9	1.1														Concrete bridge with flat soffit - no trash screen. Spill for bridge deck. Railing not modelled. Arched bridge applied despite a flat soffit because the water is likely to come into contact with the soffit and the arched bridge approach offers greater stability at the soffit with the steep gradients of the river channel.
21BANT00120D	100020	048230	Masonry arch bridge with flat concrete soffit ARCH BRIDGE	18.11	1	0	1																					Arched sides represented as vertical sides - soffit flat as surveyed. Deck spill in 2D.
21BANT00105D	099890	048270	Arched bridge with flat soffit BERNOULLI LOSS	15.28	1	0	1																					Chapel Street Bridge - arched bridge with flat soffit. Modelled as a Bernoulli Loss
21BANT00092D	099790	048270	Concrete footbridge with flat soffit	9.141	1	0	1																					Library Bridge - gate depth represents bridge deck.
21BANT00092W	099780	048270	Weir SHARP CRESTED WEIR					8.53	6.932		1																	Weir to represent weir crest and steep slope on downstream side to culvert inlet
BANT00091C01	099780	048290	Rectangular Culvert RECTANGULAR CULVERT												3.17	1	2.17	0.41	7	7.21	255	0.469	0.5	0.696	NO		NO	Library culvert with change in section after 225m from rectangular to sprung. Culvert survey not undertaken. Dimensions and invert level at change in section shape estimated from inlet and outlet dimensions. The sprung culvert unit was applied with the inlet and outlet dimensions to improve model stability as the backwater hit the soffit under tide-locked conditions.
BANT00067J	099780	048290	Rectangular culvert SPRUNG CULVERT												3.07	1	0.41	-1.39	14.4	6.54	200				NO		NO	Sprung arch with Manning's n weighted equivalent wetted perimeter to match rectangular culvert in survey. Sprung arch used to stabilise high tide levels.
21MILE00075C	101040	049320	Concrete pipe CIRCULAR CULVERT												29.64	1	29.34	29.44	0.07	0.30	4.3	0.0045	0.3	2	NO		NO	Culvert outlet invert set to surveyed upstream level but downstream bed level is above the inlet invert limiting flow.
21MILE00051I	100850	049260	Concrete pipe												24.48	1	23.88	19.11	0.28	0.60	62				NO		NO	QH to represent culvert capacity based on CIRIA culvert design calculations to improve stability for this small culvert once overtopped.
21RBEG00061D	101840	049730	Rectangular masonry culvert ORIFICE	47.15	1	45	1					47.53	0.9	1														Steep culvert modelled as inlet controlled
21RBEG00040H	101640	049760	Steep channel SPILL									38.177	0.9	1.5														Steep channel modelled as a spill for stability. The spill represents the drop along the reach at the upstream end. The surveyed chainage was added to the downstream open channel section to maintain river length.
21RBEG00029I	101580	049810	Concrete pipe ORIFICE												34.94	1	34.34	33.989	0.28	0.60	10.3				NO		NO	10m pipe with 1 in 30 slope. D/S very steep so modelled culvert as an orifice unit. The orifice calculates the inlet and outlet controlled modes based on the default orifice equations in ISIS.
21DONE00065H	101780	049570	Steep channel SPILL									43.37	0.9	1.5														Spill to represent rough river bed and natural rifts
21DONE00047D	101640	049610	Masonry bridge with four openings. Flat soffits. ARCH BRIDGE	41	4	0	1																					Bridge with four rectangular openings. Deck spill in 2D.
21DONE00032H, 21DONE00025H, 21DONE00015H, 21DONE00000H	101540 to 101270	049590 to '049810	Steep channel SPILL										0.9	1.5														Spill to represent rough river bed and natural rifts
21MEAL00079H	100450	050060										7.553	0.9	1.5														Spill to represent waterfall down to tidal reach
ARDN00106I	101566	48520	Culvert/Pipe CULVERT												89.68	1	89.03	87.44	1.33	0.65	20.12	1	0.5		NO		NO	Pipe culvert surveyed. Standard ESTRY circular culvert used to simulate entry and exit losses as well as pipe flow.
ARD00104I	101557	48537	Culvert/Pipe CULVERT												87.42	2	87.67	84.84	0.28	0.30	23.02	1	0.5		NO		NO	Two pipes under access road to property which outfall over a grate and into culverts downstream. The grate is sufficiently sized that all flow from this culverts enters the pit below based do site visits and design flow analysis.
ARDN00103I	101545	48536	Culvert/Pipe CULVERT												84.4	2	84.05	80.1	0.05	0.25	50		0.5		NO		NO	The outlet of the culvert at the downstream end of Ardnageehy was not identified in the survey. The culvert has been assumed to outfall on the far side of the road downstream of the Ardnageehy reach.
21CARR00018W	099980	048080	Aqueduct WEIR					39.32	1.5		1																	An aqueduct over the old railway/narrow valley has been modelled as an open channel to represent the aqueduct capacity and a weir at the end which drops the water level over a distance of the 10m to the channel at the other end.
DROL00026D	099600	048150	Rectangular Bridge ESTRY BRIDGE	21.56	1	35	1																					Highly skewed bridge losses calculated TUFLOW's US Highways equations loss table and adjusted to account for the significant skew.
DROL00025I	099600	048160	Concrete Pipe												17.08	1	16.33	14.5	0.64	0.9	54		0.5		NO		NO	Vertical pipe at outlet not modelled.
21DROL00014E	099670	048220	Footbridge (not modelled)																									Insubstantial footbridge not modelled.
21DROM00072W	098100	047720	Steep channel WEIR					18.71	3.2																			Steep section modelled using weir instead of a steep channel upstream of Westlodge Hotel bridge
21KILE00000J	098530	048190	Rectangular masonry leading to circular concrete culvert												3.89	1	3.04	-0.25	u/s = 0.422 d/s = 0.64	u/s = 0.56 d/s = 0.9	52	1	0.5		NO		NO	Survey does not indicate that the culvert is flapped.
21KNOC00024I	100790	048390	Culvert												49.11	1	48.01	45.06	0.95	1.1	34	2	0.5		NO		NO	

B.2 Model Performance Proforma

Bantry Model Performance

1D Convergence

Convergence Plot
1% AEP Fluvial Event

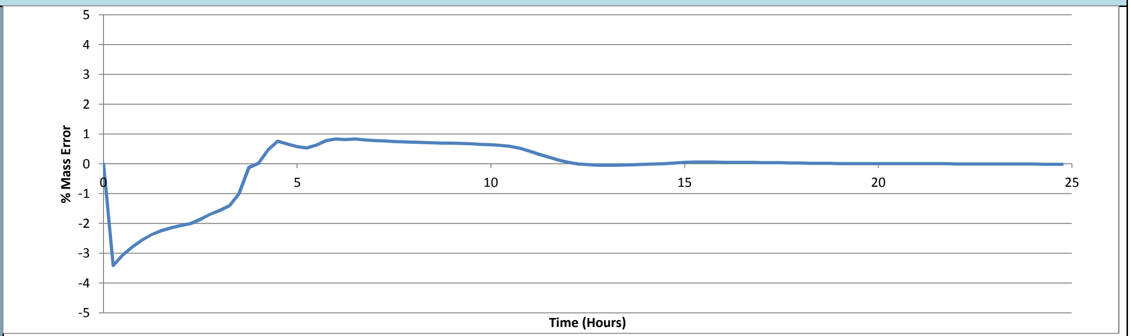


Comments

The 1D model components were convergent and within the recommended tolerances for the majority of the event. The higher number of iterations used at the start and end of the event are to accommodate the low flow in the channel and flow through the steep culverts.
The orifice linearization and the modular limit of the downstream ROUR culvert has been adjusted to minimise the issues as the structure switches between backwater control and orifice modes but there remains a short period of poor convergence at 17 and 21 hours. However this does not affect the peak water level and flow.

2D Convergence

Mass Balance Plot
1%AEP Fluvial Event



Comments

The final cumulative mass balance error was 0.1% of 72877m^3. The 2D model remains within the recommended tolerance of ±1% mass error by 4 hours (> 10 hours before the peak).

The period of higher percentage mass error between 0 and 4 hours is due to rapid flow at Slip (on the right bank of the Reenrour), at the 2D modelled downstream extents of the Cappanaloha, Milleencolla West and Ardnageehy. A negative mass balance means that there is less volume in the model than expected from the volume entering and leaving the 2D domain so depth could be under predicted at the initial wetting of cells as the 2D cells are rapidly wetting and the flow through the model is relatively small such as at the start of flooding.

The negative percentage mass error is exaggerated because there are very few active 2D cells during the first 10 hours however, as flooding increases the mass error reduces to -0.02% by 12 hours (before the peak). Therefore, the mass balance of volume entering and leaving the model is accurate within recommended tolerances at the peak and flood depth, velocity and extent can be deemed to be reliable.

Hydrological Performance

Target Flows

			10% AEP m^3/s			1%AEP m^3/s			0.1%AEP m^3/s		
HEP ID	Location	Model Node	Design	Modelled	% Difference	Design	Modelled	% Difference	Design	Modelled	% Difference
21_7060_2	Bantry d/s Knocknaveagh	21BANT00202H	3.4	3.6	6%	4.7	5.7	21%	6	8.4	39%
21_7249_2	Bantry d/s Sheskin	21BANT00141H	5.1	4.9	-3%	7.1	6.7	-5%	9.1	10.1	11%
21_7092_1	Bantry d/s Carrignagat	21BANT00118H	5.8	6.4	11%	8.1	8.7	7%	10.4	12.9	24%
21_7096_1	Bantry d/s Dromleigh	21BANT00091I	6.9	7.2	4%	9.6	9.7	1%	12.3	14.0	14%
21_7225_2	Bantry d/s	21BANT0045J	9.4	8.4	-11%	13.2	11.4	-14%	16.9	16.2	-4%
21_7668_2	Dromacoosane d/s Cappanaloha	DROM00063D	3.8	4.0	5%	4.9	4.8	-2%	7.3	7.1	-3%
21_6183_1	Mealagh d/s Raheen Beg	21MEAL00195H	124.3	117.7	-5%	181.3	173.2	-4%	266.3	252.9	-5%
21_6412_1	Mealagh d/s Derryginagh	21MEAL00175H	131.6	138.0	5%	191.9	198.2	3%	282.0	287.4	2%
21_6258_3	Mealagh d/s	21MEAL00094H	133.3	128.0	-4%	194.5	202.6	4%	285.7	279.9	-2%

Comments

The flows in the 1D ISIS and ESTRY channels were combined with the 2D flow parallel to the channel where there was out-of-bank flows.

Flows along Bantry Stream are greater than the design flows because up to 1m3/s of the Ardnaheehy flows cross the watershed into the Bantry catchment. The watershed between Bantry and Ardnageehy is a flat bog like area so it possible for water to cross the watershed as reported by the river channel survey.
The modelled flows at the outfall of Bantry Stream are less than the design flows due backwater from the tidal influence (highlighted in yellow). The design hydrology does not consider backwater.

Flows along the Mealagh, are typically within +/-5% of the design flows. The variation along the Mealagh is due some inherent uncertainty in the momentum of flow when transferring from ISIS to TUFLOW over the river banks and back again in this meander channel. This is a feature of the software link but the small variation flow does not affect flood risk as levels and extent matches with the flood evidence from the local engineers.

Flows along the Dromacoosane upstream of the tidal influence match well with the design flows.

Calibration Event 1

Model Run ID: I30BY_CCC20121017_D1

Period Modelled: 16/11/2012 14:00 to 17/11/2012 15:00 with the peak at 17/11/2012 07:00

Hydraulic Modification to Design Model: No hydraulic modifications were made to the design model.

Hydrological inflows: The flooding in Bantry in the November 2012 event was due to high tide levels. The calibration model was configured with inflows that were less than or equal to the QMED inflows to simulate relatively low water levels in the river channels.

Calibration Plot: See Schedule 3 - Calibration and Sensitivity

Comments: The tidal flooding during the November 2012 event mainly affected the Bantry harbour, with less impact on the Mealagh harbour and at the downstream of the Dromacoosane. Tidal flood water flowed through low points in the harbour wall and affected properties along the side of the roads in Bantry town square.

The modelled flood outline was compared with an outline that was recorded during a site visit following the event. Both the south and north side of the town square are shown as flooding, and the east-west extent agrees well on the south side while slightly exaggerating the extent on the north side. Flood depths are slightly higher in the model results than were recorded following the event. However, the differences in flood depth are small and are less than 0.15m everywhere except in front of the Bantry Bay Hotel where the difference is approximately 0.25m.

Sensitivity Test 1: Increased Flow

Model Run ID: I30BY_FHD010_D2

Hydraulic Modification to Design Model: No hydraulic modifications were made to the design model.

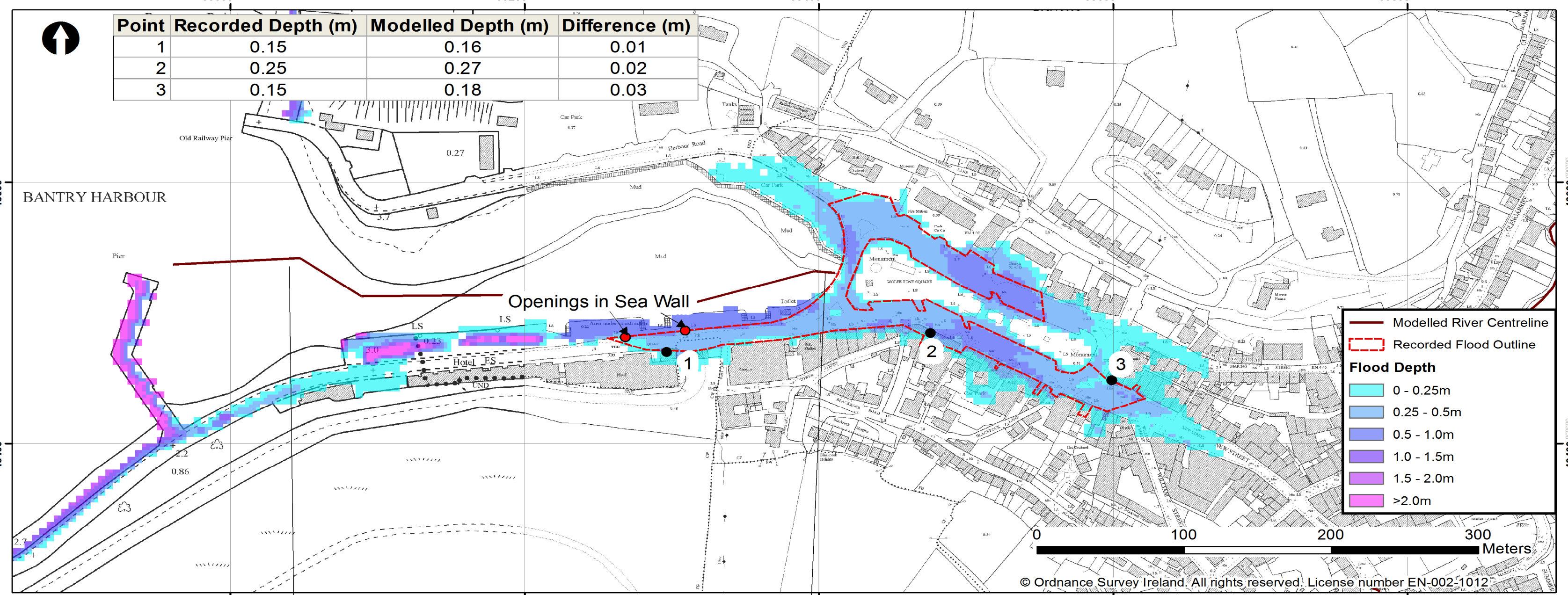
Hydrological inflows: All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED, the pooling group and the pivotal site selected.
This is broadly equivalent to the HEFS 1%AEP as the increase in urban extent has less the 1% impact on peak flow. Therefore, the HEFS 1%AEP results (FHD010) have been used as the sensitivity test results.

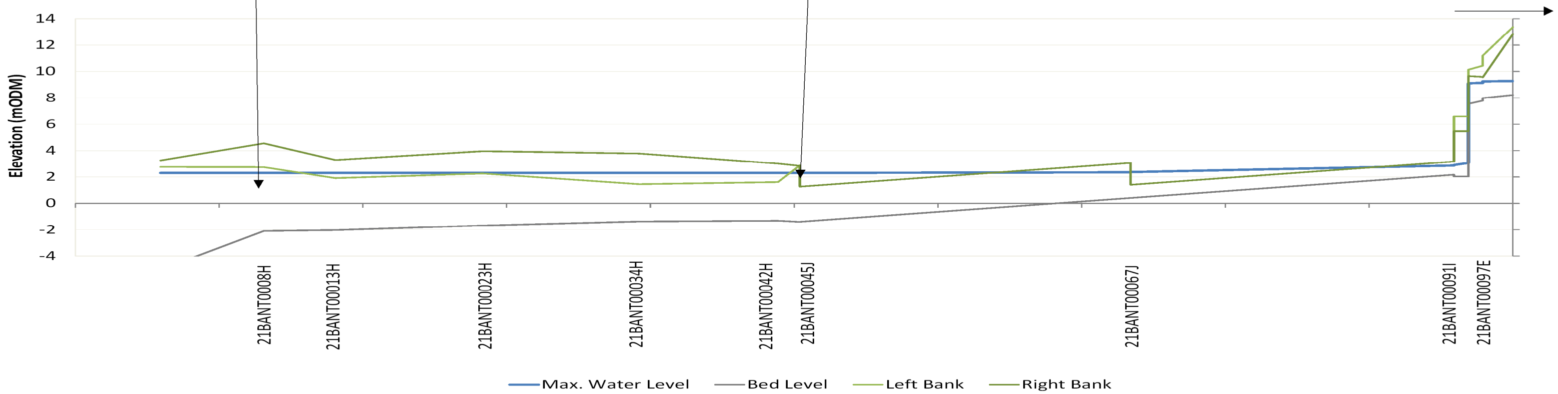
Sensitivity Plot: See Schedule 3 - Calibration and Sensitivity

Comments	A 30% increase in flows resulted in a significant increase in the flood extents with the largest increases in flood risk occurring in Bantry town between the Sheskin and the Carrignagat and greater out of bank flow upstream of the Library to flood Wolfetone Square. The flood extent did not increase significantly along the Mealagh due to the well-defined floodplain. However, flood depth and hazard increased with the increase in flow. The increase in extent at 100200,050000 is relate to the sea level rise applied in future HEFS scenario. However this does not affect flood risk upstream of the 10m high waterfall. Therefore flood risk in the centre Bantry was found to be sensitive to the uncertainties in flow. The design flows are based on gauged flow on the Mealagh and the design flows reproduced the relative frequency of flooding on the ungauged catchments to have confidence in the design flow estimates. An allowance should be made when interpreting the design flood outlines and the in the sizing of any flood risk management option due to this uncertainty in flood level and extent caused by the uncertainties in flow.
Sensitivity Test 2: Increased Downstream Level	
Model Run ID	I30BY_CMD010_D2
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	A 0.5m increase in water level was applied to the downstream boundary. This is broadly equivalent to the MRFS which increases sea level by 0.55m. Therefore, the MRFS 1%AEP results (CMD010) have been used to conduct the sensitivity test.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A 0.5m increase in level resulted in greater flooding in and around Wolfetone Square. The increase in flood extent elsewhere is smaller and restricted to a slight increase in flood risk along the N71 adjacent to Bantry House. However, flood depth and hazard increased with the increase in downstream water level. Therefore flood risk at Bantry was deemed to be sensitive to the uncertainties in tidal level at the 0.5%AEP. The design tidal levels were defined by the previous ICPSS (2011) levels which were informed by the nearby tidal gauge at Castletown Bearhaven and transformed up the Bay using a calibrated model in agreement with OPW.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I30BY_FCSN01_D2
Hydraulic Modification to Design Model	The Manning's 'n' values were increased to the upper limit of the industry recommended ranges. All active channels 0.040 to 0.050 All river banks 0.060 to 0.080 Pasture / parkland / garden 0.060 to 0.080 Buildings 0.200 to 0.300 Roads 0.033 to 0.040
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in roughness values in bank and out-of-bank resulted in increased flood extents along the Ardnageehy tributary and greater out-of-bank flow along the Reenrour tributary to increase flooding in Wolfetone Square. However, the additional flooding is typically shallow (< 0.1m deep). The increases in flooding extent are generally accompanied by a reduction in flow velocities and a consequent reduction in flood hazard, except in areas a deep (>1m) flooding. Flood risk along the Dromacoosane and Mealagh catchment was deemed to be insensitive to the uncertainties in vegetative and land use roughness. Therefore the design Manning's 'n' values were selected for the final model. The flood risk along Bantry Stream was more sensitive to the uncertainties in the Manning's 'n' values used to represent vegetation and land use roughness. An allowance should be made when interpreting the design flood outlines and the in the maintenance of any flood risk management option due to this uncertainty in Manning's 'n' values selected. The design Manning's 'n' values were applied as a best estimate for the Bantry catchment as they best reproduced the frequency of flooding as reported by the local engineers.

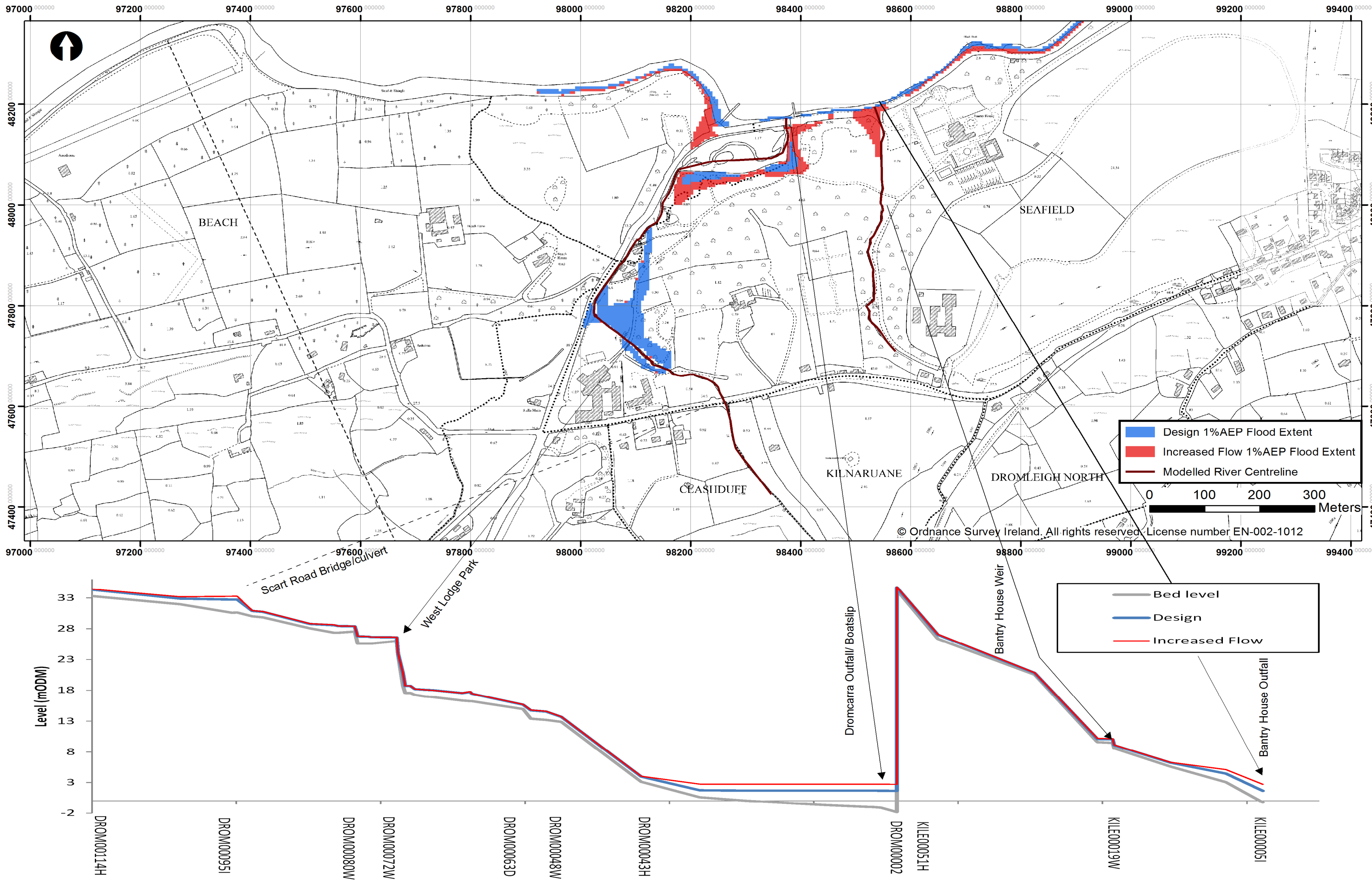
Map B.1: Calibration to 17th October 2012 Coastal Flood Event

Point	Recorded Depth (m)	Modelled Depth (m)	Difference (m)
1	0.15	0.16	0.01
2	0.25	0.27	0.02
3	0.15	0.18	0.03

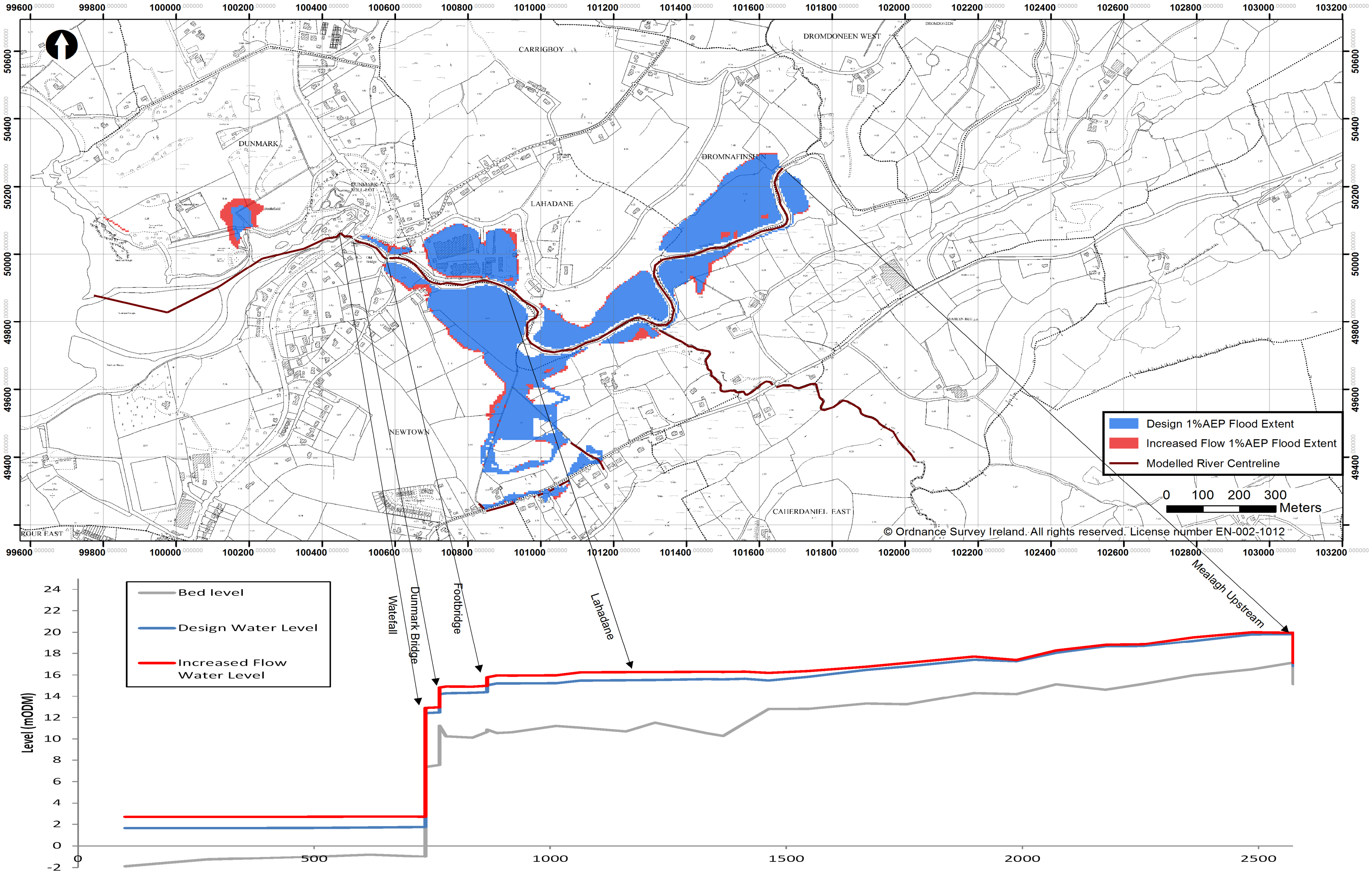




Map B.2: Sensitivity to 30% Increased Flow in the Dromacoosane Catchment



Map B.3: Sensitivity to 30% Increased Flow in the Mealagh Catchment



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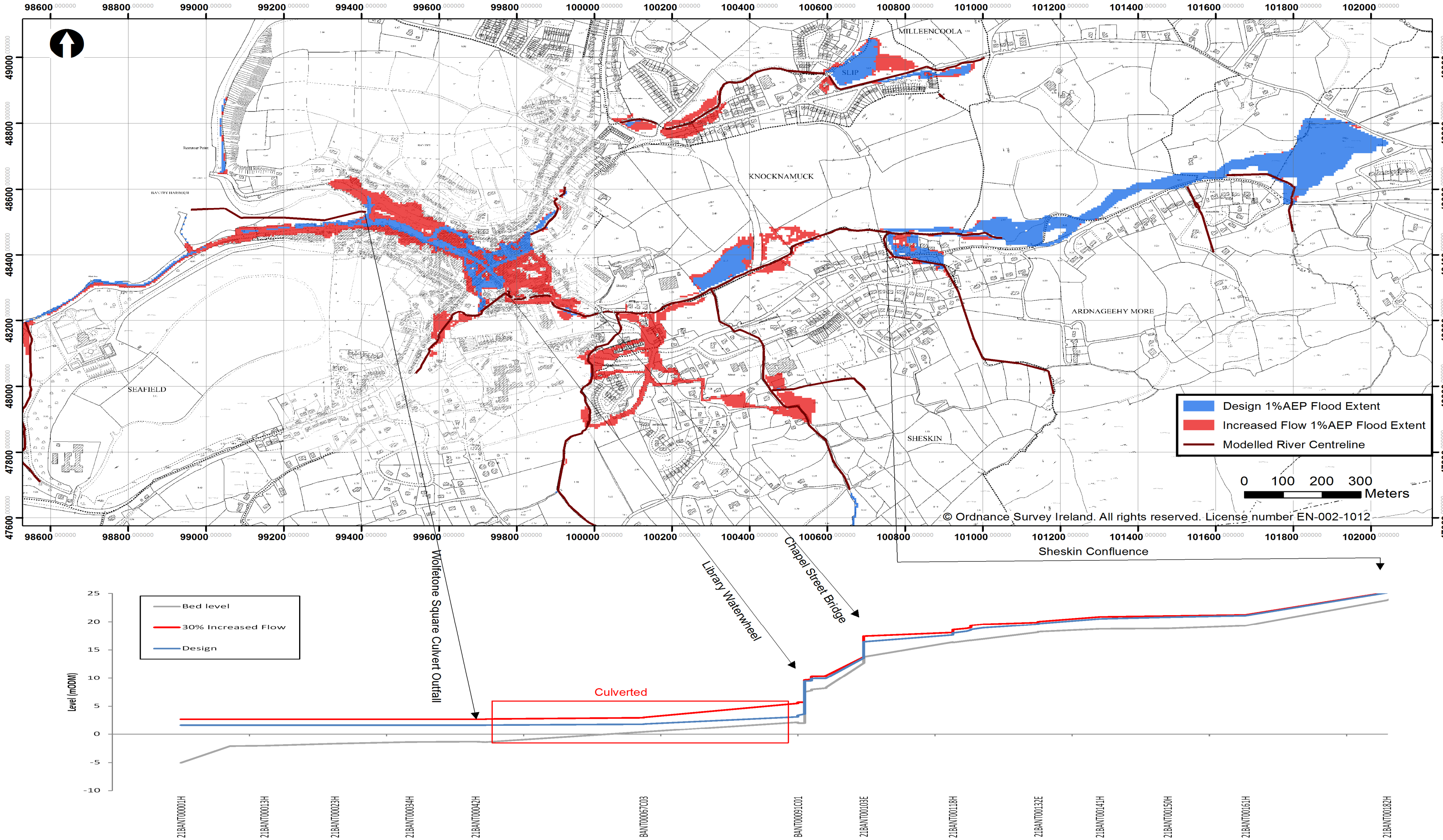
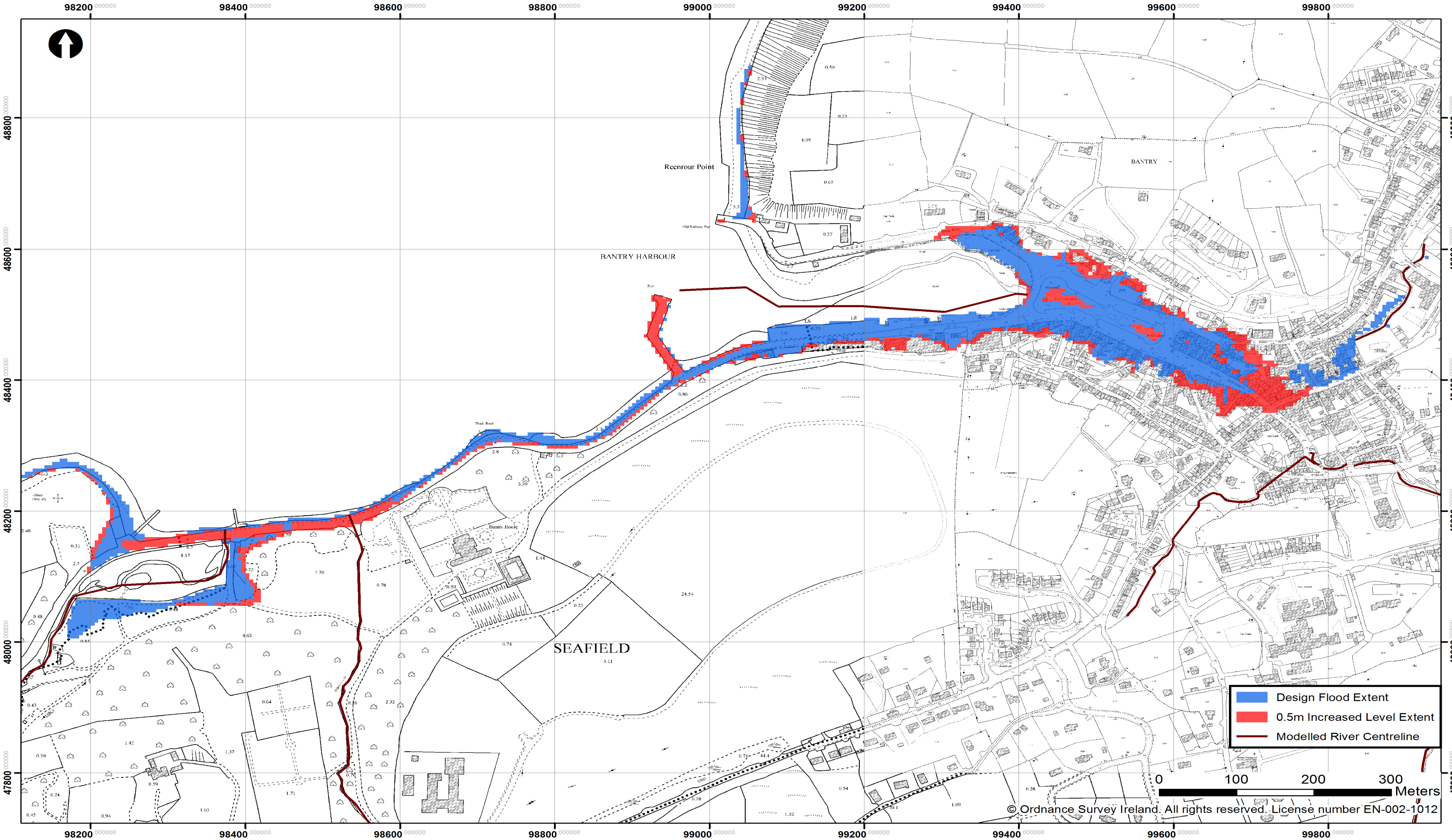
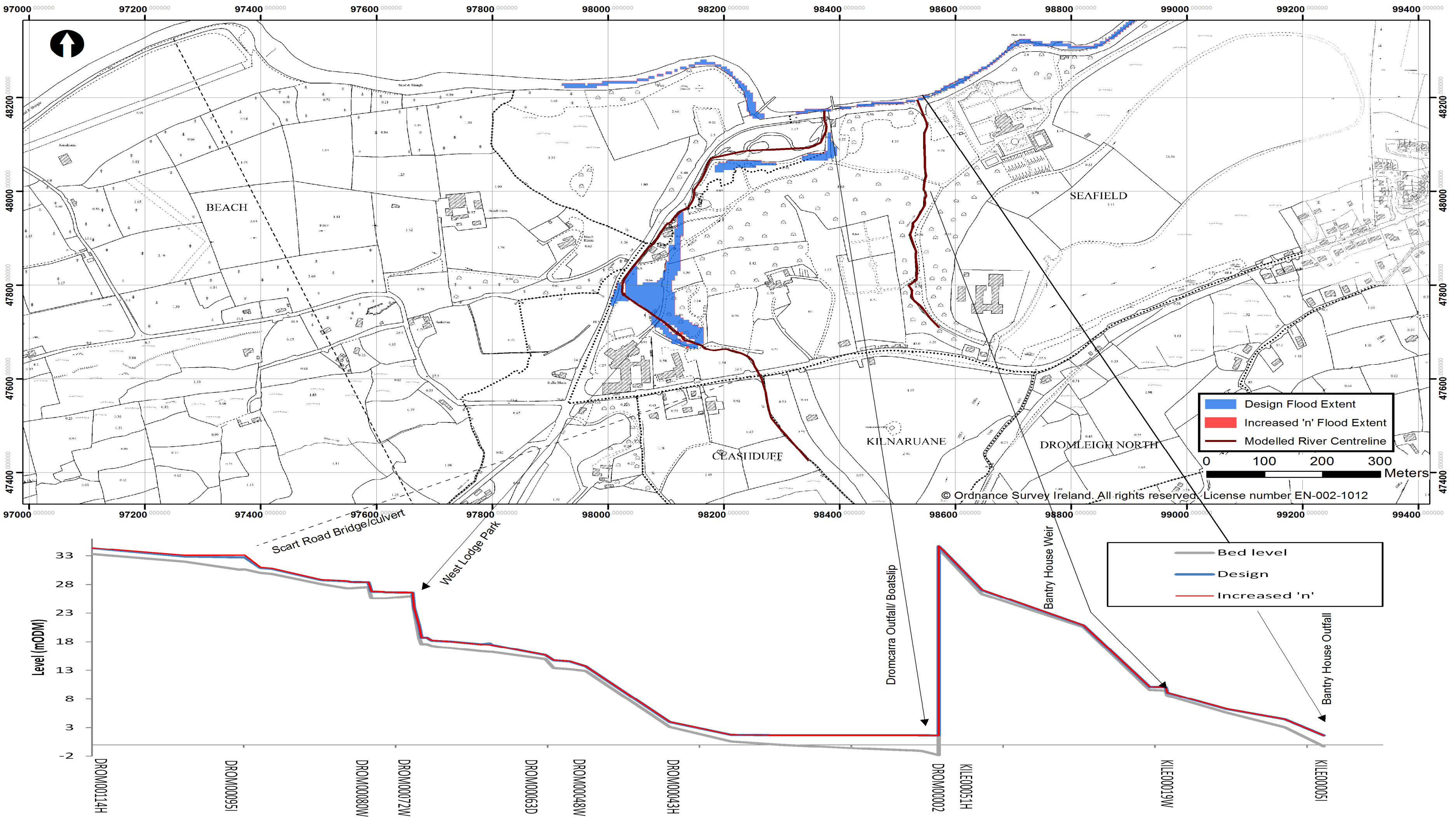
Map B.4: Sensitivity to 30% Increased Flow in the Bantry Town Catchment



Map B.5: Sensitivity to Increased Downstream Boundary in Bantry



Map B.6: Sensitivity to Increased Manning's 'n' in the Dromacoosane Catchment



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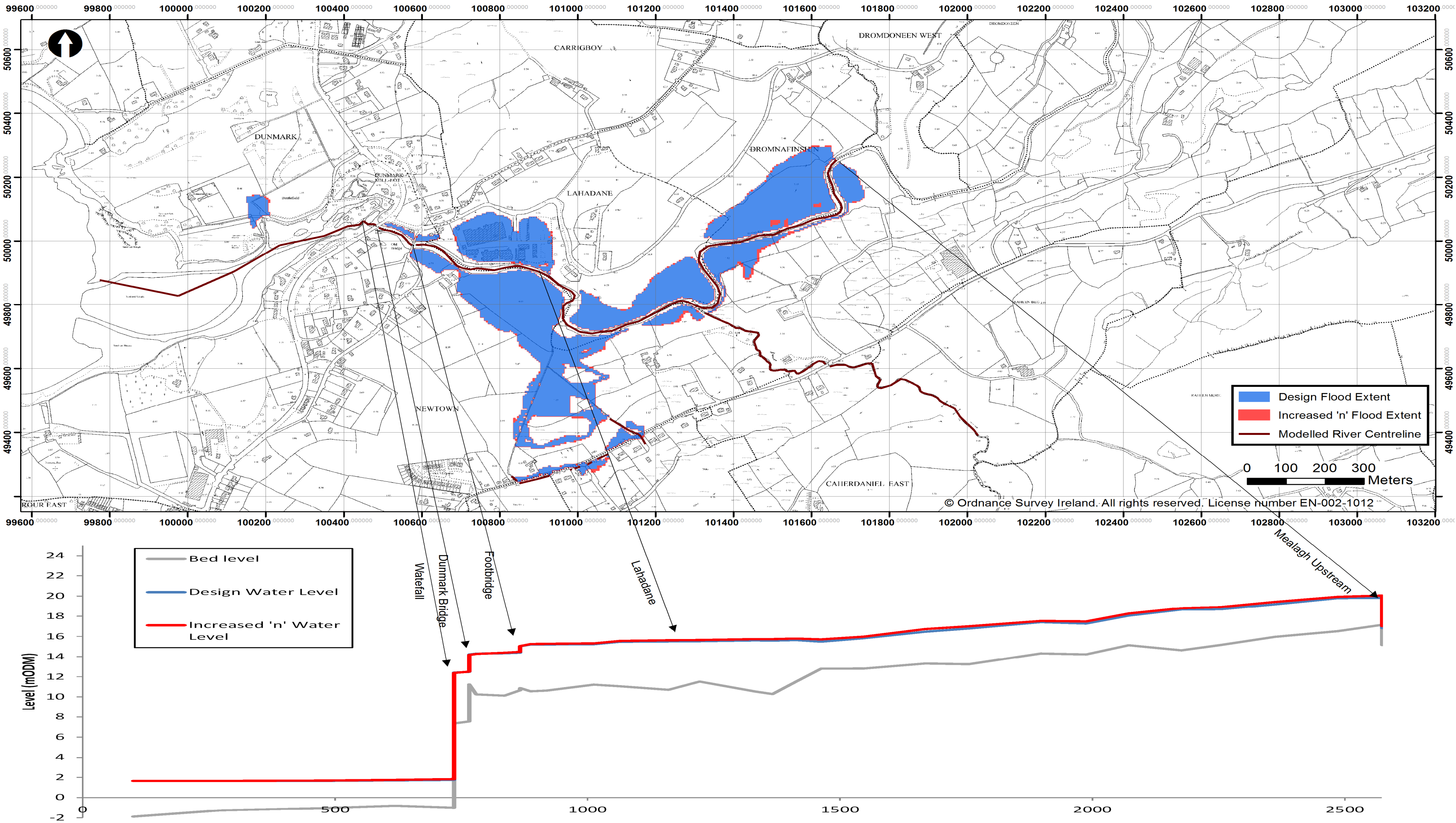
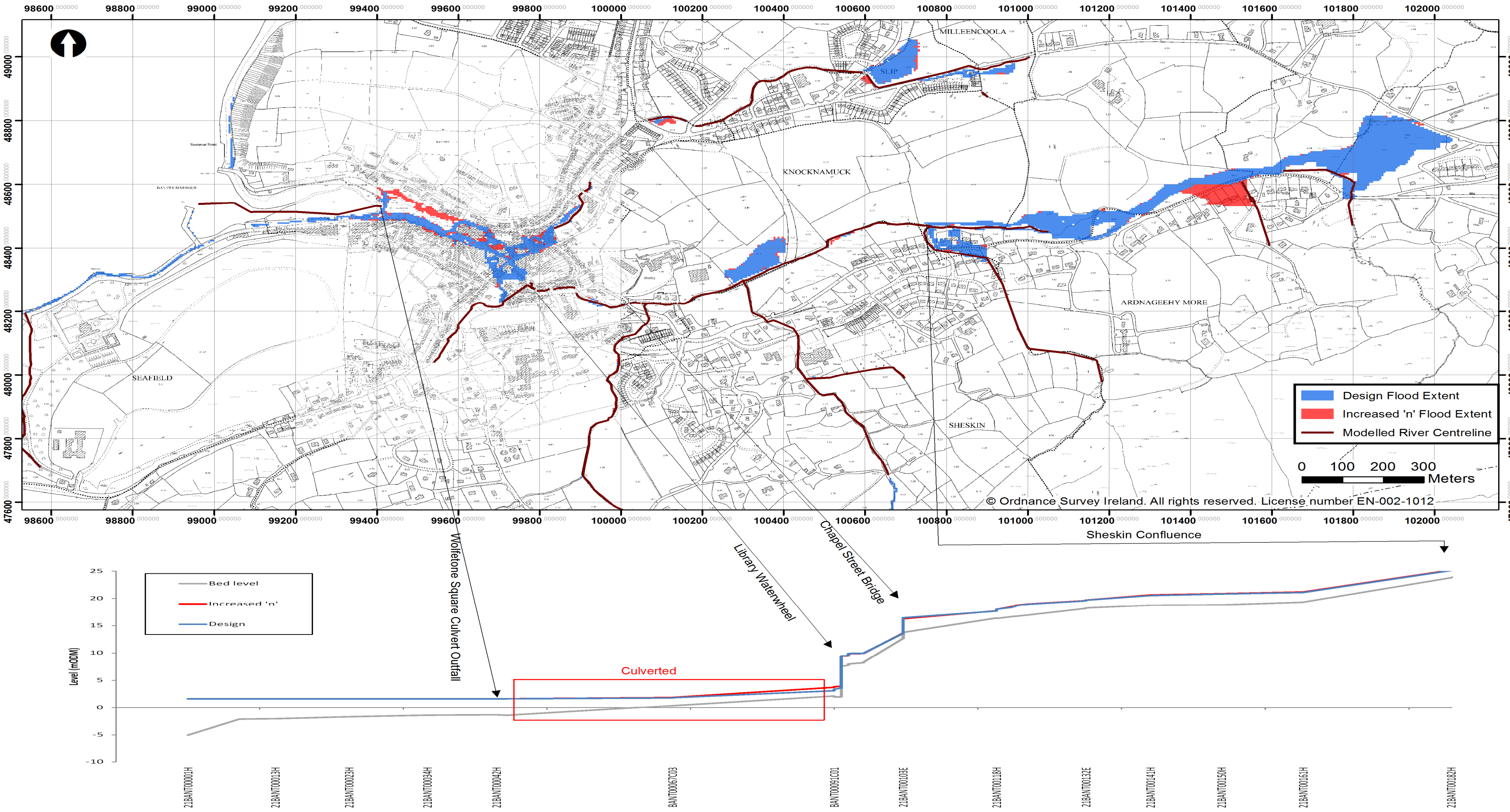
Map B.7: Sensitivity to Increased Manning's 'n' in the Mealagh Catchment



Map B.8: Sensitivity to Increased Manning's 'n' in the Bantry Town Catchment



B.3 Model Outputs

Bantry Model Outputs

Threshold of Property Flooding	The key thresholds and areas affects by flooding in Bantry are: - 50%AEP floods gardens of properties along Glengarriff Road. - 1%AEP fluvial event causes flooding at Knocknaveagh tributary but is shallow and affects < 3 properties - 1%AEP fluvial event causes flooding in central Bantry due to overtopping upstream of the Millwheel on Bantry Stream and overtopping of the downstream culvert on Reenrour. - 0.1%AEP fluvial event causes flooding at Heatherfields due to the capacity of the downstream culverts. - 5-10%AEP fluvial event overtops the right bank at the low point in the Lahadane business park embankment but does not affect properties. This matches well with the estimated frequency of flooding provided by the local authority staff during the flood risk review. - 2%AEP fluvial event on the Mealagh results in extensive flooding of the Lahadane business park. - 10%AEP coastal event overtops the gaps in the sea wall and flood Wolfetone Square. - No buildings are affected by the 10%AEP fluvial event but over 100 buildings are affected in the 1%AEP fluvial event. - Approximately 60 properties are affected by the 10% AEP coastal event increasing to 100 in the 0.5%AEP coastal event.
Critical Structures for Flood Risk	The critical structures in determining flood risk include: - Culvert downstream of the Millwheel, - Downstream culvert on the Knocknaveagh and Ardnageehy Streams for extreme events - Culverts on the Mileencoola East Stream - The quayside sea wall at Wolfetone Square.
Areas affected by flooding	The greatest risk to life is associated with deep flooding at Lahadane business park on the Mealagh. However, there is also significant risk to life along Bridge Street, High Street and across the Caherdaniel Road in the 1%AEP and larger magnitude events. In comparison, extreme flood hazard from coastal flooding occurs in the 10%AEP and larger events across Wolfetone Square.
Risk to people	There is significant and extreme risk to people for the 50%AEP and larger magnitude events. The greatest risk to people is associated with deep and fast flowing water at the Lahadane Business Estate and with the flow capacity of culverts on the Mileencoola East tributary and the Ardnageehy and Sheskin tributaries being exceeded.
Consideration for Flood Risk Management Options	- Increased conveyance at downstream culvert of Bantry Stream and downstream culverts of the Knocknaveagh and Ardnageehy Stream are likely to reduce flood risk. - Increased conveyance of the downstream culverts along the Bantry Stream is unlikely to reduce flood risk during tide-locked periods without additional pumping. - Raising of riverside embankments at Lahadane and the filling in gaps in the sea wall at Wolfetone Square is likely to reduce flood risk to the centre of Kenmare. - Flood warning for fluvial events on the Bantry and Dromacoosane catchments is unlikely to be effective catchment given the time to peak of flood hydrograph is less than a 3 hours. Therefore there may not be sufficient time to undertake temporary flood defence measures (e.g. sandbags) - Flood warning on the Mealagh catchment is likely to be more effective as there would several hours before the peak flow at the Inchiclogh Gauge. This gauge is a good indicator of the expected flow and therefore flooding downstream at Lahadane.

Flood Map Outputs

The following table outlines the print-ready flood mapping deliverables provided in the accompanying digitial data.

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Map	Flood Zone Map	Flood Depth Map	Flood Velocity Map	Flood Hazard Map
I30BY_FCD200_D2	Design	10	MHWS	I21HDS30_EXFCDEXF_D2		I21HDS30_DPFCD200_D2	I21HDS30_VLFCD200_D2	I21HDS30_HZFCD200_D2
I30BY_FCD010_D2	Design	1	MHWS	I21HDS30_EXFCDEXF_D2	I21HDS30_ZNFCDFZF_D2	I21HDS30_DPFCD010_D2	I21HDS30_VLFCD010_D2	I21HDS30_HZFCD010_D2
I30BY_FCD001_D2	Design	0.1	MHWS	I21HDS30_EXFCDEXF_D2	I21HDS30_ZNFCDFZF_D2	I21HDS30_DPFCD001_D2	I21HDS30_VLFCD001_D2	I21HDS30_HZFCD001_D2
I30BY_FMD200_D2	Design	10	MHWS	I21HDS30_EXFMDEXF_D2				
I30BY_FMD010_D2	Design	1	MHWS	I21HDS30_EXFMDEXF_D2				
I30BY_FMD001_D2	Design	0.1	MHWS	I21HDS30_EXFMDEXF_D2				
I30BY_CCD200_D2	Design	10	MHWS	I21HDS30_EXCCDEXF_D2		I21HDS30_DPCCD200_D2	I21HDS30_VLCCD200_D2	I21HDS30_HZCCD200_D2
I30BY_CCD005_D2	Design	0.5	MHWS	I21HDS30_EXCCDEXF_D2	I21HDS30_ZNCCDFZF_D2	I21HDS30_DPCCD005_D2	I21HDS30_VLCCD005_D2	I21HDS30_HZCCD005_D2
I30BY_CCD001_D2	Design	0.1	MHWS	I21HDS30_EXCCDEXF_D2	I21HDS30_ZNCCDFZF_D2	I21HDS30_DPCCD001_D2	I21HDS30_VLCCD001_D2	I21HDS30_HZCCD001_D2
I30BY_CMD200_D2	Design	10	MHWS	I21HDS30_EXCMDEXF_D2				
I30BY_CMD005_D2	Design	0.5	MHWS	I21HDS30_EXCMDEXF_D2				
I30BY_CMD001_D2	Design	0.1	MHWS	I21HDS30_EXCMDEXF_D2				

GIS Outputs

The following table outlines the GIS deliverables provided in the accompanying digital handover.

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Polygon and Nodes	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
I30BY_FCD500_D2_001	Design	50	MHWS	I30EXFCD500D2		I30DPFCD500D2	I30VLFCD500D2	I30HZFCD500D2
I30BY_FCD200_D2_001	Design	20	MHWS	I30EXFCD200D2		I30DPFCD200D2	I30VLFCD200D2	I30HZFCD200D2
I30BY_FCD200_D2_001	Design	10	MHWS	I30EXFCD200D2		I30DPFCD200D2	I30VLFCD200D2	I30HZFCD200D2
I30BY_FCD050_D2_001	Design	5	MHWS	I30EXFCD050D2		I30DPFCD050D2	I30VLFCD050D2	I30HZFCD050D2
I30BY_FCD020_D2_001	Design	2	MHWS	I30EXFCD020D2		I30DPFCD020D2	I30VLFCD020D2	I30HZFCD020D2
I30BY_FCD010_D2_001	Design	1	MHWS	I30EXFCD010D2	I30ZNFCD010D2	I30DPFCD010D2	I30VLFCD010D2	I30HZFCD010D2
I30BY_FCD005_D2_001	Design	0.5	MHWS	I30EXFCD005D2		I30DPFCD005D2	I30VLFCD005D2	I30HZFCD005D2
I30BY_FCD001_D2_001	Design	0.1	MHWS	I30EXFCD001D2	I30ZNFCD001D2	I30DPFCD001D2	I30VLFCD001D2	I30HZFCD001D2
I30BY_FMD500_D2_001	Design	50	MHWS	I30EXFMD500D2		I30DPFMD500D2	I30VLFMD500D2	I30HZFMD500D2
I30BY_FMD200_D2_001	Design	20	MHWS	I30EXFMD200D2		I30DPFMD200D2	I30VLFMD200D2	I30HZFMD200D2
I30BY_FMD200_D2_001	Design	10	MHWS	I30EXFMD200D2		I30DPFMD200D2	I30VLFMD200D2	I30HZFMD200D2
I30BY_FMD050_D2_001	Design	5	MHWS	I30EXFMD050D2		I30DPFMD050D2	I30VLFMD050D2	I30HZFMD050D2
I30BY_FMD020_D2_001	Design	2	MHWS	I30EXFMD020D2		I30DPFMD020D2	I30VLFMD020D2	I30HZFMD020D2
I30BY_FMD010_D2_001	Design	1	MHWS	I30EXFMD010D2		I30DPFMD010D2	I30VLFMD010D2	I30HZFMD010D2
I30BY_FMD005_D2_001	Design	0.5	MHWS	I30EXFMD005D2		I30DPFMD005D2	I30VLFMD005D2	I30HZFMD005D2
I30BY_FMD001_D2_001	Design	0.1	MHWS	I30EXFMD001D2		I30DPFMD001D2	I30VLFMD001D2	I30HZFMD001D2
I30BY_FHD200_D2_001	Design	10	MHWS	I30EXFHD200D2		I30DPFHD200D2	I30VLFHD200D2	I30HZFHD200D2
I30BY_FHD010_D2_001	Design	1	MHWS	I30EXFHD010D2		I30DPFHD010D2	I30VLFHD010D2	I30HZFHD010D2
I30BY_FHD001_D2_001	Design	0.1	MHWS	I30EXFHD001D2		I30DPFHD001D2	I30VLFHD001D2	I30HZFHD001D2
I30BY_CCD500_D2_001	Design	50	MHWS	I30EXCCD500D2		I30DPCCD500D2	I30VLCCD500D2	I30HZCCD500D2
I30BY_CCD200_D2_001	Design	20	MHWS	I30EXCCD200D2		I30DPCCD200D2	I30VLCCD200D2	I30HZCCD200D2
I30BY_CCD200_D2_001	Design	10	MHWS	I30EXCCD200D2		I30DPCCD200D2	I30VLCCD200D2	I30HZCCD200D2
I30BY_CCD050_D2_001	Design	5	MHWS	I30EXCCD050D2		I30DPCCD050D2	I30VLCCD050D2	I30HZCCD050D2
I30BY_CCD020_D2_001	Design	2	MHWS	I30EXCCD020D2		I30DPCCD020D2	I30VLCCD020D2	I30HZCCD020D2
I30BY_CCD010_D2_001	Design	1	MHWS	I30EXCCD010D2		I30DPCCD010D2	I30VLCCD010D2	I30HZCCD010D2
I30BY_CCD005_D2_001	Design	0.5	MHWS	I30EXCCD005D2	I30ZNCCD005D2	I30DPCCD005D2	I30VLCCD005D2	I30HZCCD005D2
I30BY_CCD001_D2_001	Design	0.1	MHWS	I30EXCCD001D2	I30ZNCCD001D2	I30DPCCD001D2	I30VLCCD001D2	I30HZCCD001D2
I30BY_CMD500_D2_001	Design	50	MHWS	I30EXCMD500D2		I30DPCMD500D2	I30VLCMD500D2	I30HZCMD500D2
I30BY_CMD200_D2_001	Design	20	MHWS	I30EXCMD200D2		I30DPCMD200D2	I30VLCMD200D2	I30HZCMD200D2
I30BY_CMD200_D2_001	Design	10	MHWS	I30EXCMD200D2		I30DPCMD200D2	I30VLCMD200D2	I30HZCMD200D2
I30BY_CMD050_D2_001	Design	5	MHWS	I30EXCMD050D2		I30DPCMD050D2	I30VLCMD050D2	I30HZCMD050D2
I30BY_CMD020_D2_001	Design	2	MHWS	I30EXCMD020D2		I30DPCMD020D2	I30VLCMD020D2	I30HZCMD020D2
I30BY_CMD010_D2_001	Design	1	MHWS	I30EXCMD010D2		I30DPCMD010D2	I30VLCMD010D2	I30HZCMD010D2
I30BY_CMD005_D2_001	Design	0.5	MHWS	I30EXCMD005D2		I30DPCMD005D2	I30VLCMD005D2	I30HZCMD005D2
I30BY_CMD001_D2_001	Design	0.1	MHWS	I30EXCMD001D2		I30DPCMD001D2	I30VLCMD001D2	I30HZCMD001D2
I30BY_CHD200_D2_001	Design	10	MHWS	I30EXCHD200D2		I30DPCHD200D2	I30VLCHD200D2	I30HZCHD200D2
I30BY_CHD005_D2_001	Design	1	MHWS	I30EXCHD005D2		I30DPCHD005D2	I30VLCHD005D2	I30HZCHD005D2
I30BY_CHD001_D2_001	Design	0.1	MHWS	I30EXCHD001D2		I30DPCHD001D2	I30VLCHD001D2	I30HZCHD001D2

Appendix C. Castletown Bearhaven AFA

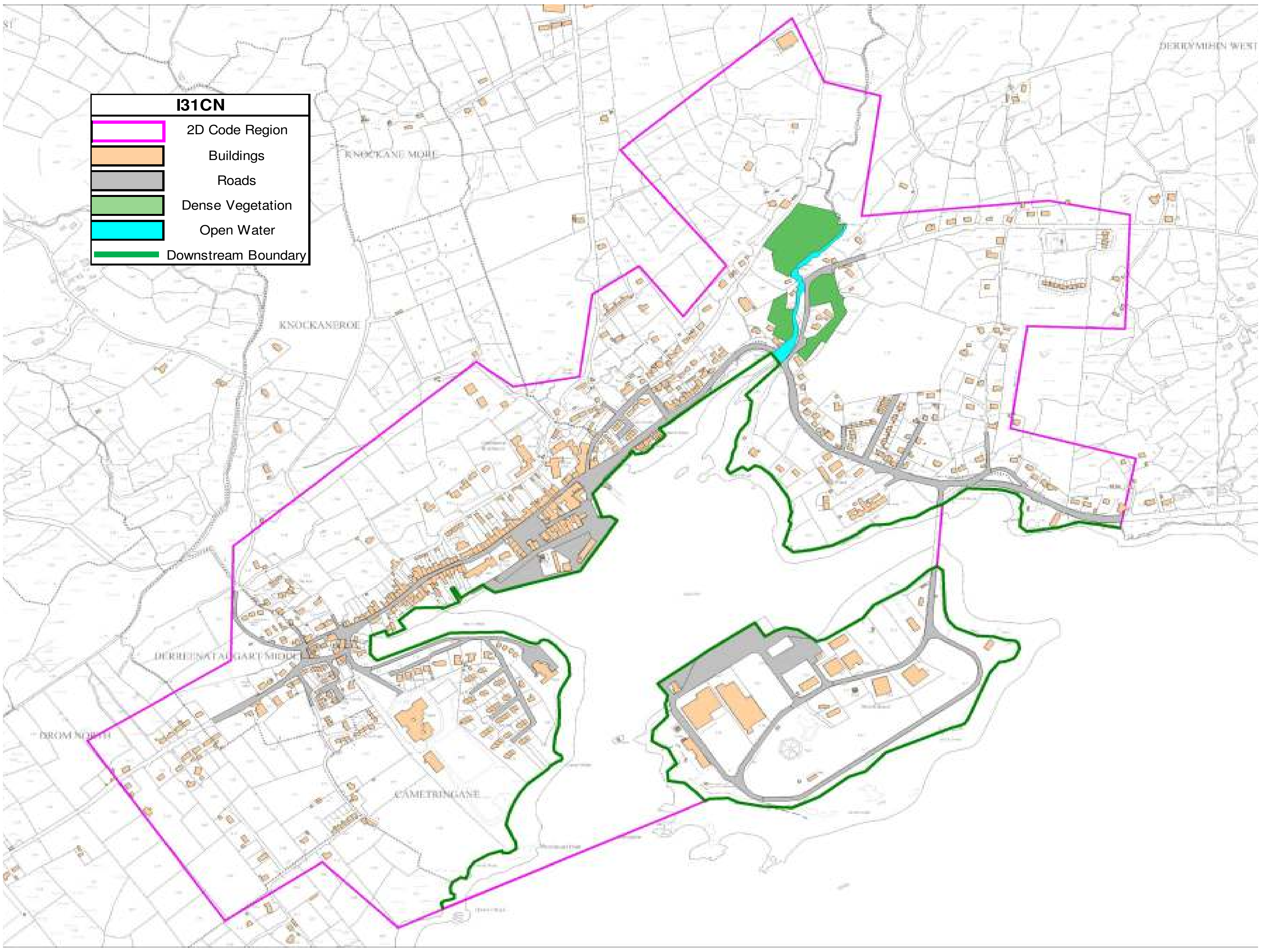
C.1 Model Build Proforma

UOM	**21**		
AFA/ MPW Reach	**Castletown Bearhaven**		
Model ID	**I31CN**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourse	**N/A**	**FLUVIAL RISK**	No
Length Modelled (km)	**N/A**	**COASTAL RISK**	Yes
Area Modelled (km^2)	**1.6**	**VULNERABLE TO WAVES**	Yes

Input Data	
River Channel Topographic Data	Not applicable as an assessment of fluvial flood risk is not required
Floodplain Topographic Data	Filtered LIDAR DTM "CtownBl2mdtm.asc" 2m grid resolution with +/- 0.1m RMSE captured in April 2012, covering the mainland portion of the AFA. National Digital Height Model (nDHM) based on IFSAR data 5m grid resolution was adjusted by -0.8m to be consistent with the LIDAR on flat surfaces and used to inform elevations on Dinish Island/port. The LIDAR and IFSAR data was merged together with LIDAR prioritised in overlapping regions. The final DTM "Castletown_Bearhaven_spliced_002.asc" was then used as the basis for the 2D model of the floodplain.
Map data	1:5000 Osi mapping tiles 6647, 6648,6675 and 6676 The OSI mapping was found to include all current developments and was consistent with site observations, the river channel survey and aerial photography.

Model Build					
General Schematisation	A 2D TUFLOW approach was taken for Castletown Bearhaven to accurately simulate multidirectional flow across the narrow urban area. The 2D domain covered the AFA extent to consider coastal flood risk along the quayside and on Dinish Island. The 2D model was set to 5m to represent the urban area without compromising run time. The sea wall and quayside banks were based on LIDAR elevations in the absence of detailed spot levels. Buildings were raised above the floodplain by 0.15m to represent the threshold and then a high Manning's 'n' value of 0.2 applied to represent the storage of the building. The threshold level was set based on site visits and survey photographs of the AFA. This approach means accurate flood depths can be extracted for flood damage analysis. The channel at Brandyhall Bridge has been enforced based on LIDAR elevations using the 2d_Zsh layer. The other urban materials such as roads have been represented by varying the Manning's 'n' applied, detailed below.				
Software Versions Used	TUFLOW version 2012-05-AC-iSP-w32				
Total No of 1D nodes	N/A				
Open channel (H)					
Bridges (D)					
Culverts (I)					
Weirs (W)					
Model Extent	Reach/Feature	Upstream Limit (ING)		Downstream Limit (ING)	
	Coastline	067667, 045180		068650, 046030	
Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Open pasture	N/A	N/A	0.06	OSi Mapping
	Dense vegetation	N/A	N/A	0.085	OSi Mapping
	Buildings	N/A	N/A	0.2	OSi Mapping
	Roads	N/A	N/A	0.03	OSi Mapping
Structures	No hydraulic structures considered in this coastal model.				
Upstream boundary	N/A Coastal boundary only				
Lateral inflows	N/A Coastal boundary only				
Downstream boundary	The tide plus total surge levels were applied as level-time(HT) boundary to the 2D code region along the mainland coastline and around Dinish Island. The wave overtopping discharges were applied as a discharge-time (QT) on the landward side of the quayside for the relevant scenarios.				
Run Settings	Unsteady simulation of the full 57 hour tide plus surge hydrograph (> 2 days and 5 tidal cycles) to fully consider the surge event. The 2D timestep was set to 2.5s which is half the grid cell size as recommended by TUFLOW. All other parameters set to default.				

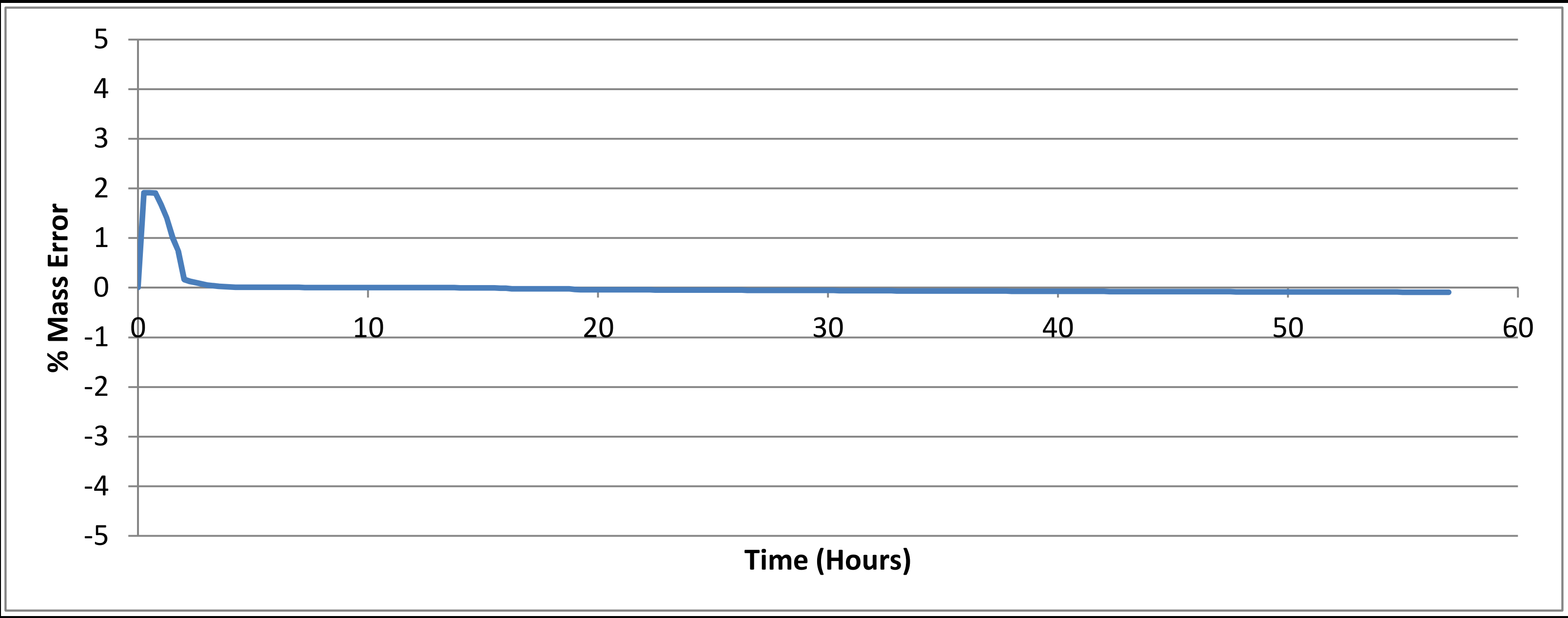
Model Geoschematic



SCHEDULE 1 : PHOTOGRAPHS
Photo 1: Main Street at Black Rock Terrace

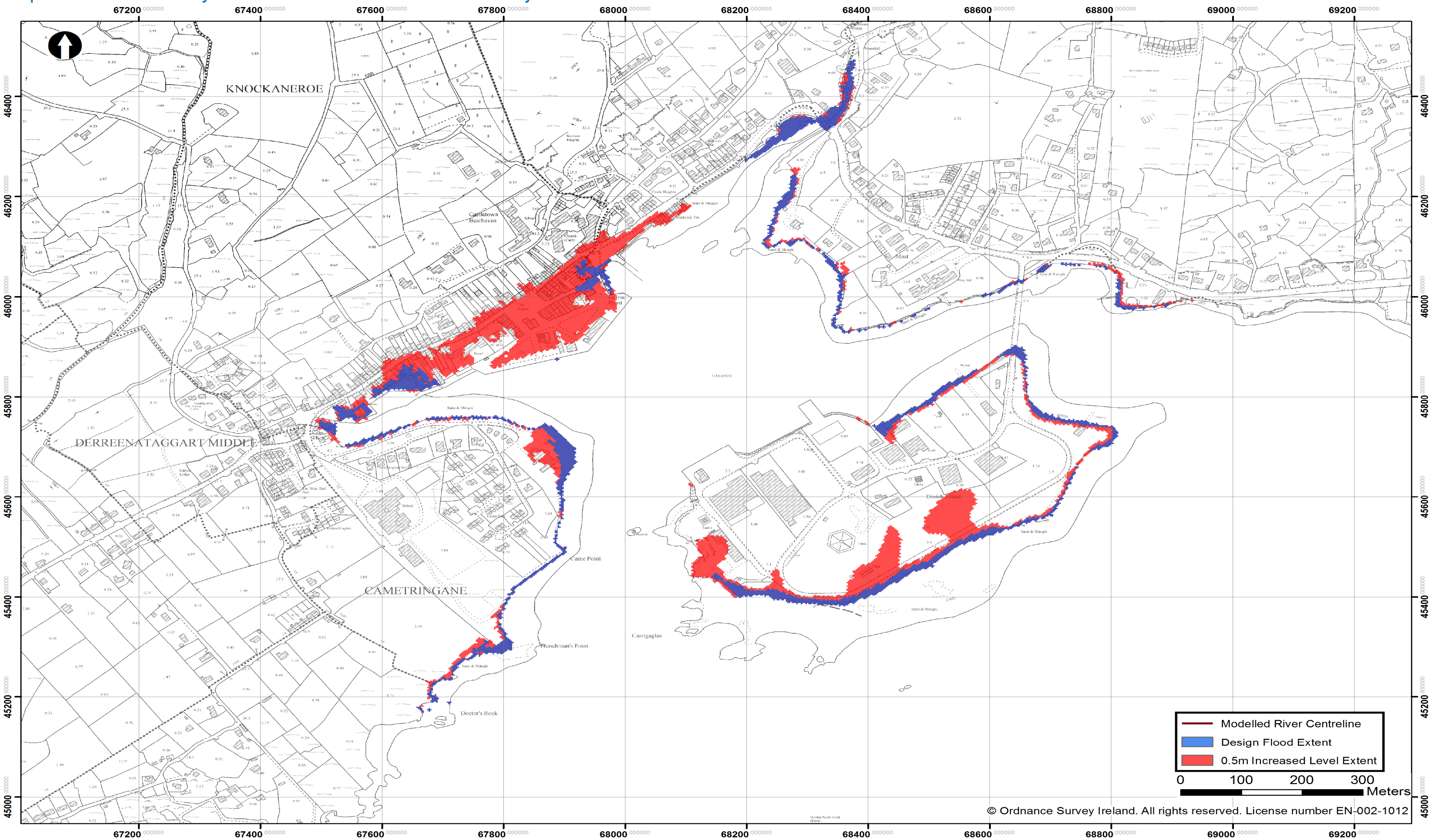
There is no Schedule 2 Structures for the Castletown Bearhaven model as no hydraulic structures have been modelled.

C.2 Model Performance Proforma

Castletown Bearhaven Model Performance						
1D Convergence						
Convergence Plot	N/A					
Comments						
2D Convergence						
Mass Balance Plot 0.5%AEP Coastal Event						
Comments	The overall culmulative mass error was -89m^3 or -0.1%. There is an initial increase in cumulative mass error the start of the Castletown Bearhaven model caused by the initial wetting of the cells at Brandyhall Bridge. However, the mass error rapidly decreases to less than 0.1% within an hour and does not affect the model results at the peak tide.					
Hydrological Performance						
Target Flows	HEP ID	Location	Model Node	Design Flow (m3/s)	Modelled Flow (m3/s)	Difference
	N/A Coastal Only					
Comments						
Calibration Event 1: N/A Insufficient Calibration Data to Perform Hydraulic Calibration						
Model Run ID						
Period Modelled						
Hydraulic Modification to Design Model						
Hydrological inflows						
Calibration Plot						
Comments						
Sensitivity Test 1: Increased Downstream Level						
Model Run ID	I31CN_CMD010_D1_001					
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.					
Hydrological inflows	The assumed impacts of seiche in Bantry Bay cause differing water level profiles along Bantry Bay where water level does not increase progressively up the bay, and this effect differs for each of the %AEP events. Total Tide plus surge levels vary by up to ±0.13m. GN 22 recommends a sensitivity test that considers a 0.5 m increase in water levels for the design events, which is broadly equivalent to the mid-range future scenario. Therefore, the MRFS 1%AEP results (CMD010) have been used to conduct the sensitivity test.					
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity					
Comments	The increase in level resulted in a significant increase in flood risk along Main Street where the entire quayside was overtopped by the extreme tide plus surge level. There is also an increase in coastal flood risk along the southern coast of Dinish Island which partially floods the port buidlings and coastal road. Therefore flood risk in Castletown Bearhaven was deemed to be sensitive to the uncertainties in level. The ICPSS(2011) study was used to set design tide plus surge levels. These are deemed appropriate as they are based on the tidal gauge within the Haven and the ICPSS model has been calibrated to this gauge. An allowance should be made when interpreting the design flood outlines and the in the sizing of any flood risk management option due to this uncertainty in total tide plus surge levels selected.					
Sensitivity Test 2: Increased Manning's 'n'						
Model Run ID	I31CN_CCS__N_D1_001					
Hydraulic Modification to Design Model	The Manning's 'n' values were increased to the upper limit of the industry recommended ranges. Pasture/ parkland /garden 0.060 to 0.070 Dense vegeations 0.080 to 0.100 Buildings 0.200 to 0.300 Roads 0.030 to 0.035					
Hydrological inflows	No modifications were made to the design inflows.					
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity					
Comments	The increase in the Manning's 'n' values used in the model resulted in less than 0.13m Increase in water level (RMSE) and less than 11% increase in extent for the 1%AEP event. Therefore, the Castletown Bearhaven model was not deemed sensitive to the Manning's 'n' values applied to the model.					

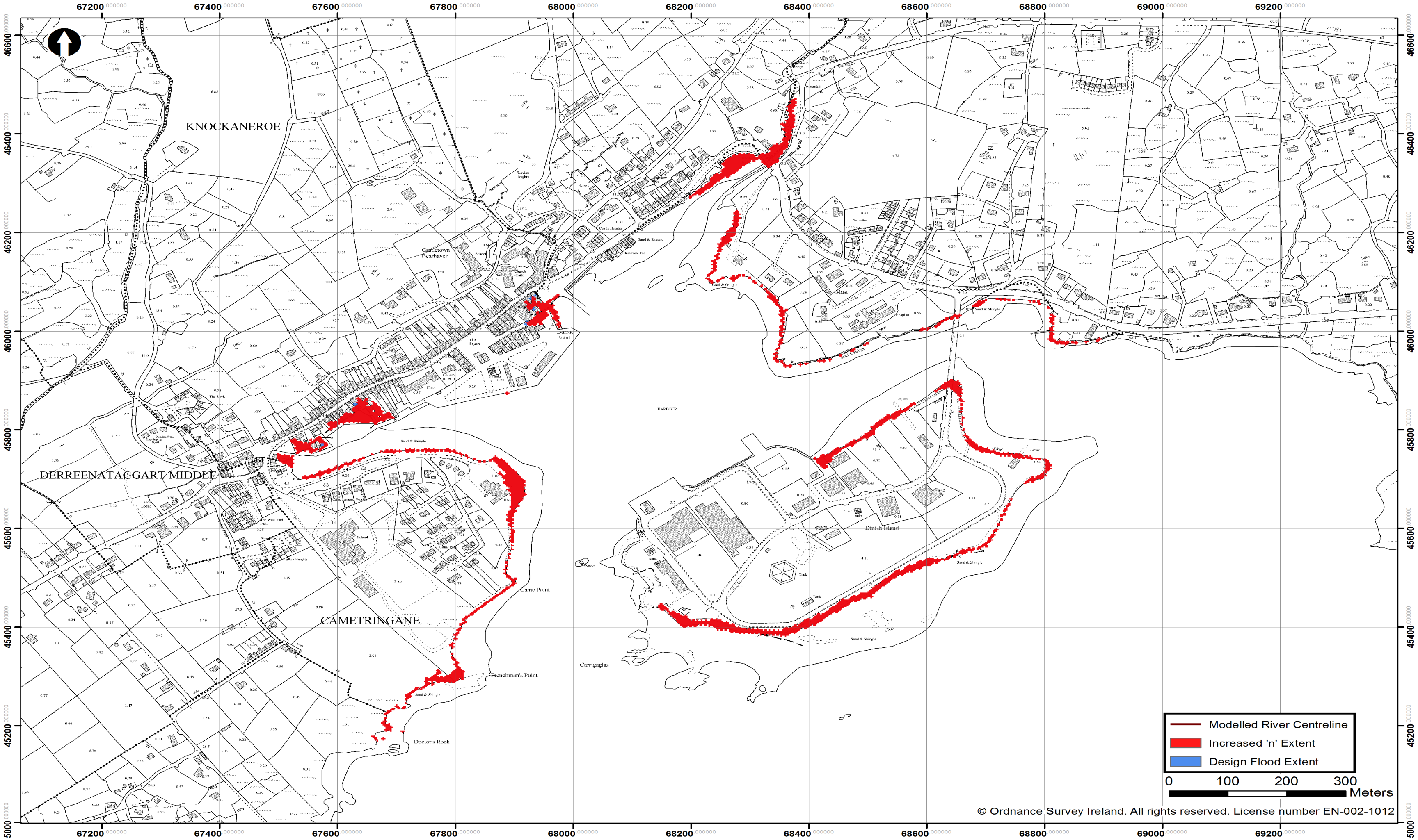
Mott MacDonald

Map C.1: Sensitivity to Increased Downstream Boundary



296235/IWE/CCW/R020/C 04 August 2014
Document2

Map C.2: Sensitivity to Increased Manning's 'n'



C.3 Model Outputs

Castletown Bearhaven Model Results

Threshold of Property Flooding	20%AEP Coastal Current Scenario behind the Garda Station. 2%AEP Coastal Current Scenario at the slipway. 1%AEP Coastal Current Scenario along Main Street. 5%AEP Wave Overtopping Current Scenario under the MRFS along the quayside.
Critical Structures for Flood Risk	The sea wall by the slipway and behind Garda Station
Areas affected by flooding	Coastal dominated events: Behind the Garda Station, Brandhall Bridge, Main Street Wave dominated events: Quayside
Risk to people	There is significant risk to people for the 1%AEP and larger magnitude events by the slipway and along Main Street.
Consideration for Flood Risk Management Options	Localised property protection and/or infilling of the gaps in the sea wall is likely to reduced flood risk Flood warning is likely to be effective given that the highest astronomical tide can be predicted and > 6 hours warning can be given of storm surges from offshore buoys.

Flood Map Outputs

The following table outlines the print-ready flood mapping deliverables provided in the accompanying digital data.

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Map	Flood Zone Map	Flood Depth Map	Flood Velocity Map	Flood Hazard Map
I21CN_CCD100_D1_001	Design	50	10	I21HCD31_EXCCD_D1		I21HCD31_DPCCD100_D1	I21HCD31_VLCCD100_D1	I21HCD31_HZCCD005_D1
I21CN_CCD005_D1_001	Design	50	0.5	I21HCD31_EXCCD_D1	I21HCD31_ZNCCD_D1	I21HCD31_DPCCD005_D1	I21HCD31_VLCCD005_D1	I21HCD31_HZCCD100_D1
I21CN_CCD001_D1_001	Design	50	0.1	I21HCD31_EXCCD_D1	I21HCD31_ZNCCD_D1	I21HCD31_DPCCD001_D1	I21HCD31_VLCCD001_D1	I21HCD31_HZCCD001_D1
I21CN_CMD100_D1_001	Design	50	10	I21HCD31_EXCMD_D1				
I21CN_CMD005_D1_001	Design	50	0.5	I21HCD31_EXCMD_D1				
I21CN_CMD001_D1_001	Design	50	0.1	I21HCD31_EXCMD_D1				

GIS Outputs

Print Ready Maps are denoted by the highlighted cells and provided in Schedule 4

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Polygon and Nodes	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
I31CN_CCD500_D1_001	Design	50	50	I31EXCCD500D1		I31DPCCD500D1	I31VLCCD500D1	I31HZCCD500D1
I31CN_CCD200_D1_001	Design	50	20	I31EXCCD200D1		I31DPCCD200D1	I31VLCCD200D1	I31HZCCD200D1
I31CN_CCD100_D1_001	Design	50	10	I31EXCCD100D1		I31DPCCD100D1	I31VLCCD100D1	I31HZCCD100D1
I31CN_CCD050_D1_001	Design	50	5	I31EXCCD050D1		I31DPCCD050D1	I31VLCCD050D1	I31HZCCD050D1
I31CN_CCD020_D1_001	Design	50	2	I31EXCCD020D1		I31DPCCD020D1	I31VLCCD020D1	I31HZCCD020D1
I31CN_CCD010_D1_001	Design	50	1	I31EXCCD010D1		I31DPCCD010D1	I31VLCCD010D1	I31HZCCD010D1
I31CN_CCD005_D1_001	Design	50	0.5	I31EXCCD005D1	I31ZNCCD005D1	I31DPCCD005D1	I31VLCCD005D1	I31HZCCD005D1
I31CN_CCD001_D1_001	Design	50	0.1	I31EXCCD001D1	I31ZNCCD001D1	I31DPCCD001D1	I31VLCCD001D1	I31HZCCD001D1
I31CN_CMD500_D1_001	Design	50	50	I31EXCMD500D1		I31DPCMD500D1	I31VLCMD500D1	I31HZCMD500D1
I31CN_CMD200_D1_001	Design	50	20	I31EXCMD200D1		I31DPCMD200D1	I31VLCMD200D1	I31HZCMD200D1
I31CN_CMD100_D1_001	Design	50	10	I31EXCMD100D1		I31DPCMD100D1	I31VLCMD100D1	I31HZCMD100D1
I31CN_CMD050_D1_001	Design	50	5	I31EXCMD050D1		I31DPCMD050D1	I31VLCMD050D1	I31HZCMD050D1
I31CN_CMD020_D1_001	Design	50	2	I31EXCMD020D1		I31DPCMD020D1	I31VLCMD020D1	I31HZCMD020D1
I31CN_CMD010_D1_001	Design	50	1	I31EXCMD010D1		I31DPCMD010D1	I31VLCMD010D1	I31HZCMD010D1
I31CN_CMD005_D1_001	Design	50	0.5	I31EXCMD005D1		I31DPCMD005D1	I31VLCMD005D1	I31HZCMD005D1
I31CN_CMD001_D1_001	Design	50	0.1	I31EXCMD001D1		I31DPCMD001D1	I31VLCMD001D1	I31HZCMD001D1
I31CN_CHD100_D1_001	Design	50	10	I31EXCHD100D1		I31DPCHD100D1	I31VLCHD100D1	I31HZCHD100D1
I31CN_CHD010_D1_001	Design	50	0.5	I31EXCHD010D1		I31DPCHD010D1	I31VLCHD010D1	I31HZCHD010D1
I31CN_CHD001_D1_001	Design	50	0.1	I31EXCHD001D1		I31DPCHD001D1	I31VLCHD001D1	I31HZCHD001D1
I31CN_WMD005_D1_001	Design	50	10	I31EXWMD005D1		I31DPWMD005D1	I31VLWMD005D1	I31HZWMD005D1
I31CN_WMD001_D1_001	Design	50	5	I31EXWMD001D1		I31DPWMD001D1	I31VLWMD001D1	I31HZWMD001D1

Appendix D. Kenmare AFA

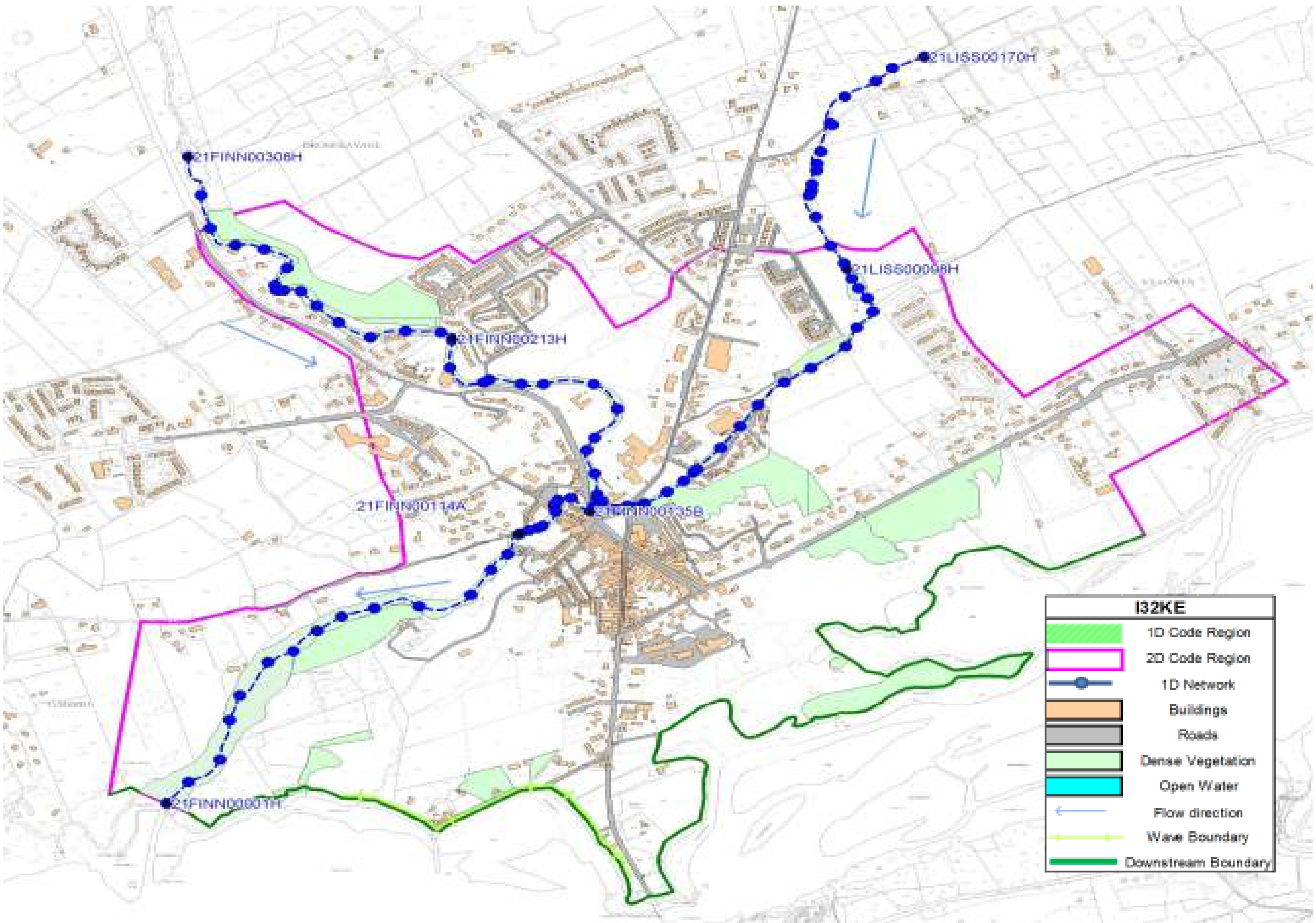
D.1 Model Build Proforma

UOM	21		
AFA/ MPW Reach	Kenmare		
Model ID	I32KE		
Purpose of Model Build	Flood Mapping		
Main Watercourse	Finnihy	FLUVIAL RISK	Yes
Length Modelled (km)	4.7	COASTAL RISK	Yes
Area Modelled (km^2)	2.3	VULNERABLE TO WAVES	Yes

Input Data	
River Channel Topographic Data	River channel survey was undertaken by Murphy Surveys Limited as part of the CFRAM Study. 21FINN_Finnihy_V1.dwg surveyed March 2013: The survey data was found to be consistent with independent spot checks. However, the effective weir at the old stepping stones location (ING 90631,71425) was absent from the original survey. Infill survey (Muprhys Ltd) was undertaken in April 2014 to improve conceptualisation of the steeping stones structure. 21LISS_Lissaniska_V1.dwg surveyed November 2012 : No errors or gaps were found within the survey and the data was found to be consistent with independent spot checks.
Floodplain Topographic Data	Filtered LIDAR DTM "Kenmare2mdtming_001.asc" 2m grid resolution with +/- 0.2m RMSE captured in April 2012 The DTM was used as the basis for the 2D model of the floodplain. The LIDAR was checked against the river channel survey on expansive flat surfaces such as roads and found to be within +/- 0.1m of the surveyed level. The accuracy of the LIDAR on the steep slopes of Gortamullen Height was less accurate however this is not anticipated to be within the floodplain and affect results.
Map data	1:5000 Osi mapping tiles 6363 and 6364 1:2500 OSI mapping tiles 6363-A,-B,-C and -D The OSI mapping was found to include all current developments and was consistent with site observations, the river channel survey and aerial photography.

Model Build					
General Schematisation	A 1D/2D ISIS/TUFLOW approach was taken for Kenmare to accurately model flow along the main watercourses and head loss through hydraulic structures whilst enabling multidirectional flow across the urban areas such as Shelbourne Street. The 1D model considers the Finnihy and Lissaniska as the main watercourses. However, Gortamullen and Kilowen have not been modelled hydraulically as the flows were found to remain in bank for these catchments less than 1km2. The design inflows were input directly to the main watercourses at the confluences. The 2D domain covered the AFA extent to consider flood risk from the Finnihy as well as coastal flood risk along the estuary (Kenmare river). The 2D model grid was set to 5m to represent the urban area without compromising run time. River banks were explicitly enforced using the 2D_zlns in the 2D domain based on the river channel survey spot levels. Buildings were raised above the floodplain by 0.15m to represent the threshold and then a high Manning's 'n' value of 0.2 applied to represent the storage of the building. The threshold of 150mm was selected as typical from threshold surveys and survey photographs.This approach means accurate flood depths can be extracted for flood damage analysis.				
Software Versions Used	ISIS version 6.6 TUFLOW version 2012-05-AC-iSP-w32				
Total No of 1D nodes	**107**				
Open channel (H)	97				
Bridges (D)	7				
Culverts (I)	0				
Weirs (W)	3				
Model Extent	Reach/Feature	Upstream Limit (ING)	Downstream Limit (ING)		
	Finnihy	090073, 071935	090025, 070199		
	Lissaniska (aka Kealnagower)	091650, 072203	090967, 070993		
Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Finnihy	0.05	0.08	0.06	Schedule 1: Photographs
	Lissaniska	0.05	0.08	0.06	Schedule 1: Photographs
	Open pasture	N/A	N/A	0.06	Schedule 1: Photographs
	Dense vegetation	N/A	N/A	0.085	Schedule 1: Photographs
	Buildings	N/A	N/A	0.2	Schedule 1: Photographs
	Roads	N/A	N/A	0.03	Schedule 1: Photographs
Structures	See Schedule 2 for Hydraulic Structure Parameters				
Upstream boundary	The Finnihy upstream boundary was located at 21FINN00308H at the upstream end of the AFA where all flows were within the narrow valley sections below the road and no flows were likely to enter the AFA across the floodplain. The Lissaniska upstream boundary was located at 21LISS00170H to account for any flow attenuation through the road bridge.				
Lateral inflows	The Gortamullen inflows added directly to the Finnihy confluence at the outfall of the culvert (21FINN00253). The other intermediate inflows were distributed evenly across the open channel sections as the contributing area increased fairly linearly along the modelled reach.				
Downstream boundary	The downstream boundary of the 1D area was located at the outfall of the Finninhy into the estuary (Kenmare River) at node 21 FINN0000H. The design tidal conditions were applied directly to the 1D node. The design tidal conditions and wave overtopping 2D downstream boundary was located along the quayside/coastline of the estuary/Kenmare River. The tide plus total surge levels were applied as level-time(HT) boundary. The wave overtopping discharges were applied as a discharge-time (QT) boundary on the landward side of the coastline crest and a separate HT boundary with the associated tidal plus surge levels located in the seaward cell to enable excess wave discharge to flow back out to sea when water level on the floodplain was above the crest of the defence.				
Run Settings	Unsteady simulation of the full 25 hour hydrograph. The 1D timestep was set to 1s which is divisible in to the 2D timestep of 2s which is less than half the grid cell size as recommended by TUFLOW. No minimum flows were set for Kenmare model. All other parameters set to default.				

[Map(s) including: cross-sections, boundary locations, any 2D model extent and any 2D floodplain modifications]



SCHEDULE 1 : PHOTOGRAPHS

Photo 1: Lissaniska Active Channel

ING 091515,071620 captured on 29/11/12

Photo 2: Lissaniska Vegeated River Banks

ING 091293,071267 captured on 29/11/12

Photo 3: Finnihy Active River Channel

ING 090636,071396 captured on 03/04/2014

Photo 4: Finnihy River Banks

ING 090950,071030 captured on 07/03/13

Photo 5: Stepping Stones "Weir" Section Looking Upstream

Various rocks in channel, vegeated island and banks ING 091515,071620 captured on 29/11/12

SCHEDULE 2: Structures

Data file: P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I32KE\DESIGN\model\I32KE_D2.dat

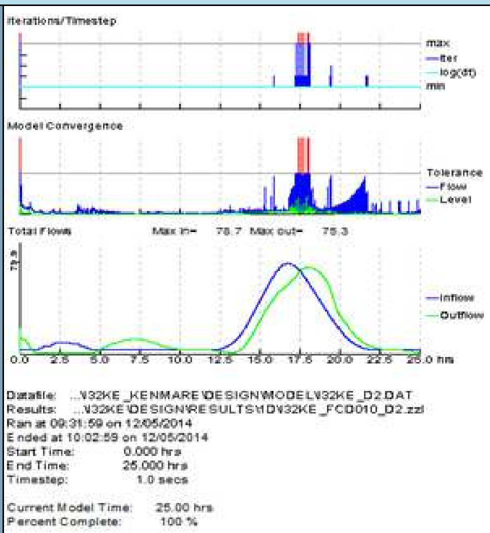
Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Comments/ Justification
				Soffit Elevation	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation	Length	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation	Modular Limit	Weir Coeff.	
21LISS00140D	91447	72024	Bridge Arched	28.35	1	0	1	N/A	N/A	N/A	N/A	27.91	0.9	1.1	Arched bridge constricting the river channel above 26.25mODM. Spill representing flow over road and parapet
21LISS00127D	91419	71897	Bridge not modelled	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Bridge not modelled explicitly as the Footbridge bypassed as springing level at or above bankfull.
21LISS00122D	91409	71843	Bridge not modelled	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Bridge not modelled explicitly as the Footbridge bypassed as springing level at or above bankfull on left bank.
21LISS00026D	91169	71104	Bridge USBPR	5.3	1	0	1	N/A	N/A	N/A	N/A	5.79	0.9	1	Flat soffit bridge with spill representing spill over the parapet
21LISS00010D	91028	70993	Bridge Bernoulli Loss	4.85	1	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Arched bridge represented as a Bernoulli Loss to stabilise the transition to orifice flow and consider the impact of the pipe crossing upstream. The head loss has been calibrated to the 2008 event observations
21LISS00006D	90987	70987	Bridge USBPR	4.61	1	0	1	N/A	N/A	N/A	N/A	5.33	0.9	1.1	Flat soffit bridge with spill representing spill over the parapet
21FINN00198D	90702	71340	Bridge USBPR	8.15	1	0	1	N/A	N/A	N/A	N/A	9.83	0.9	1.1	Flat soffit bridge which does not affect flow below the soffit. Spill represents flow over the deck, The wide railings were assumed to have a negligible impact on flow hence the spill coefficient above 1.
21FINN00136D	90942	70989	Bridge USBPR	3.815	2	0	1	N/A	N/A	N/A	N/A	6.91	0.9	1	Pipe assumed to be effective soffit as conservative estimate. Spill represents flow over parapet.
21FINN00126D	90850	71005	Bridge USBPR	4.16	2	45	1	N/A	N/A	N/A	N/A	5.22	0.9	1	Pedestrian Creamery Bridge. Spill represents flow over parapet. Skew angle set to 45 degrees to represent losses around the acute bend
21FINN00118H	90820	70937	Bridge not modelled	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Cromwell Bridge, springing level is above bankfull so bridge bypass/no constriction
21FINN00114D	90780	70922	Bridge USBPR	3.05	1	0	0	N/A	N/A	N/A	N/A	3.25	0.9	1	Footbridge. Spill represents flow over deck with lowered coefficient to represent the losses through the railings.
21LISS00138E	91447	72024	Weir RNWEIR	N/A	N/A	N/A	N/A	25.972	1	25.972	1	N/A	N/A	N/A	Weir sill downstream of bridge face used to stabilise low flows.
21LISS00005E	90987	70987	Weir RNWEIR	N/A	N/A	N/A	N/A	3.11	1	3.11	1	N/A	N/A	N/A	Weir sill downstream of bridge face used to stabilise low flows into the Finnihy.
21FINN00259W	90259	71575	Weir RNWEIR	N/A	N/A	N/A	N/A	12.594	1	12.594	1	N/A	N/A	N/A	Natural waterfall represented as a single weir to drop bed level and maintain sub-critical flow in the river channel
FINN00213S01	90631	71425	Weir SPILL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.97	0.9	0.5	Stepping stones weir at surveyed section 215W combined with the higher bed elevations at 216H to simplfiy the combined bed drop and supercritical flow. Coefficient set to 0.5 to represent the inefficienices witht eh larger boudlers and vegetated island in the middle.

D.2 Model Performance Proforma

Kenmare Model Performance

1D Convergence

Convergence Plot 1% AEP Fluvial Event

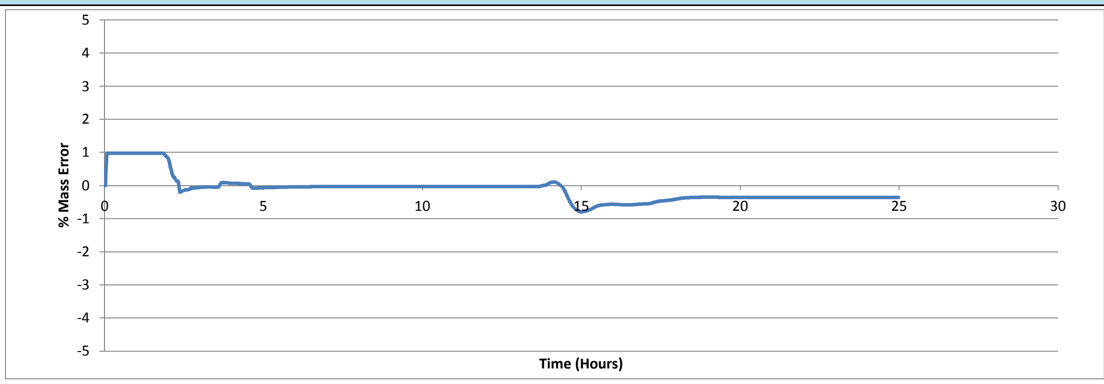


Comments

The 1D model components were convergent and within the recommended tolerances for the majority of the event. Poor model convergence occurred at 17.5 hours (peak) at 21LISS00006D due to the backwater from the Finnihy and bypassing of flow across the confluence. Flood level, extent, depth and hazard are not effected by this instability as the stage is not affected by the instability in flow and the flood level from the Finnihy determines flood risk at this location at the peak.
The initial poor convergence is related to the initial conditions which are an average for all events assessed. Therefore some events, such as the 1% AEP, there is some initial instability as the flowsstablise. However, this does not affect the flood peaaks as it occurs 10 horus before the fluvial event starts.

2D Convergence

Mass Balance Plot 1%AEP Fluvial Event



Comments

The 2D model remains within the recommended tolerance of ±1% cumulative mass error throughout the 1%AEP event. The highest mass error of 0.99% is experienced at the initial wetting of the 2D cells at 0 hours which is within the +/-1% tolerance. Mass error reduces when water spills out of bank and remains with the recommended tolerances throughout the event.
The total culmulative mass error is -0.36% which is within the recommened tolerance and the results are deemed to be reliable.

Hydrological Performance

Target Flows

			10% AEP m³/s			1%AEP m³/s			0.1%AEP m³/s		
HEP ID	Location	Model Node	Design	Modelled	% Difference	Design	Modelled	% Difference	Design	Modelled	% Difference
21_2408_1	Finnihy downstream of Gortamullen	21FINN00253H	44.5	42.5	-4%	66.3	64.3	-3%	98.8	93.6	-5%
21_2495_1	Finnihy downstream of Lissaniska	21FINN00137B	50.8	49.0	-4%	75.7	75.6	0%	112.8	113.7	1%
21_2495_4	Downstream of Finnihy (tidal outfall)	21FINN00001H	52.5	53.1	1%	78.1	73.7	-6%	116.4	109.9	-6%
21_6311_1	Lissaniska downstream of Kilowen	21LISS00085H	3.4	3.7	9%	5.1	5.3	4%	7.5	7.9	6%
21_6311_3	Lissaniska downstream (confluence with Finnihy)	21LISS00003A	4.3	4.4	2%	6.4	6.2	-4%	9.5	7.8	-17%

Comments

The 1%AEP fluvial flows were within 1% to 8% of the design target flows. The greatest difference occurred at 21_2495_4 (Finnihy downstream) and 21_6311_3 (Lissaniska Downstream) because both of these locations are significantly impacts by backwater from the tide and the confluence with the Finnihy respectively.
Therefore, the peak flow at the 21_2495_4 and 21_6311_3 will be less than the design hydrology which assumes no backwater.

Calibration Event 1

Model Run ID	I32KE_FCC20081023_19hr_70pc_d2
Period Modelled	22 Oct 2008 22:00 to 23 Oct 2008 16:00 (19 hours total)
Hydraulic Modification to Design Model	The footbridge at 21FINN00114D was partially blocked to represent the increased loss due to the construction activities at this location during October 2008 and reproduce the observed backwater effect into the town.
Hydrological inflows	The rainfall profile was transferred from Valentia Observatory and hydrographs produced using the FSSR16 rainfall-runoff approach. The percentage runoff parameter was raised to 77% to represent the saturated catchment conditions as recorded by Met Eireann's SMD dataset for the 22 -23rd October 2008 on well-drained soils.
Calibration Plot	See Schedule 3 - Calibration and Sensitivity

Comments

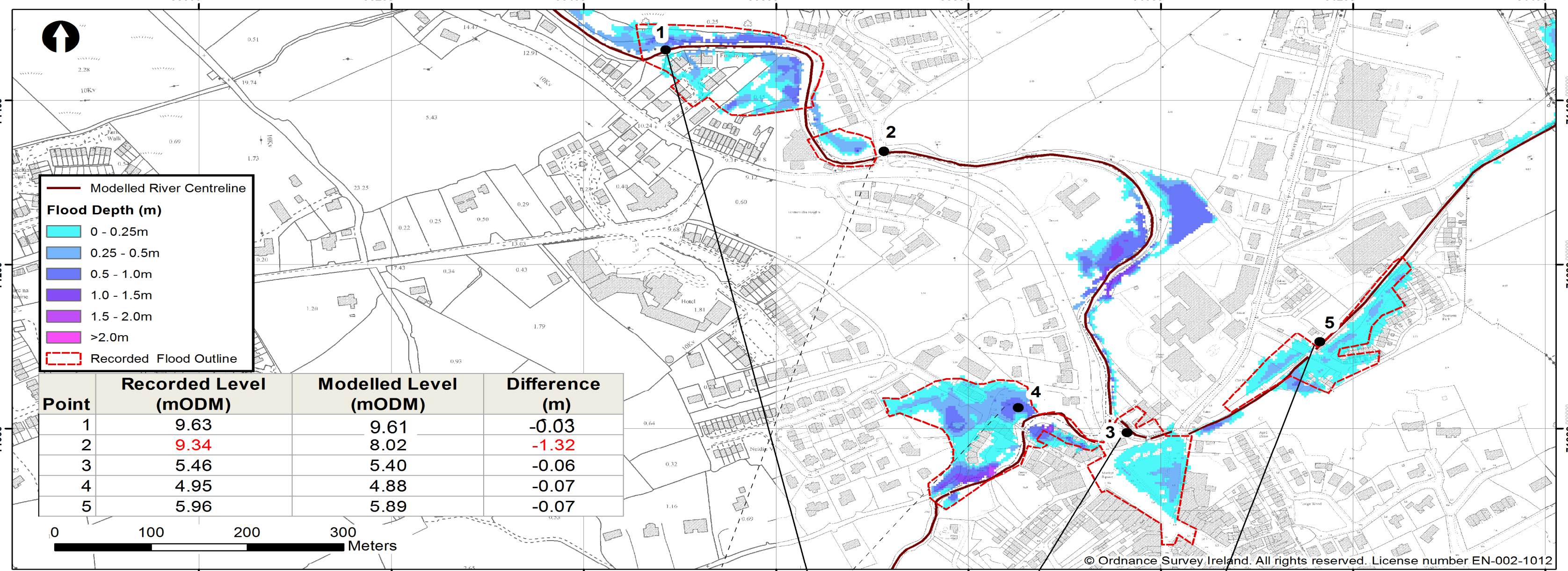
The flood outline and levels generally matched well with the photos, recorded outline and levels. The calibration at Finnihy Banks Estate was improved with the infill survey data for the steeping stones weir "structure" and adjacent bank levels.
The greatest discrepancies were at:
1) Villas Bridge where the structure does not act constrict flow in the model nor was the bridge observed to affect water levels and flows in the river channel survey undertaken in March 2013.The recorded flood level was based on wrack marks in the field upstream of the bridge and is reported as only being accurate to 1m in horizontal plane on the flood photo. This could equate to 0.3 to 1m difference in elevation on the steep ground depending where the surveyed level was taken. Furthermore, the recorded flood outline was found to intersect the DTM at approximately 8.5mODM. Therefore, there is up to 0.8m uncertainty in the observed level which should be considered when comparing with the modelled results.
2) Convent grounds where the model predicted greater flooding than recorded. However, this location was identified as at risk of regular flooding during the flood risk review. Therefore, it is not unreasonable to expect this location to flood during this extreme flood.

Sensitivity Test 1: Increased Flow

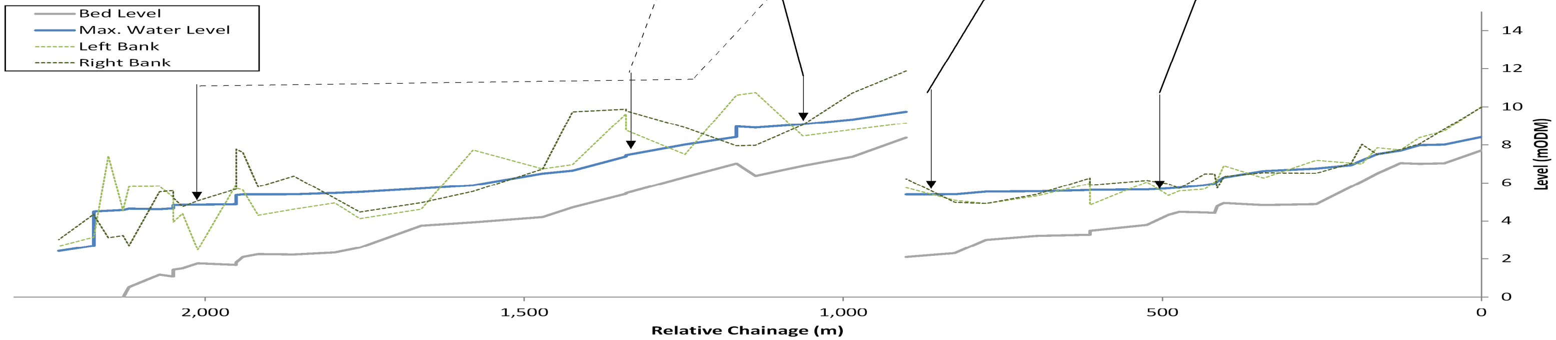
Model Run ID	I32KE_FHD010_D2
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.

Hydrological inflows	All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED, the pooling group and the pivotal site selected. This is broadly equivalent to the HEFS 1%AEP as the increase in urban extent has less the 1% impact on peak flow. Therefore, the HEFS 1%AEP results (FHD010) have been used as the sensitivity test results.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A 30% increase in flows resulted in a 37% increase in the flood extent. The the largest changes in flood risk occurring around the Convent, Henry Street and New Road due to the increase in backwater upstream of Finnihy Bridge. The flood extent did not significantly increase at the Finnihy Banks Estate or along the Lissaniska due to the narrow floodplain. However, flood depth and hazard increased with the increase in flow. Therefore flood risk in centre Kenmare was deemed to be sensitive to the uncertainties in flow. The design flows reproduce the relative frequency of flooding in the AFA and correspond well with local engineer's estimates. Therefore the design peak flows have been applied for the design scenarios. An allowance should be made when interpreting the design flood outlines and the in the sizing of any flood risk management option due to this uncertainty in flood level and extent caused by the uncertainties in flow.
Sensitivity Test 2: Increased Downstream Level	
Model Run ID	I32KE_CMD010_D1
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	A 0.5m increase in water level was applied to the downstream boundary. This is broadly equivalent to the MRFS which increases sea level by 0.55m. Therefore, the MRFS 1%AEP results (CMD010) have been used to conduct the sensitivity test.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A 0.5m increase in level resulted in a significant 61% in flood extent with the largest increases in flood risk occurring around the suspension bridge and the outfall of the Finnihy. There is also a small increase in flood risk along the Finnihy up to the Creamery Bridge as the increased tidal levels cause greater backwater and flood risk near Cromwell's Bridge. Therefore flood risk at the suspension bridge and downstream of the Cromwell's Bridge on the Finnihy was deemed to be sensitive to the uncertainties in level. Flood risk upstream of Cromwell's Bridge was deemed to be insensitive to the downstream level. The design ICPSS tide plus surge levels were applied in the absence of more detailed guage data at Kenmare in agreement with OPW and the Study Breif. An allowance should be made when interpreting the design flood outlines and in the sizing of any flood risk management option due to this uncertainty in tidal level and extent.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I32KE_FCSN01_D2
Hydraulic Modification to Design Model	The Manning's 'n' values were increased to the upper limit of the industry recommended ranges. Finnihy active channel 0.050 to 0.055 Finnihy river banks 0.080 to 0.100 Lissaniska active channel 0.050 to 0.055 Lissaniska river banks 0.080 to 0.100 Pasture/ parkland /garden 0.060 to 0.070 Dense vegetation 0.080 to 0.100 Buildings 0.200 to 0.300 Roads 0.030 to 0.035
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The increase in the Manning's 'n' values used in the model resulted in less than 0.13m Increase in water level (RMSE) and less than 11% increase in extent for the 1%AEP event. The greatest increase in flood risk was behind the School and near Pound Lane. However the increase in depth of flooding was shallow (< 0.25m). Therefore, the Kenmare model was not deemed sensitive to the Manning's 'n' values at the target 1%AEP event.
Sensitivity Test 4: Reduced Finnihy Bridge Pipe Obstruction	
Model Run ID	I32KE_FCSS01_D2
Hydraulic Modification to Design Model	The soffit of the Finnihy Bridge (21FINN00136D) was raised by 1.39m to 5.15mODM to remove the influence of the pipe crossing which is assumed to be present in the design scenario.
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The removal of the utility pipe at Finnihy Bridge significantly reduced flood risk to Rose Cottages, Market Street and even Scarteen Park Estate. This reduction is flood risk occurs because the Finnihy Bridge is able to pass an additional 11 m3/s or 20% compared with the design scenario. This increased capacity of the bridge reduces the backwater effects upstream on the Finnihy and Lissaniska and therefore the amount of water spilling out-of-bank upstream and flooding the left bank floodplain. In reality, the amount of head loss due to the blockage of the pipe and any debris that gets caught against it will be somewhere between the two scenarios tested. The design scenario assumes 100% blockage above the pipe as a worst-case scenario. This assumption corresponds well with levels and flood risk upstream of the Finnihy Bridge in the 2008 event and deemed appropriate to assess flood risk. The effective capacity of Finnihy Bridge should be carefully considered when interpreting flood maps, deriving flood risk management options and assessing any future flood events.

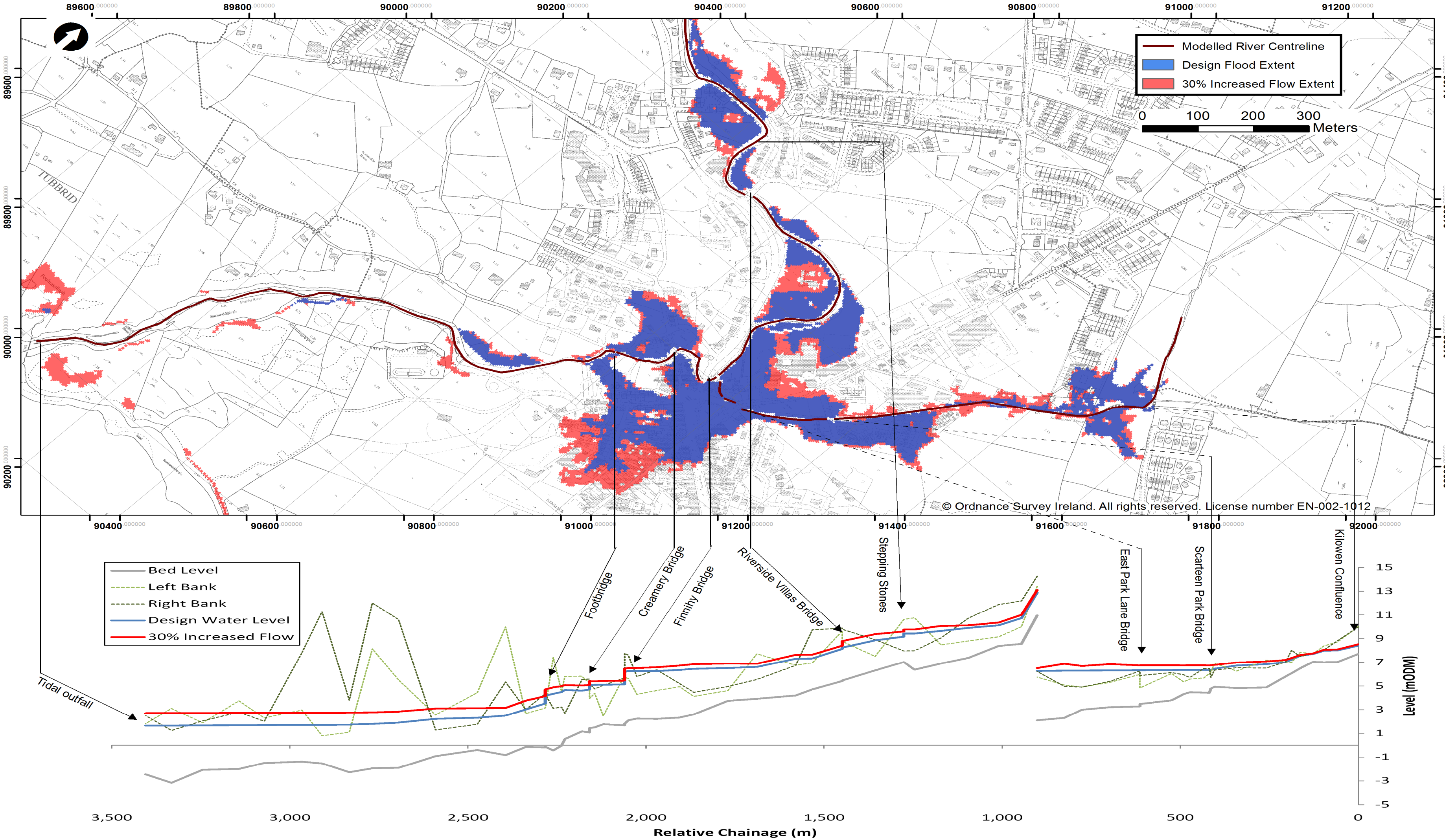
Map D.1: Calibration to 22 October 2008 Flood Event



Point	Recorded Level (mODM)	Modelled Level (mODM)	Difference (m)
1	9.63	9.61	-0.03
2	9.34	8.02	-1.32
3	5.46	5.40	-0.06
4	4.95	4.88	-0.07
5	5.96	5.89	-0.07

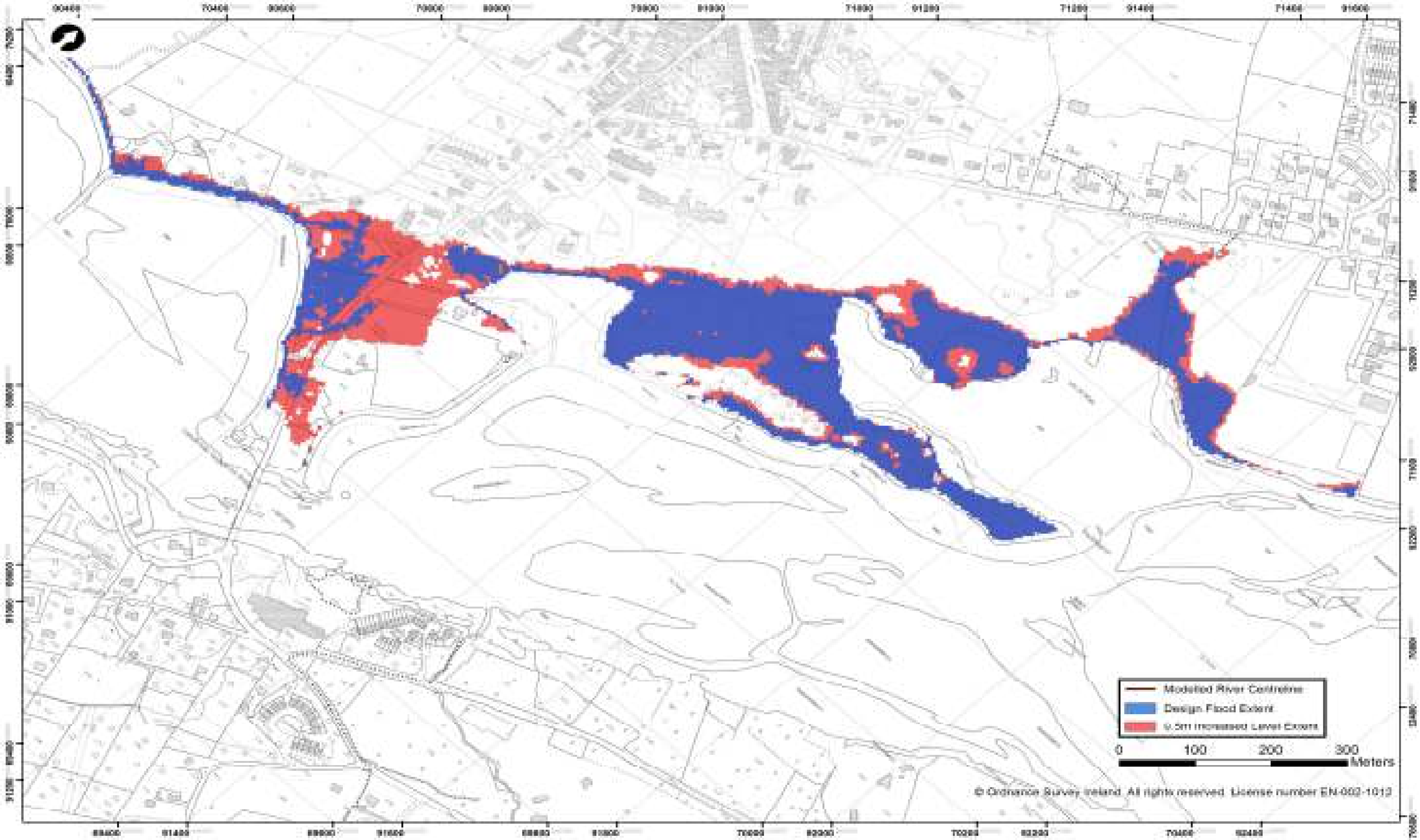


Map D.2: Sensitivity to 30% Increased Flow



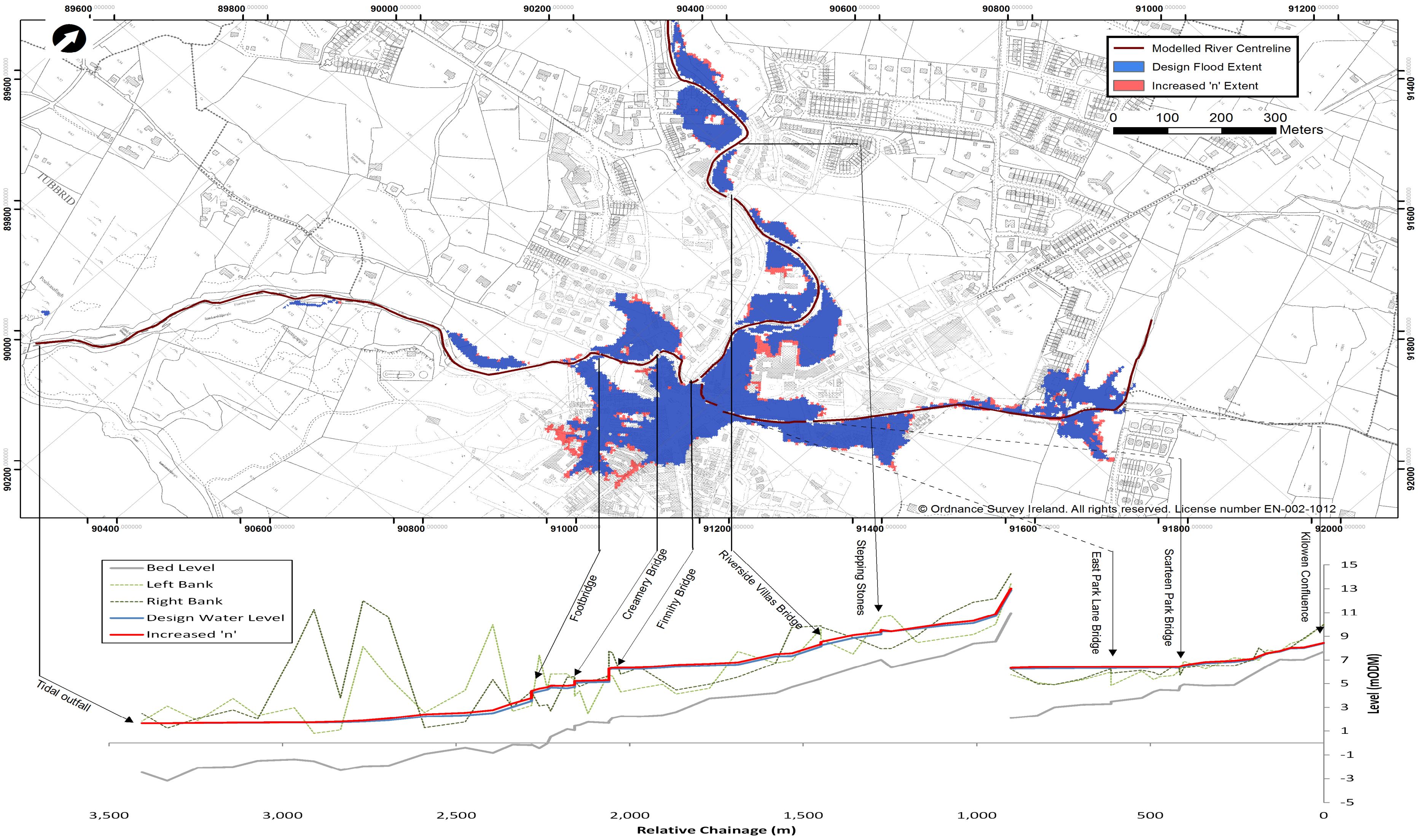
Mott MacDonald

Map D.3: Sensitivity to Increased Downstream Boundary



Mott MacDonald

Map D.4: Sensitivity to Increased Manning's 'n'



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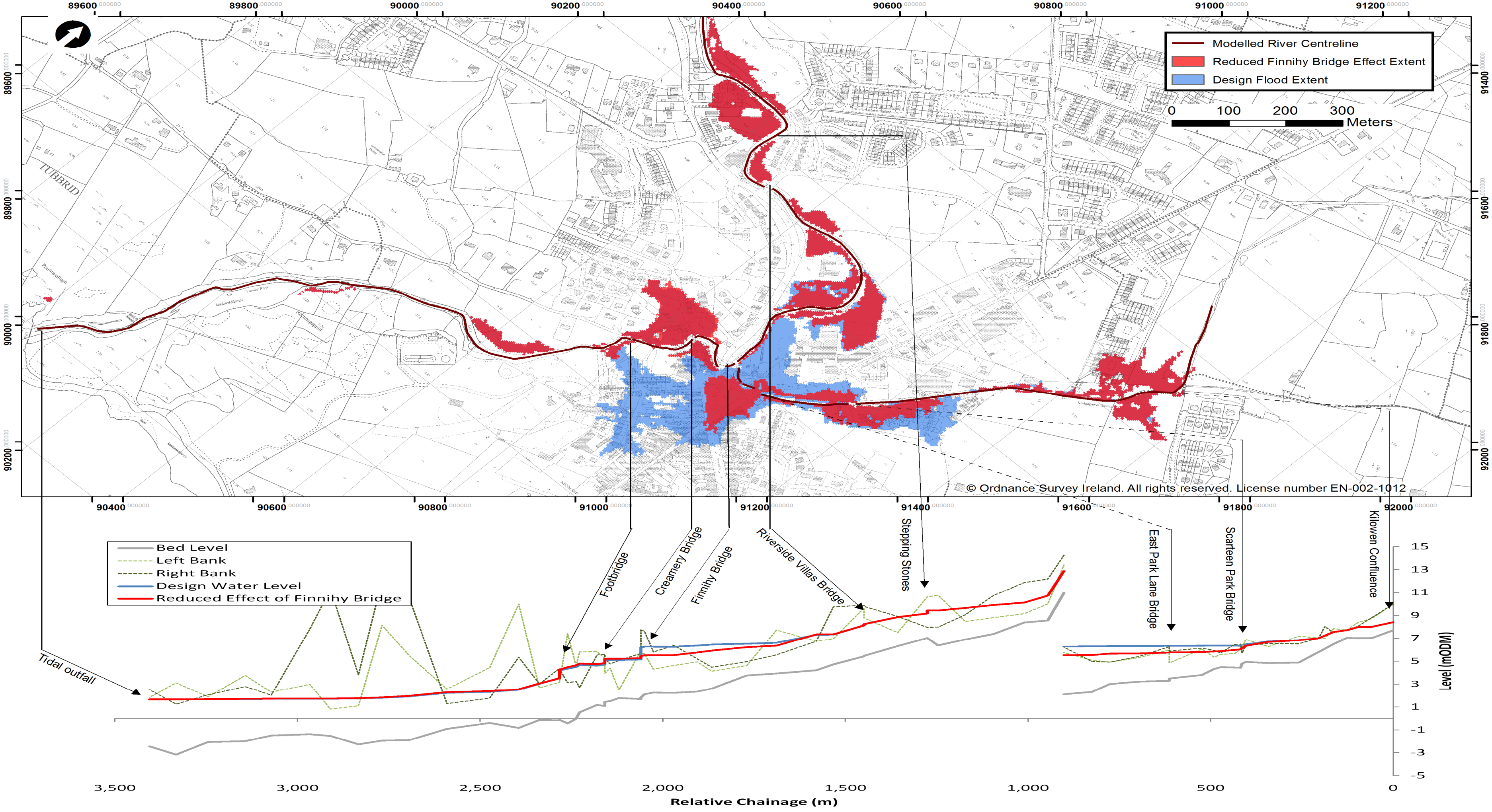
Map D.5: Sensitivity to Assumptions of Pipe Obstructions at Finnihy Bridge



D.3 Model Outputs

Kenmare Model Outputs	
Threshold of Property Flooding	10%AEP Fluvial Current Scenario at Finnihy Banks Estate 2%AEP Coastal Current Scenario at Kenmare Cooperage/ Suspension Bridge 5%AEP Wave overtopping at Kenmare Cooperage and Pier Road
Critical Structures for Flood Risk	Finnihy Bridge, Footbridge, Steeping Stones, East Park Bridge
Areas affected by flooding	Fluvial dominated events: Finnihy Banks Estate, Rose Cottages, Main Square, Creamery Car Park Coastal dominated events: Golf course, Pier Road, Kenmare Cooperage Wave dominated events: Pier Road, Kenmare Cooperage
Risk to people	There is significant and extreme risk to people for the 5%AEP and larger magnitude events. The greatest risk to people is associated with deep and fast flowing water immeadiately upstream of Riverside Villas Bridge and near Rose Cottages by the Main Square.
Consideration for Flood Risk Management Options	The time to peak is less than 5 hours which limits the time available for flood warning. Increased conveyance measures should be considered for the critical structures identified above. There is limited storage available upstream of the golf course on the Lissaniska Stream/Kealnagower Stream to enable any storage or attenuation measures.

Flood Map Outputs

The following table outlines the print-ready flood mapping deliverables provided in Schedule 4.

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Map	Flood Zone Map	Flood Depth Map	Flood Velocity Map	Flood Hazard Map
I32KE_FCD200_D2_001	Design	10	MHWS	I32HCD33_EXFCD_D2		I32HCD33_DPFCD200_D2	I32HCD33_VLFCD200_D2	I32HCD33_HZFCD200_D2
I32KE_FCD010_D2_001	Design	1	MHWS	I32HCD33_EXFCD_D2	I32HCD33_ZNFCD_D2	I32HCD33_DPFCD010_D2	I32HCD33_VLFCD010_D2	I32HCD33_HZFCD010_D2
I32KE_FCD001_D2_001	Design	0.1	MHWS	I32HCD33_EXFCD_D2	I32HCD33_ZNFCD_D2	I32HCD33_DPFCD001_D2	I32HCD33_VLFCD001_D2	I32HCD33_HZFCD001_D2
I32KE_FMD200_D2_001	Design	10	MHWS	I32HCD33_EXFMD_D2				
I32KE_FMD010_D2_001	Design	1	MHWS	I32HCD33_EXFMD_D2				
I32KE_FMD001_D2_001	Design	0.1	MHWS	I32HCD33_EXFMD_D2				
I32KE_CCD100_D1_001	Design	50	10	I32HCD33_EXCCD_D2		I32HCD33_DPCCD200_D2	I32HCD33_VLCCD200_D2	I32HCD33_HZCCD005_D2
I32KE_CCD005_D1_001	Design	50	0.5	I32HCD33_EXCCD_D2		I32HCD33_DPCCD005_D2	I32HCD33_VLCCD005_D2	I32HCD33_HZCCD200_D2
I32KE_CCD001_D1_001	Design	50	0.1	I32HCD33_EXCCD_D2		I32HCD33_DPCCD001_D2	I32HCD33_VLCCD001_D2	I32HCD33_HZCCD001_D2
I32KE_CMD100_D1_001	Design	50	10	I32HCD33_EXCMD_D2				
I32KE_CMD005_D1_001	Design	50	0.5	I32HCD33_EXCMD_D2				
I32KE_CMD001_D1_001	Design	50	0.1	I32HCD33_EXCMD_D2				

GIS Outputs

Print Ready Maps are denoted by the highlighted cells and provided in Schedule 4

Model Run ID	Scenario	Fluvial %AEP	Coastal %AEP	Flood Extent Polygon and Nodes	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
I32KE_FCD500_D2_001	Design	50	MHWS	I32EXFCD500D2		I32DPFCD500D2	I32VLFCD500D2	I32HZFCD500D2
I32KE_FCD200_D2_001	Design	20	MHWS	I32EXFCD200D2		I32DPFCD200D2	I32VLFCD200D2	I32HZFCD200D2
I32KE_FCD200_D2_001	Design	10	MHWS	I32EXFCD200D2		I32DPFCD200D2	I32VLFCD200D2	I32HZFCD200D2
I32KE_FCD050_D2_001	Design	5	MHWS	I32EXFCD050D2		I32DPFCD050D2	I32VLFCD050D2	I32HZFCD050D2
I32KE_FCD020_D2_001	Design	2	MHWS	I32EXFCD020D2		I32DPFCD020D2	I32VLFCD020D2	I32HZFCD020D2
I32KE_FCD010_D2_001	Design	1	MHWS	I32EXFCD010D2	I32ZNFCD010D2	I32DPFCD010D2	I32VLFCD010D2	I32HZFCD010D2
I32KE_FCD005_D2_001	Design	0.5	MHWS	I32EXFCD005D2		I32DPFCD005D2	I32VLFCD005D2	I32HZFCD005D2
I32KE_FCD001_D2_001	Design	0.1	MHWS	I32EXFCD001D2	I32ZNFCD001D2	I32DPFCD001D2	I32VLFCD001D2	I32HZFCD001D2
I32KE_FMD500_D2_001	Design	50	MHWS	I32EXFMD500D2		I32DPFMD500D2	I32VLFMD500D2	I32HZFMD500D2
I32KE_FMD200_D2_001	Design	20	MHWS	I32EXFMD200D2		I32DPFMD200D2	I32VLFMD200D2	I32HZFMD200D2
I32KE_FMD200_D2_001	Design	10	MHWS	I32EXFMD200D2		I32DPFMD200D2	I32VLFMD200D2	I32HZFMD200D2
I32KE_FMD050_D2_001	Design	5	MHWS	I32EXFMD050D2		I32DPFMD050D2	I32VLFMD050D2	I32HZFMD050D2
I32KE_FMD020_D2_001	Design	2	MHWS	I32EXFMD020D2		I32DPFMD020D2	I32VLFMD020D2	I32HZFMD020D2
I32KE_FMD010_D2_001	Design	1	MHWS	I32EXFMD010D2		I32DPFMD010D2	I32VLFMD010D2	I32HZFMD010D2
I32KE_FMD005_D2_001	Design	0.5	MHWS	I32EXFMD005D2		I32DPFMD005D2	I32VLFMD005D2	I32HZFMD005D2
I32KE_FMD001_D2_001	Design	0.1	MHWS	I32EXFMD001D2		I32DPFMD001D2	I32VLFMD001D2	I32HZFMD001D2
I32KE_FHD200_D2_001	Design	10	MHWS	I32EXFHD200D2		I32DPFHD200D2	I32VLFHD200D2	I32HZFHD200D2
I32KE_FHD010_D2_001	Design	1	MHWS	I32EXFHD010D2		I32DPFHD010D2	I32VLFHD010D2	I32HZFHD010D2
I32KE_FHD001_D2_001	Design	0.1	MHWS	I32EXFHD001D2		I32DPFHD001D2	I32VLFHD001D2	I32HZFHD001D2
I32KE_CCD500_D1_001	Design	50	50	I32EXCCD500D2		I32DPCCD500D2	I32VLCCD500D2	I32HZCCD500D2
I32KE_CCD100_D1_001	Design	50	20	I32EXCCD200D2		I32DPCCD200D2	I32VLCCD200D2	I32HZCCD200D2
I32KE_CCD100_D1_001	Design	50	10	I32EXCCD200D2		I32DPCCD200D2	I32VLCCD200D2	I32HZCCD200D2
I32KE_CCD050_D1_001	Design	50	5	I32EXCCD050D2		I32DPCCD050D2	I32VLCCD050D2	I32HZCCD050D2
I32KE_CCD020_D1_001	Design	50	2	I32EXCCD020D2		I32DPCCD020D2	I32VLCCD020D2	I32HZCCD020D2
I32KE_CCD010_D1_001	Design	50	1	I32EXCCD010D2		I32DPCCD010D2	I32VLCCD010D2	I32HZCCD010D2
I32KE_CCD005_D1_001	Design	50	0.5	I32EXCCD005D2	I32ZNCCD005D2	I32DPCCD005D2	I32VLCCD005D2	I32HZCCD005D2
I32KE_CCD001_D1_001	Design	50	0.1	I32EXCCD001D2	I32ZNCCD001D2	I32DPCCD001D2	I32VLCCD001D2	I32HZCCD001D2
I32KE_CMD500_D1_001	Design	50	50	I32EXCMD500D2		I32DPCMD500D2	I32VLCMD500D2	I32HZCMD500D2
I32KE_CMD100_D1_001	Design	50	20	I32EXCMD200D2		I32DPCMD200D2	I32VLCMD200D2	I32HZCMD200D2
I32KE_CMD100_D1_001	Design	50	10	I32EXCMD200D2		I32DPCMD200D2	I32VLCMD200D2	I32HZCMD200D2
I32KE_CMD050_D1_001	Design	50	5	I32EXCMD050D2		I32DPCMD050D2	I32VLCMD050D2	I32HZCMD050D2
I32KE_CMD020_D1_001	Design	50	2	I32EXCMD020D2		I32DPCMD020D2	I32VLCMD020D2	I32HZCMD020D2
I32KE_CMD010_D1_001	Design	50	1	I32EXCMD010D2		I32DPCMD010D2	I32VLCMD010D2	I32HZCMD010D2
I32KE_CMD005_D1_001	Design	50	0.5	I32EXCMD005D2		I32DPCMD005D2	I32VLCMD005D2	I32HZCMD005D2
I32KE_CMD001_D1_001	Design	50	0.1	I32EXCMD001D2		I32DPCMD001D2	I32VLCMD001D2	I32HZCMD001D2
I32KE_CHD100_D1_001	Design	50	10	I32EXCHD200D2		I32DPCHD200D2	I32VLCHD200D2	I32HZCHD200D2
I32KE_CHD010_D1_001	Design	50	0.5	I32EXCHD010D2		I32DPCHD010D2	I32VLCHD010D2	I32HZCHD010D2
I32KE_CHD001_D1_001	Design	50	0.1	I32EXCHD001D2		I32DPCHD001D2	I32VLCHD001D2	I32HZCHD001D2
I32KE_WCD100_D1_001	Design	50	10	I32EXWCD200D2		I32DPWCD200D2	I32VLWCD200D2	I32HZWCD200D2
I32KE_WCD050_D1_001	Design	50	5	I32EXWCD050D2		I32DPWCD050D2	I32VLWCD050D2	I32HZWCD050D2