Cullompton Eastern Distributor

Flood Risk Assessment

Model Operation Manual

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Flood Risk Assessment

Model Operation Manual

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Front cover. Upstream view of the Spratford Millstream

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1 Introduction

Hyder Consulting (UK) Ltd. (Hyder) has been commissioned by Devon County Council to prepare a Flood Risk Assessment (FRA) in support of a planning application for an Eastern Distributor Road (EDR) around Cullompton, Mid Devon. The route options cross the floodplain of the River Culm (Figure 1).

To inform the FRA, Hyder has undertaken detailed hydraulic modelling of the River Culm and its tributaries. In particular, an existing ISIS 1D model, built by PDMM Posford Haskoning[1] (Haskoning) on behalf of the Environment Agency in 2002, has been reviewed and improved, and then linked to a 2D representation of the floodplain.

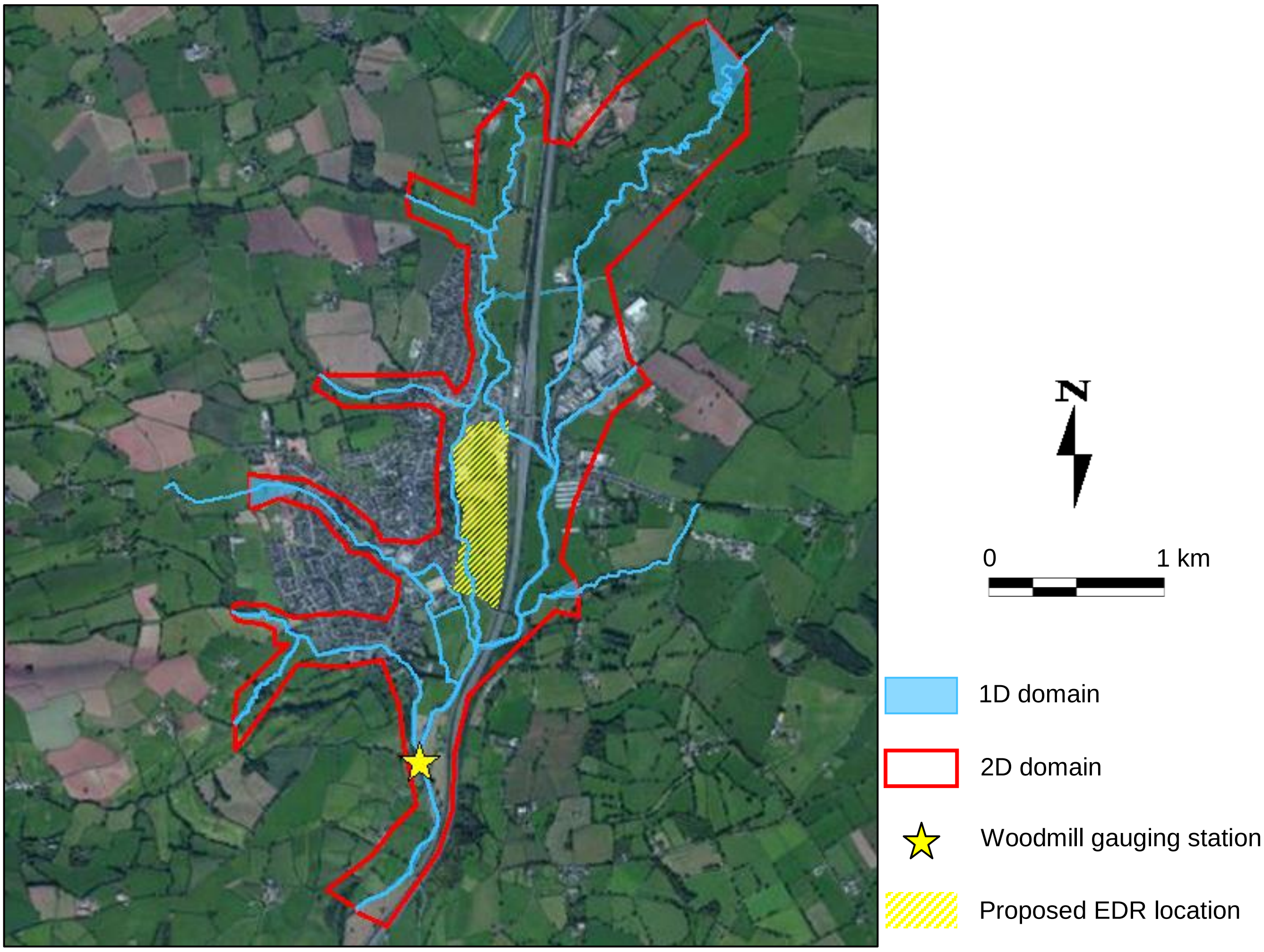
This report describes the key features of the model update, with the intention of enabling future users to operate the model easily. Initial comments on the baseline model results are also provided.

Figure 1. The River Culm floodplain, towards the southern end of Cullompton Community Association's (CCA) fields - the trees mark the line of the river

[1] Now Royal HaskoningDHV

2 Technical summary of the model build

Software chosen and why:	A linked 1D-2D model of the River Culm and its tributaries has been built to simulate flood events. This modelling approach has been taken, since it combines the strength of 1D models in representing in-bank flows and channel features such as bridges and culverts accurately, and the strength of 2D models in simulating complex out-of-bank floodplain flows. ISIS-TUFLOW software (ISIS version 3.6.3.163 and TUFLOW build 2012-05-AC-iDP-w64) has been used to construct the model. This software is a reliable hydrodynamic engine that enables an integrated approach to modelling, combining open channel, closed pipe and overland flow.
Model extent:	The model covers a 7 km stretch of the River Culm, extending from Skinner's Farm in the north (NGR ST 04156 09932) to the vicinity of Highdown in the south (NGR ST 01680 04946; Figure 2). The Spratford Millstream and the lower reaches of Heron's Bank Stream, St. Andrew's Well Stream, Spratford Stream, Crow Green Stream, Cole Brook and the River Ken (North and South), are also represented.



© Bing Maps (2014)

Figure 2. Coverage of the 1D and 2D model domains

1D geometry, including node labelling:	As mentioned in section 1, an existing ISIS 1D model of the River Culm, developed by Haskoning in 2002, has formed the basis of the model build. In constructing the existing model, Haskoning used survey data collected between 1999 and 2001. Since then, there have been some changes to channel and floodplain geometry in Cullompton, associated with a new residential development at Millenium Way, the construction of a Tesco Superstore off Station Road, and desilting of the M5 flood relief channel. Sumo Services Ltd. (Sumo) has, therefore, been commissioned, as part of the Cullompton EDR FRA, to collect new survey data in these areas. The new data have been used to update the model geometry. The key changes that have been made to the existing ISIS 1D model, as part of the Cullompton EDR FRA work, are as follows: **1** Improved representation of key structures (e.g. Spratford Stream mill race sluice, First Bridge, Last Bridge, weir at Woodmill gauging station, Baulk Bridge), using latest hydraulic units and new survey data (where structures are known to have been modified since 2001); **2** Removal of artificial slots from river sections (used by Haskoning for model stability); **3** Addition of interpolates between surveyed cross-sections to improve model stability; **4** Cross-sections trimmed to bank top, with the floodplain now being represented in the 2D model domain; **5** Revised inflow hydrographs; **6** Update of downstream boundary conditions; **7** Geo-referencing of cross-sections. It should be noted that efforts to improve the existing model have focussed on the reaches likely to be affected by the Cullompton EDR, i.e. the River Culm, Spratford Stream and Spratford Millstream; tributaries remote from the proposed road have been left largely as previously modelled by Haskoning (apart from the cross-sections having been trimmed to bank top and linked to a 2D representation of the floodplain). The labelling convention adopted by Haskoning for the ISIS nodes has been maintained and generally takes the following format: XXXXYYYY, where XXXX is an abbreviation of the watercourse name and YYYY is channel chainage starting at 0 m at the downstream end of the model.
2D geometry:	A Digital Terrain Model (DTM) has been created using 1 m resolution filtered LiDAR data; the LiDAR data have been obtained from the Environment Agency's Geomatics Group. The DTM has a grid cell size of 4 m, which is sufficiently small to reproduce hydraulic behaviour, whilst maintaining efficient model run-times. The entire ISIS 1D model, with the exception of the upper reaches of the Crow Green Stream and the River Ken (South), has been linked to the 2D model domain, mainly via HX lines. Key features of the 2D model build are as follows: **1** Representation of floodplain channels and flood relief culverts using a 2D flow constriction layer and TUFLOW's new Storage Reduction Feature (SRF). The flow constriction layer allows the modeller to constrict the flow across a 2D cell side, while SRF values can be used to reduce or increase the storage of the 2D cells. Embedding the floodplain channels within the 2D model domain provides several advantages over Haskoning's 1D representation, including a smoother transition between channel and floodplain conveyance, an inherent representation of the channel sinuosity, and improved flood mapping output for in-channel areas (BMT WBM Pty Ltd., 2012); **2** Modification of the DTM, via z shape layers, using the survey data collected by Sumo in 2013;

	3 Representation of flood defences using a 2d_zln layer. The crest heights of the defences have been set according to the elevations given in the Environment Agency's National Flood and Coastal Defence Database (NFCDD).

Channel roughness (1D domain):

A walk-over survey of the River Culm, Spratford Stream and Spratford Millstream, between Millenium Way and Duke Street, was conducted by Devon County Council, the Environment Agency and Hyder on 30 April 2013. Channel and floodplain conditions were observed and photographed. These field observations, combined with guidance given by Chow (1959), have been used to review the channel roughness values set by Haskoning and update them as appropriate; final values vary between 0.03 and 0.06.

Floodplain roughness (2D domain):

Ground cover on the floodplain has been classified and digitised from OS MasterMap data and Google Earth aerial imagery. The frictional effect of the ground cover on flood flows has been represented by a spatially varying Manning's n – see Table 1. Cell roughness within building footprints has been set to 1, representing the increased energy dissipation of water flowing through and around buildings. This approach is favoured over blocking out the buildings as it includes the storage effects of the buildings being inundated (Syme, 2008).

Table 1. Roughness in the 2D domain

Ground cover	Manning's n	Ground cover	Manning's n
Roads	0.030	Trees scattered	0.060
Footpaths	0.035	Dense scrub	0.070
Gardens/yards/fields	0.045	Trees mixed	0.075
Scrubby grass/marsh	0.050	Trees	0.080
Rail/heath	0.055	Buildings	1.000

Inflows and design runs:

Inflow hydrographs have been derived using Revitalised Flood Hydrograph (ReFH) method boundaries, based on catchment descriptors. A winter design storm of 14 hours duration has been adopted, reflecting the critical duration of the River Culm at the downstream model limit. The hydrographs have been scaled to fit the peak flow estimates from the Environment Agency's Devon Hydrology Strategy (DHS; 2013 version), with the exception of Crow Green Stream, St. Andrew's Well Stream and St. Georges Well Stream plus intervening areas INTER03 and INTER04 (Appendix A, drawing A1). The DHS does not cover the three previously mentioned watercourses, and peak flows for them have, therefore, been derived as part of the Cullompton EDR FRA work. The methods chosen for estimating the flows are as follows:

Lower Crow Green Stream – the modified ReFH method, due to the highly urbanised nature of this watercourse

Upper Crow Green Stream, St. Andrew's Well Stream and St. Georges Well Stream – the Flood Estimation Handbook (FEH) statistical method, due to the highly permeable nature of these catchments (BFIHOST > 65 per cent)

Use of the DHS to derive peak flows for INTER03 and INTER04 was explored, but subtraction of the DHS flows at the upstream end of these intervening areas from those at the downstream end gave unrealistic specific discharge values (either too high or negative). The standard ReFH model has, therefore, been used instead.

The inflow hydrographs have been entered into the ISIS model at the same locations and using the same node labels established by Haskoning. Exceptions to this are the inflows for St. Georges Well Stream and the intervening areas, which were not modelled explicitly by Haskoning; new boundary units have, therefore, been created for these inflows.

	The revised inflow hydrographs are compared against those adopted by Haskoning in Appendix A, for a 1% AEP event. It can be seen that, with the exception of SA0935 (St. Andrew's Well Stream) and Crow2496 (the upper Crow Green Stream), the revised hydrographs generally have a steeper rising limb, higher peak and larger volume than Haskoning's hydrographs. As explained above, the peak flows for SA0935 and Crow2496 are based on manual application of the FEH statistical method, rather than the DHS. The model has been run for the 50%, 2%, 1%, 1% plus climate change and 0.1% annual exceedance probability (AEP) events.
Downstream boundary:	Haskoning used a Flow-Head boundary unit to set the downstream boundary conditions of the ISIS model. Since the floodplain is now being represented in the 2D model domain, Haskoning's stage-discharge relationship for out-of-bank flows is no longer applicable to the 1D model domain. This relationship has, therefore, been revised using ISIS Utilities (the program generates a flow-head boundary for any river/channel unit). A HQ boundary has also been established in the 2D model domain, using longitudinal floodplain slope and TUFLOW's automatic stage-discharge curve generation. It is important to note that the backwater effect of the downstream boundary condition diminishes gradually upstream, to just 1 mm at Baulk Bridge (Baulku, Figure 3). This bridge is located approximately 660 m upstream of the model boundary. The backwater effect does not reach the location of the proposed Cullompton EDR.

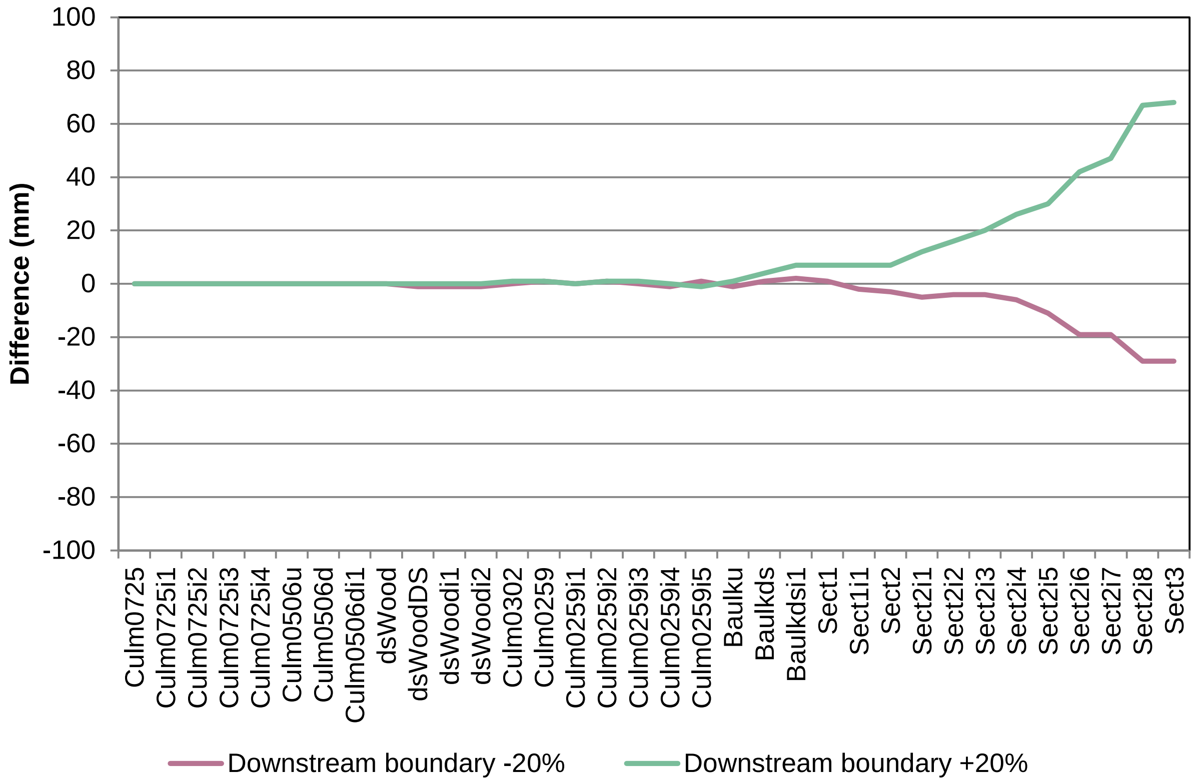


Figure 3. Backwater effect of the downstream boundary condition

Model convergence and stability:	The model shows good convergence and stability; convergence information for the 1% AEP event is given in Figure 4. Some periods of poor convergence do remain, but this is not considered an issue: the poor convergence is short-lived and does not cause any anomalous spikes and wobbles in stage and flow values. TUFLOW mass errors are also within acceptable limits: they exceed 1 per cent near the start of the simulations, but diminish quickly to less than 0.2 per cent (based on _MB.csv; Figure 5).

Hydraulic model calibration:	The gauged flow record for Woodmill, together with rainfall data from local tipping bucket and storage rain gauges[2], has been inspected to identify past flood events that are suitable for model calibration purposes. Three events, covering both in-bank and out-of-bank flows, have been selected (Table 2).

Table 2. Observed flood events selected for calibration purposes

Event	Start date/time	Peak flow ($m^3 s^{-1}$)	AMAX rank
30-Oct-08	29/10/2008 17:00	169	5
03-Jan-12	03/01/2012 00:00	39	Bankfull
21-Nov-12	20/11/2012 01:00	239	1

For each of these events, catchment average event rainfall has been derived in accordance with the FSR/FSSR16 method. A detailed description of this method is given in volume 4 of the FEH (p. 160-161). The ISIS-TUFLOW model has then been run using the event rainfall. The performance of the model is discussed in section 3.

Model sensitivity:	Sensitivity tests have been conducted to examine the effects of changing selected model parameters (Manning's n, peak flow, downstream boundary condition, storm duration and 2D flow constriction size) on maximum stage, in a 1% AEP event. In these sensitivity runs, one parameter value has been modified at a time, while the remaining parameters have been held at their baseline value. The results of the sensitivity tests are presented in section 3.
Model strengths:	The model provides an integrated representation of the River Culm and its floodplain, combining the strength of ISIS 1D in accurately depicting channel features such as narrow cross-sections and hydraulic structures, and the strength of TUFLOW 2D in simulating complex floodplain flows. The dynamically linked ID-2D model gives increased confidence in flooding results compared to a standalone 1D model, due to the reduced interpretation required in flood mapping. It also allows visual presentation of flood results, including time-varying maps of water depths, flow velocities and flood hazard.
Model weaknesses:	The hydrological model is uncalibrated, model inflows having been based on the DHS. Rainfall-runoff model parameters have not been optimised and are based on catchment descriptors. The performance of the Woodmill rating is suspect at high flows, limiting the potential for model calibration and verification. Field-based verification of the model geometry adopted by Haskoning (2002) for *every* hydraulic structure, particularly those on the tributaries of the River Culm, is beyond the scope of the current project. Despite these weaknesses, the hydraulic model is considered sufficiently robust to assess the potential impacts of the Cullompton EDR on flood risk. The performance and robustness of the model is discussed further in section 3.
Future development:	To increase confidence in model outputs and enable the 1D-2D model to be used in the future, for purposes other than the Cullompton EDR FRA, it is recommended that the following work is undertaken: ▪ A review of the Woodmill rating, in particular at high flow conditions

[2] Tipping bucket rain gauges - Clayhanger, Craze Lowman, Culmstock, Dunkeswell, Hemyock, Tiverton; Storage rain gauges - Hemyock Marl Pit, Dunkeswell Aerodrome, Sampford Peverell and Clayhanger

- Detailed hydrological assessment of the River Culm and its tributaries, including an evaluation of the peak flow estimates from the DHS and hydrological calibration
- Field-based verification of the model representation of every hydraulic structure as well as flow routes, across the entire 1D and 2D model domains

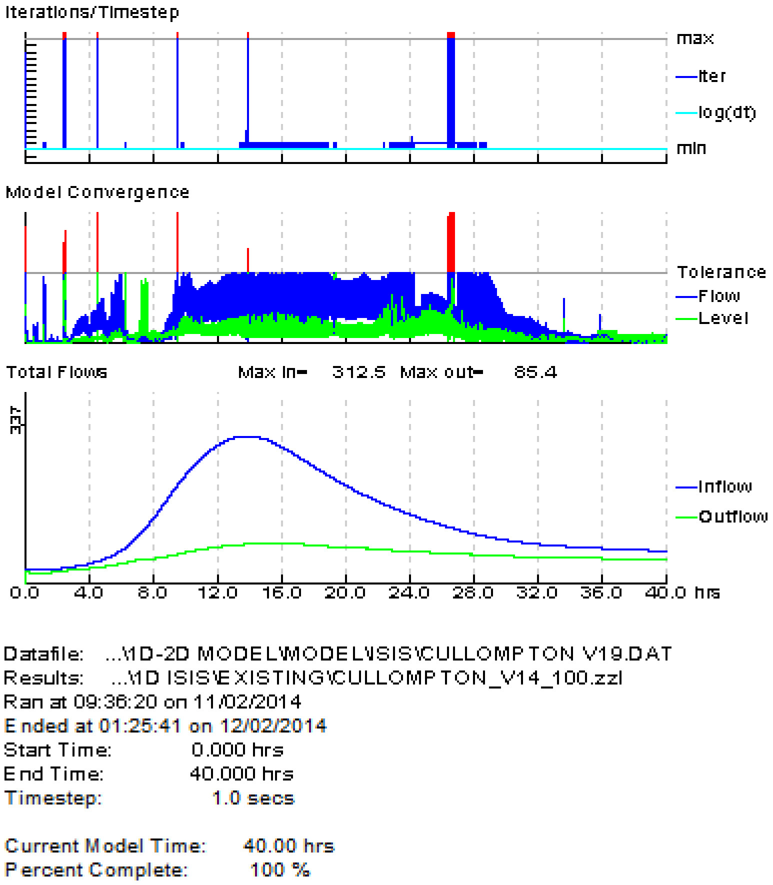


Figure 4. Convergence information for the 1% AEP event

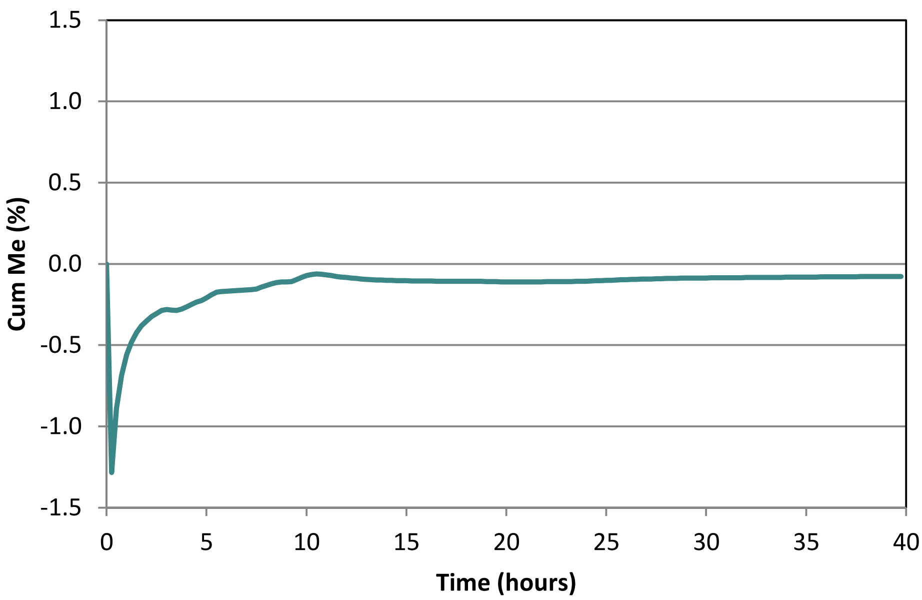


Figure 5. Percentage mass error for the 1% AEP event

3 Baseline modelling results

The key results and findings of the baseline hydraulic modelling and calibration runs are summarised below. Comparison of observed and simulated flow and stage at Woodmill gauging station is made in Figures 6 and 7, while flood depth maps for selected scenarios are provided in Appendix B (drawings B2 to B7).

1 For all three calibration events, using unoptimised rainfall-runoff model parameters, there is good agreement between observed and simulated time-to-peak. The rising and falling limbs of the flow hydrographs are also simulated reasonably well by the hydraulic model up to around bankfull.

2 There is very close agreement between observed and simulated peak water level for the in-channel event of 03-Jan-12; the simulated peak is just 38 mm higher than the observed. Although the hydraulic model does not simulate flow quite as well as stage during this event, there is still reasonable agreement with the observed flow hydrograph: the simulated peak flow is approximately 6 $m^3 s^{-1}$ less than the observed, which equates to a difference of 15 per cent.

3 Much larger discrepancies between observed and simulated flow are evident during the out-of-bank flood events of 30-Oct-08 and 21-Nov-12. Simulated peak flows are 61 to 64 per cent less than observed (104 to 153 $m^3 s^{-1}$). The hydraulic model also underestimates stage by 648 to 834 mm during these events.

4 Comparison of the simulated flood peaks for the 21-Nov-12 event with wrack marks surveyed by the Environment Agency reveals mixed results (Appendix B, drawing B1). Simulated water levels are generally less than observed, although there is good agreement between the two on the northern outskirts of Cullompton, near Venn Farm, and on the playground towards the southern end of the CCA fields. Differences in model performance across the 1D and 2D domains are attributed primarily to the uncalibrated ReFH boundaries, rather than issues with the hydraulic model, as explained in more detail below.

5 In an attempt to better understand the causes of the discrepancies between observed and simulated flow and stage, the hydraulic model has been re-run for the two out-of-bank calibration events with the rainfall-runoff model parameters optimised. In particular, C_{MAX} values have been decreased via application of a donor correction factor, while a blanket value has been used for C_{INI}. It is important to note that these adjustments are crude. The optimisation has been undertaken using a limited number of flood events and is intended for evaluation purposes only; the adjusted parameter values have not been used in the design runs.

Modelling results based on the optimised rainfall-runoff model parameters are displayed as dashed lines in Figure 6. The simulated peak water level matches the observed closely for both out-of-bank events. However, the model still underestimates peak flow by up to 27 per cent. These findings point to two causes of the discrepancies described in points 1 to 4 above:

i. At least some of the uncalibrated ReFH boundaries are not representative of the hydrology of the calibration events. This is not surprising given that the ReFH model parameters are based solely on catchment descriptors. Moreover, a few of the sub-catchments draining to the modelled reach are permeable and/or heavily urbanised. And, the ReFH model is known to perform poorly on such catchments.

For the 21-Nov-12 calibration event, the maximum total flow generated by the uncalibrated ReFH boundaries at any given time is 89 $m^3 s^{-1}$ compared to an

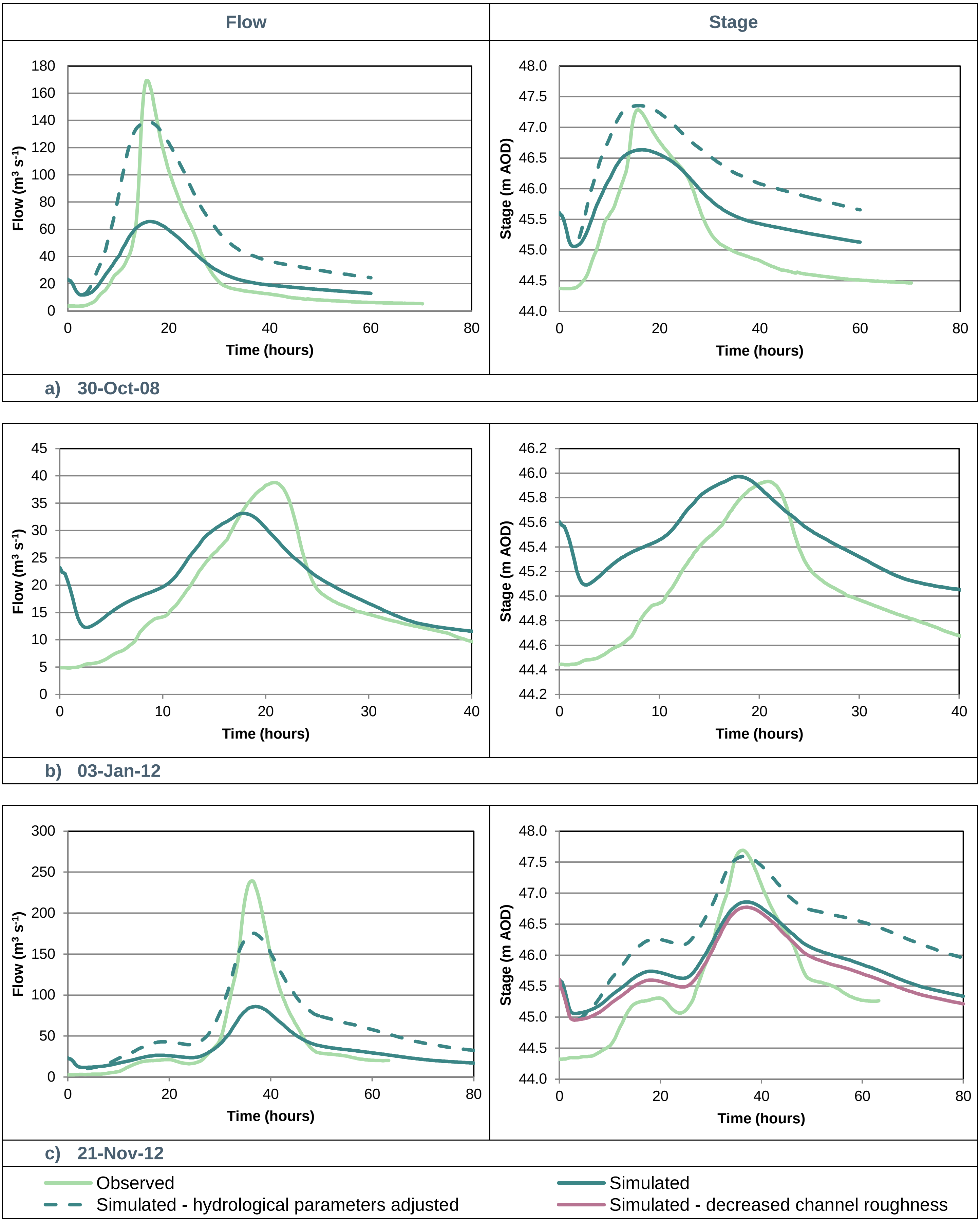


Figure 6. Comparison of observed and simulated flow and stage at Woodmill

observed peak flow of 239 $m^3 s^{-1}$ at Woodmill gauging station. Model inflow increases to 180 $m^3 s^{-1}$ with the optimised rainfall-runoff model parameters. The uncalibrated ReFH boundaries are, therefore, underestimating flows quite considerably. However, this is not considered to be an issue for the design runs, since the design hydrographs have been scaled to fit the peak flow estimates from the DHS and are, therefore, less sensitive to ReFH model parameter values. This point is reinforced by Figure 7, which shows that adjustment of the ReFH model parameters has only a minor influence on the shape of the 1% AEP design hydrograph for the River Culm.

ii. The fact that the hydraulic model simulates peak water level much better than peak flow for the in-channel event of 03-Jan-12 and the re-runs of the out-of-bank events brings the performance of the Environment Agency's current rating for Woodmill gauging station into question. In particular, modelling results suggest that the rating overestimates flow for a given stage, the discrepancy increasing with increasing flood magnitude. The Environment Agency (2013, pers. comm.) itself suspects that the Woodmill rating overestimates high flows.

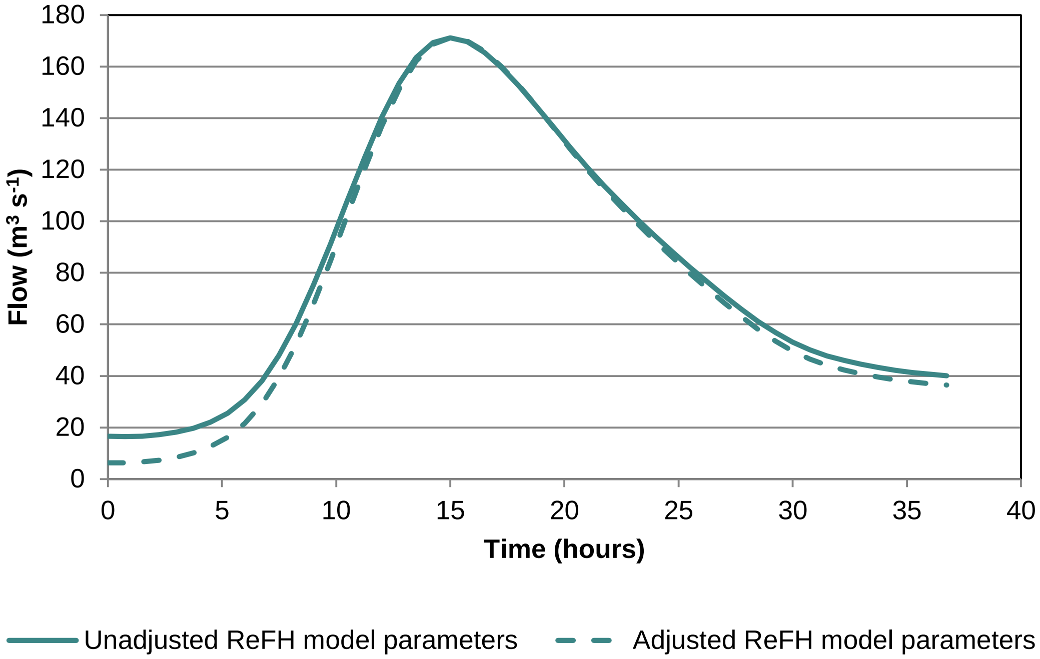


Figure 7. Impact of adjusting ReFH model parameters on the 1% AEP design hydrograph for the River Culm (ISIS node Culm6173)

6 Plots of flow versus stage at Woodmill highlight the differences between the modelled stage-discharge (H-Q) relationship and the Environment Agency's rating (Figure 8). A better match between the two below bankfull can be obtained by decreasing channel roughness locally (from 0.045 to 0.035 at ISIS nodes Culm0506d to Baulku inclusive). However, this adjustment of Manning's n values also serves to decrease simulated peak stage, worsening the match above bankfull (Figure 6c).

The modelled H-Q relationship fits a couple of gaugings from September 2012 very well (Figure 8 inset). These gaugings are the only ones to have been carried out at relatively high flows (>30 $m^3 s^{-1}$) in the last ten years. It would, therefore, be useful to collect more high flow gaugings to see if they display a similar relationship between stage and flow. It is important to bear in mind, however, that the modelled stage-discharge relationship at Woodmill will not have a direct impact on the modelling results for the Cullompton EDR, due to the relatively short backwater length.

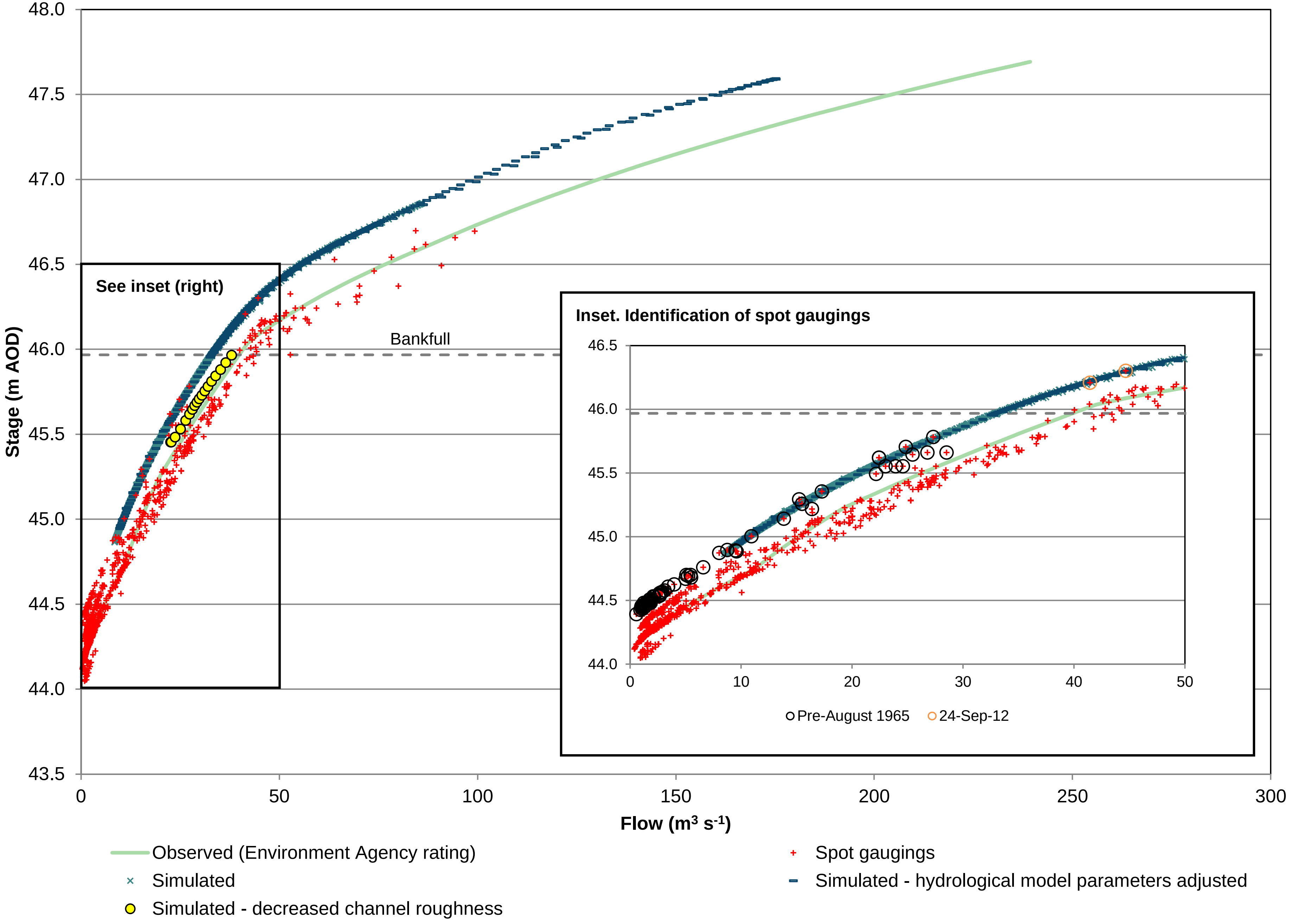


Figure 8. Comparison of observed and simulated stage-discharge relationships at Woodmill gauging station

7 The Environment Agency has suggested that the return period of the 21-Nov-12 flood event was around 1 in 50 years, i.e. 2% AEP. Indeed, the observed peak flow at Woodmill gauging station during this event (239 $m^3 s^{-1}$) is reasonably consistent with the 2% AEP peak flow estimate given by the 2013 DHS (191 $m^3 s^{-1}$), bearing in mind the overestimation of high flows by the Woodmill rating.

Although the model inflows are based largely on the DHS, the modelled 2% AEP peak flow at Woodmill (269 $m^3 s^{-1}$) is notably higher than the DHS peak flow. This difference stems from inconsistencies in the DHS flow estimates at confluences. As illustrated in Figure 9, the sum of the DHS estimates on tributaries is greater than the estimates downstream of confluences. Since the tributary flows have been used as inputs to the hydraulic model, the model predicts higher flows at Woodmill than the DHS for a given AEP, and deeper and more extensive flooding during a 2% AEP design event than was observed in November 2012.

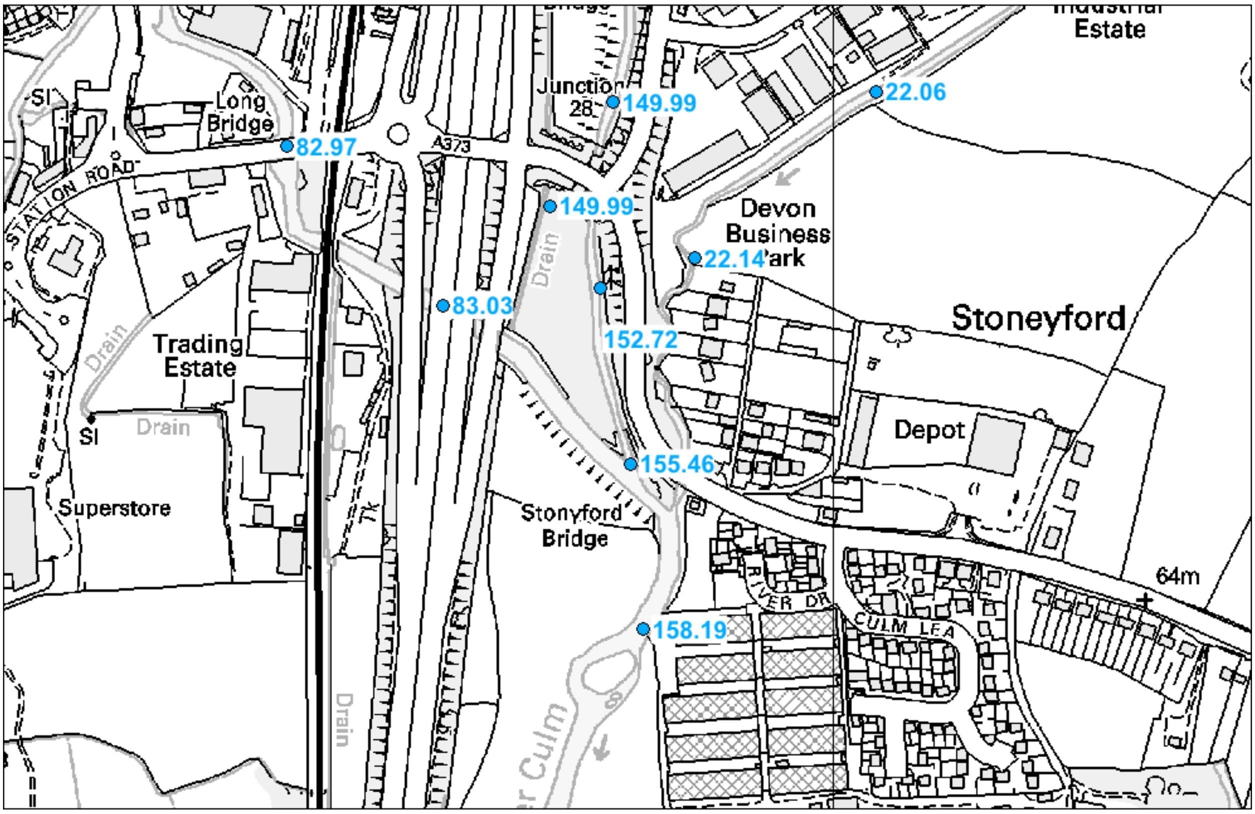


Figure 9. An example of the inconsistencies in DHS peak flow estimates ($m^3 s^{-1}$) at confluences (the flow values shown are for the 2% AEP event)

8 As mentioned in section 2, sensitivity tests have been conducted to examine the effects of changing selected model parameters on maximum stage, in a 1% AEP event. The results of the sensitivity tests are summarised in Table 3. The following observations can be drawn from these results:

- Generally speaking, the model is not very sensitive to Manning's n, peak flow and storm duration. Apart from a few isolated exceptions (26 out of 624 ISIS nodes), the percentage change in water depth is less than the percentage adjustment made to the parameter.

- Decreasing the storm duration from 14 hours to 5 hours results in a median change in water depth of just -8 mm.
- Model output is much less sensitive to increases in 2D flow constriction size (i.e. decreases in the capacity of floodplain channels and flood relief culverts) than decreases. This gives confidence that the model does not underestimate the flood risk associated with these features.

9 Flood depth maps for the 50%, 2%, 1%, 1% plus climate change and 0.1% AEP events are included in Appendix B for reference.

10 In summary, the discrepancies between observed and simulated flow and stage are due primarily to the use of unoptimised ReFH models in the calibration runs and the suspect performance of the Woodmill rating at high flows, rather than issues with the hydraulic model itself. Indeed, the sensitivity analysis has indicated that, overall, the model is not very sensitive to a range of parameters.

Given that the modelling for the Cullompton EDR FRA is fundamentally a comparative exercise, the poor calibration performance is not considered to undermine use of the model for informing the FRA. Even if a better match between the simulations and observations at Woodmill had been obtained, the river network through Cullompton is extremely complex and, as noted by Haskoning (2002), in the absence of any level or flow gauges within the town, the flow splits between the Spratford Stream and the River Culm cannot be calibrated.

Table 3. Sensitivity test results, based on a 1% AEP event

Parameter	Adjustment	Maximum decrease in 1D peak water level*		Maximum increase in 1D peak water level*		Median change (mm)	Mean of absolute % difference	Median of absolute % difference	Maximum absolute difference**
		mm	Model node	mm	Model node				
Manning's n	-20 %	304 *(-25%)*	Cr0490dsi3	110 *(7%)*	Kingsmillus	-69	5	4	26 *(5)*
	+20 %	-39 *(-1%)*	Sect3	398 *(13%)*	ST11dsi4	62	5	4	34 *(5)*
Peak flow	-20 %	-547 *(-14%)*	Culm1364i1	0 *(0%)*	Various	-92	7	6	27 *(18)*
	+20 %	0 *(0%)*	Various	382 *(11)*	Sp1056i1	90	6	5	43 *(11)*
Storm duration	Set to 5 hours	-158 *(-5%)*	NK0260i5	31 *(5%)*	SA0136ds	-8	1	1	12 *(0)*
2D flow constriction size	0.1	-1,694 (-50%)	Culm3026	1 (0%)	Various	-193	12	9	55 *(145)*
	0.5	-29 (-1%)	Culm0506di1	37 (2%)	Culmbp_370i1	0	0	0	2 *(0)*

* The percentage change in 1D peak water level, relative to the 1% AEP baseline channel water depth, is given in italicised brackets

** The number of ISIS nodes where the percentage change in 1D peak water level is greater than 20% is given in italicised brackets (there are 624 nodes in total)

4 Data structure and file names

The model and results files have been arranged into the directory structure presented in Figure 10. The files contained within each sub-directory are summarised in Table 4. With the exception of the ‘Results’ folder, the files have been archived to zip. The zip file is called *Cullompton EDR hydraulic model v0.zip* and has been uploaded to the project’s SharePoint site. The ‘Results’ folder is available separately on DVD (due to the large file sizes involved).

Figure 10. Directory structure of *Cullompton EDR hydraulic model v0.zip*

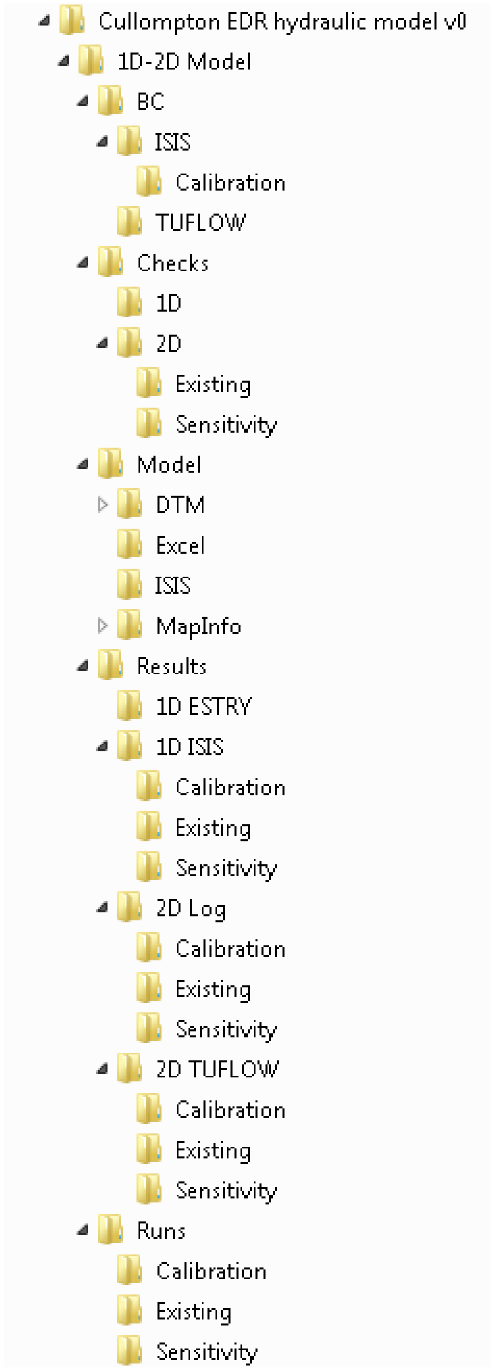


Table 4. Directory contents

Sub-folder 1	Sub-folder 2	Sub-folder 3	Contents	
BC	ISIS	-	Event data files: *UA005763 design X % AEP_Yhr.ied*	
		Calibration	Event data files: *UA005763 Oct08.ied, *Jan12.ied, *Nov12.ied*	
	TUFLOW	-	2D domain downstream boundary conditions for sensitivity tests	
Checks	2D	*Applies to* Existing *and* Sensitivity	Standard TUFLOW check files in MID/MIF format: *Cullompton_v14_100_X* Plus HQ BC: *Cullompton_v14_100_X_2d_bc_tables_check.csv*	
Model	-	-	TUFLOW boundary conditions control file: *Cullompton_v11.tbc* TUFLOW geometry control file: *Cullompton_v12.tgc* TUFLOW materials file: *Cullompton.tmf*	
	DTM	-	2D topography: *Cullompton Combined DTM v02.asc, .grd, .tab*	
	ISIS	-	User prepared datafile: *Cullompton v19.dat* GIS Visualiser schematic: *Cullompton v19.gxy*	
	MapInfo	-	*1d_isis_nodes_Cullompton_v11* *1d_nwk_Cullompton_ISIS_v11* *1d_WLL_Cullompton_ISIS_v09* *2d_bc_Cullompton_DSBDY_v01* *2d_bc_Cullompton_v10* *2d_loc_Cullompton_v01* *2d_code_Cullompton_v02* *2d_mat_Cullompton_v02*	*2d_po_Cullompton_WoodmillGauge_v01* *2d_zsh_Cullompton_FloodDefences_v01* *2d_zsh_Cullompton_BridgeDecks_v01* *2d_fcsh_Cullompton_FPChannels_v07* *2d_fcsh_Cullompton_ReliefChannel_v01* *2d_srf_Cullompton_FPChannels_v02* *2d_srf_Cullompton_ReliefChannel_v01* *2d_zsh_Cullompton_DTMSumoCorrection_v01* *2d_mat_Cullompton_StabilityPatch_v02*
Results	1D ISIS	*Applies to* Calibration, Existing *and* Sensitivity	Unsteady results: *Cullompton_v14_X.zzn* Convergence information: *Cullompton_v14_X.bmp* Other standard ISIS results files: *.exy, .mmm, .uic, .zzd, .zzl, .zzu*	
	2D Log	*Applies to* Calibration, Existing *and* Sensitivity	Simulation log file: *Cullompton_v14_X.tlf* Error, warning and check messages: *_messages.csv/.mif/.mid* Simulations input record: *Cullompton_v14_X.wor*	
	2D TUFLOW	*Applies to* Calibration, Existing *and* Sensitivity	TUFLOW results files: *Cullompton_v14_X.2dm, .2dm.info, .all.sup, .hV.sup, _d.dat, _h.dat, _q.dat, _Times.dat, _V.dat, _ZUK0.dat, _MB2D.csv, _MB.csv, PO.csv, _TS.mif, _TS.mid, _POMM.cvs, Projection.MIF/.MID*	
Runs		*Applies to* Calibration, Existing *and* Sensitivity	ISIS run parameters files: *Cullompton_v14_X.ief* TUFLOW simulation control files: *Cullompton_v14_X.tcf* TUFLOW simulation log: _ *TUFLOW Simulations.log*	

5 Model operation

5.1 General

Run reference:	ISIS-TUFLOW model of the River Culm and tributaries
Run purpose:	To inform a FRA for the Cullompton EDR
Notes on running the model:	▪ To avoid overwriting the existing 1D results, it is recommended that a copy of the .ief files is made, with the results renamed. The file paths in the .ief files should also be updated to reflect the computer drive and directory where the model is being run. ▪ To avoid overwriting the existing 2D results, a copy of the .tcf files should be made. The new .tcf files will need to be referenced in the .ief files.

5.2 ISIS

User prepared datafiles:	*Cullompton v19.dat*
Event data files:	50% AEP: *UA005763 design 50 % AEP_14hr_rev2.IED* 2% AEP: *UA005763 design 2 % AEP_14hr.IED* 1% AEP: *UA005763 design 1 % AEP_14hr_rev2.IED* 1% AEP + climate change: *UA005763 design 1 % AEP+CC_14hr_rev2.IED* 0.1% AEP: *UA005763 design 0.1 % AEP_14hr_rev2.IED*
Run parameter files:	50% AEP: *Cullompton_v14_002.ief* 2% AEP: *Cullompton_v14_050.ief* 1% AEP: *Cullompton_v14_100.ief* 1% AEP + climate change: *Cullompton_v14_100+CC.ief* 0.1% AEP: *Cullompton_v14_1000.ief*

5.3 TUFLOW

Simulation control files:	50% AEP: *Cullompton_v14_002.tcf* 2% AEP: *Cullompton_v14_050.tcf* 1% AEP: *Cullompton_v14_100.tcf* 1% AEP + climate change: *Cullompton_v14_100+CC.tcf* 0.1% AEP: *Cullompton_v14_1000.tcf*
Boundary conditions control files:	*Cullompton_v11.tbc*
Links to 1D domain:	*1d_isis_nodes_Cullompton_v11.tab and 2d_bc_Cullompton_v10.tab*
Geometry control files:	*Cullompton_v12.tgc*
2D grid information:	Grid location: *2d_loc_Cullompton_v01.tab* Grid dimensions in metres (X,Y): *3900, 5600* Cell size in metres: *4* Active domain: *2d_code_Cullompton_v02.tab*
2D grid modifications:	Flood defences: *2d_zsh_Cullompton_FloodDefences_v01.tab* Floodplain channels: *2d_fcsh_Cullompton_FPChannels_v07.tab* and *2d_srf_Cullompton_FPChannels_v02.tab* Lower Crow Green Stream: *2d_fcsh_Cullompton_ReliefChannel_v01.tab* and *2d_srf_Cullompton_ReliefChannel_v01.tab* Bridge decks: *2d_zsh_Cullompton_BridgeDecks_v01.tab* New survey data: *2d_zsh_Cullompton_DTMSumoCorrection_v01.tab*
Materials files:	*Cullompton.TMF*

5.4 Run settings and parameters

Time step:	2 (2D domain)
Model start time:	0 hours
Model end time:	40 hours
Initial conditions:	Saved in .dat file
Map output interval:	900 seconds
Map output data types:	Water depth, velocity, flow, water level, UK flood hazard
Non-default parameters:	Automated Preissmann Slot for River Sections activated; dflood set to 10; maxitr set to 19; All other parameters have been kept at their default values

6 Bibliography

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