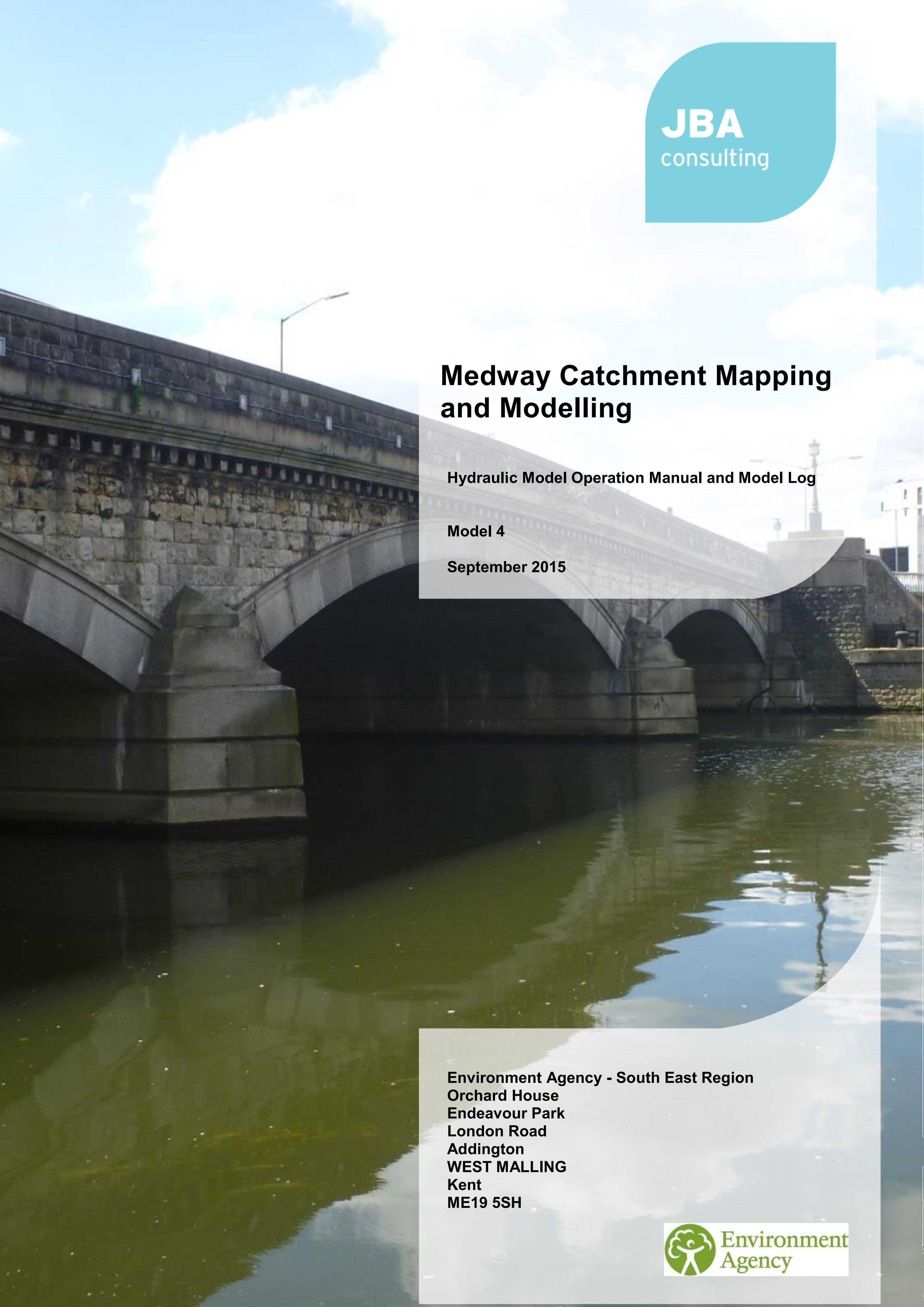


Medway Catchment Mapping and Modelling

Hydraulic Model Operation Manual and Model Log

Model 4

September 2015

Environment Agency - South East Region
Orchard House
Endeavour Park
London Road
Addington
WEST MALLING
Kent
ME19 5SH

JBA Project Manager

Rachel Huitson-Little MSc CEnv MCIWEM C.WEM
JBA Consulting
35 Perrymount Road
HAYWARDS HEATH
West Sussex
RH16 3BW

Revision History

Revision Ref / Date Issued	Amendments	Issued to
Draft v0.5 October 2014 (Issued to assist with model review)	-	Emma Dauben and Neil Gunn (Environment Agency)
Draft Final v1.0 September 2015	Amendments following draft review of Model 4.	Emma Dauben and Neil Gunn (Environment Agency)

Contract

This report describes work commissioned by Emma Dauben, on behalf of Environment Agency South East Region, for the Medway Catchment Mapping and Modelling commission under the Environment Agency's Water and Environment (WEM) Framework. Environment Agency's representative for the contract was Emma Dauben.

Prepared by .... Elizabeth Gorton BA

Assistant Analyst

.... Ben Gibson BSc MSc

Senior Analyst

Reviewed by .... Rachel Huitson-Little MSc CEnv MCIWEM C.WEM

Director

Purpose

This report provides a detailed record of information required to operate the hydraulic model of the River Medway through Maidstone (Model 4) updated and developed under the Medway Catchment Modelling and Mapping project. The appendices contain the hydraulic model check files; these should complement the information in the main report which provides more general information on the model.

Acknowledgements

Thanks to Emma Dauben and Neil Gunn for the provision of information and assistance during the project.

Copyright

Carbon Footprint

A printed copy of the main text in this document will result in a carbon footprint of 140g if 100% post-consumer recycled paper is used and 178g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

JBA is aiming to reduce its per capita carbon emissions.

Contents

List of Figures

List of Tables

Abbreviations

1D .... One-dimensional

2D .... Two-dimensional

AEP .... Annual Exceedance Probability

DSM .... Digital Surface Model

DTM .... Digital Terrain Model

EA .... Environment Agency

ESTRY .... Proprietary 1D modelling software developed by WBM BMT

FEH .... Flood Estimation Handbook

ISIS .... Proprietary modelling software developed by Halcrow/CH2M Hill (all instances of ISIS in this report refer specifically to ISIS 1D)

LIDAR .... Light Detection and Ranging

m AOD .... Metres Above Ordnance Datum Newlyn

OS .... Ordnance Survey

TCF .... TUFLOW Control File

TUFLOW .... Proprietary modelling software developed by WBM BMT (all instances of TUFLOW in this report refer to TUFLOW 'Classic' - a 2D modelling approach)

1 Introduction

The River Medway hydraulic Model 4 extends from Teston to Allington Lock, Maidstone. A section of the River Len downstream of Wat Tyler Way is connected to the hydraulic model. Modelling involves a linked 1D-2D ISIS-TUFLOW approach throughout with a single domain with a 6m grid cell size. The total length of the River Medway watercourse modelled is 15.9km. 0.6km of the River Len is modelled.

The model has been developed principally from the existing River Medway Modelling and Flood Mapping Updates (2008) ISIS model with the addition of new survey data at structures. Modelling of the River Len has been taken from the River Len Modelling and Mapping study (2010). Data implemented from previous models has undergone a detailed review as part of this Medway and Catchment Mapping and Modelling study.

Noted within this model operation manual are the more major changes made during the model update process as well as new files and model setup.

This Model Operation Manual has been put together to enable future users of the model to use the model with ease. Section 2 provides a brief technical overview of the model; further details about the model build and results can be found in the Main Report and in the Modelling Approach and Overview section (Appendix A of this document). Section 3 describes the files and folder structure in which the model has been supplied, with Section 4 providing the information required to run the model. The document also contains information as to how the model has been developed throughout the course of the study.

2 Technical Summary

What software & reason for choice	ISIS-TUFLOW: ISIS v 3.7.1 (64-bit), single precision TUFLOW build 2013-12-AC-iSP-w64 ISIS was used for the 1D component of the model due to the existing model from the 2010 study being developed in this. ISIS version 3.7.1 was used as this was the latest release of the ISIS software at project commencement. TUFLOW Build 2013-12-AC-iSP-w64 was selected as this was the latest release on undertaking design runs.
General Schematisation	The model is 1D-2D linked from the upstream boundaries to Allington Lock. The channel is represented by the ISIS 1D model and the floodplain represented by the TUFLOW 2D domain. Connections between the 1D and 2D domains are implemented as HX lines. The 2D domain has a 6m grid cell size. Downstream of, and including, Allington Lock is represented as a 1D only scheme, with section data extracted from the Lower Medway Flood Forecasting model. A section of the River Len has been connected to the hydraulic model up to the point at which the interaction with the River Medway ceases (Wat Tyler Way). The River Len model was not original developed for such large events on the Medway and as such the River Len was removed from the model for larger events (1%+CC, 0.4% and 0.1% AEP defended and 1%+CC and 0.1% AEP undefended events).
Design Events	The model was built to simulate defended design events for the following events: 20%, 10% (+20% flows to represent climate change), 5%, 3.33%, 2%, 1.33%, 1%, 1% (+20% flows to represent climate change), 0.4% and 0.1% Annual Exceedance Probability (AEP). The model was also simulated for the following undefended events: 5%, 1%, 1% (+20% flows to represent climate change) and 0.1% AEP.
Structures	Structures can be found listed in sections B.1 to B.2 of the Appendix.
Calibration Coefficients	Structure coefficients and spill weir coefficients are detailed in sections B.1 to B.2 of the Appendix. The coefficients have largely been updated from the 2008 model as they were previously considered to be low. The values chosen were all deemed appropriate for the situation being modelled.
Model Proving	**Calibration and verification** Please refer to main project report, Appendix C. **Sensitivity testing** Sensitivity testing of the following parameters were tested as part of the study. The outputs of this testing are summarised within the main study report. - A global change of +20% and -20% in the channel roughness (Manning's 'n') - A global change of +20% and -20% in the total inflows - An adjustment both up and down (+20% and -20%) on downstream boundary condition
Strengths, Weaknesses and Future development	**Strengths** The model is considered the best representation of the River Medway given the available data and scope of the flood risk mapping study. It uses the most up to date survey and LIDAR information available for the study area. **Weaknesses** *Low flows* The model has been built for the purpose of flood risk mapping; therefore it will be optimised for high flows and would need adapting before it was suitable to be used for more low flows.

	This is likely to include representing bed levels in more detail, reducing the distance between sections and representing minor channel features not currently represented e.g. informal weirs and bed level variations. *River Len* A section of the River Len Modelling and Mapping study (2010) model was incorporated into the model to understand the effects of an event on the Medway propagating up the River Len. The River Len model was not original developed for such large events on the Medway, nor was it tested with the water levels experienced on the River Medway) and as such the model in which the full River Len up to Wat Tyler Way is implemented was unstable when water levels peak on the River Medway. Numerous tests were completed to try and stabilise setup and included: - Simplifying 1D inlet and outlets at structures - Widening 1D sections and HX lines - Applying areas of elevated roughness at 1D-2D links - Increasing the A parameter within HX lines However for larger events simulated along the River Medway, the River Len was still not stable despite simplifying the schematisation. Therefore, for the defended 1%+CC, 0.4% and 0.1% AEP events, and the undefended 1%+CC and 0.1% events, the River Len from downstream of Mill Street/Palace Avenue was removed, with the structures at this location connected directly to the River Medway confluence. As well as removing a portion of the River Len a boundary viscosity factor of 5 was also specified in the TCF and the 'A' parameter within the HX lines was increased. These approaches all stabilise the model at 1D-2D links where oscillations were occurring due to the large depths of water and flow rates. Given design events along the River Len are not a focus for the flood risk mapping outputs from this study, this approach was deemed acceptable and agreed with the Environment Agency. Although part of the River Len is included within this model for all design events, it is recommended that the River Len model developed in 2010 remains the basis for understanding fluvial flood risk. **Future development** *Observed flood events* Should future flood events occur in the modelled area it is recommend that the hydrological and hydraulic model is re-visited and verification of observed vs. model predictions be made to assess the performance of the model.
Further comments	**HX widths** HX lines have been digitised to match the width of ISIS cross sections at cross section locations. Between surveyed sections these were digitised to follow a generally consistent bank top level as evidenced by LIDAR, rather than digitising rigidly to a fixed width. In practice this means there is some contraction and expansion of HX line widths between sections. This approach was taken because it provides consistent bank heights between sections and varying bank heights e.g. including very low spots where a channel widens between surveyed points may lead to instabilities. Whilst this approach will result in some differences in section area, the overall impact on floodplain volume is expected to be small.

3 Data Structure and File Names

The final design model files and results supplied contain a series of folders as displayed in Figure 3-1.

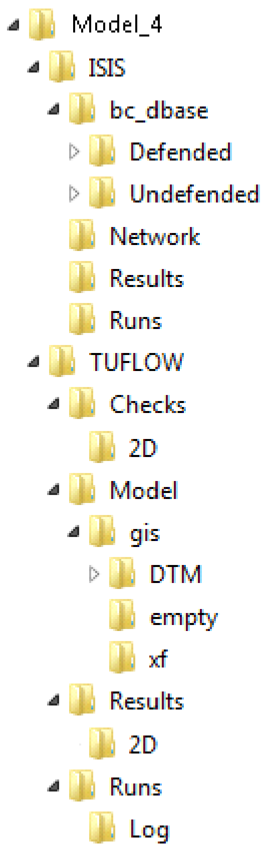
Table 3-1 shows the folder structure and notes the files stored within these.

Table 3-1: Folder Structure and contents of Final Design Model

Folder	SF1	SF2	SF3	SF4	SF5	Contents
ISIS	bc_bdase					Folder containing model boundary conditions in IED files (inflows and tidal boundary)
	Model					ISIS Data File (DAT) and GIS Visualiser File (GXY)
	Results					ISIS Results Files
	Runs					ISIS Event Files (IEF)
TUFLOW	bc_dbase					Boundary conditions for the TUFLOW component of the hydraulic model
	Checks	2D				2D TUFLOW check files Medway_Model4_036_###_####_DDMMM######## or, Medway_Model4_036b_Len_removed_###_####_DDMMM########_BVF_5
	Model					TUFLOW files: TUFLOW Materials File (.tmf) TUFLOW Boundary Conditions (.tbc) TUFLOW Geometry Control (.tgc)
		gis				Standard TUFLOW Model Files
			DTM			Ascii DTM used to define Zpts within the model
				xf		Binary dumps of selected input files, created by TUFLOW to speed up the start-up process next time a simulation is carried out
			empty			Empty geometry file templates
			xf			Binary dumps of selected input files, created by TUFLOW to speed up the start-up process next time a simulation is carried out
	Results	2D				2D TUFLOW results files Medway_Model4_036_###_####_DDMMM######## or, Medway_Model4_036b_Len_removed_###_####_DDMMM########_BVF_5
	Runs					TUFLOW Control Files (.tcf) Medway_Model4_036_~e1~.tcf Medway_Model4_036b_Len_removed_~e1~_BVF_5.tcf
		log				Standard TUFLOW Log files (.csv and .shp) Medway_Model4_036_###_####_DDMMM######## or, Medway_Model4_036b_Len_removed_###_####_DDMMM########_BVF_5

Note: ### denotes Defended or Undefended case. #### denotes return period. DDMMM######## denotes event.

Figure 3-1: File Directory of Final Design Model



4 Model Operation

Run reference	Design runs
Run purpose	Flood Risk Mapping
Operation and model running instructions	Prior to running the hydraulic model, the most straight forward approach is to save all the folders supplied (as listed in Section 3) onto the user's C drive. All the supplied files will then need to be uncompressed with care taken to preserve the supplied folder structure. The 'Default File Path' within each ISIS event file (.ief) should be amended to reflect the revised 'Runs' folder location. To run the model, open the ISIS .ief file in ISIS v3.7.1 (64-bit) and then click run simulation. It is important that both ISIS and TUFLOW are installed on the machine as the ISIS component will not provide accurate results if run independently. An ISIS run file (.ief) has been supplied with each of the models so the model should run without any alteration (provided the 'Default File Path' has been updated).
Explanation of file types	**ISIS** .dat = ISIS Data File .ied = ISIS Event Data File .zzn = ISIS Unsteady Results File .iic = ISIS Initial Conditions Files (used as initial conditions for model runs) .zzl = ISIS labels for unsteady results .ief = ISIS Run Settings (Event File) **TUFLOW** .tcf = TUFLOW Control File .tgc = TUFLOW Geometry Control File .tbc = TUFLOW Boundary Condition Control File

4.1 ISIS

DAT	Medway_Model4_036.DAT Medway_Model4_036b.DAT - for the 2% AEP defended event Medway_Model4_036_Len_removed.DAT - for 1%+CC, 0.4% and 0.1% AEP defended and 1%+CC and 0.1% AEP undefended events.
IED	The IED for each return period and defended / undefended events are displayed in the table below.
IEF	Medway_Model4_036_###_####_DDMMM########.ief, or Medway_Model4_036b_###_####_DDMMM########_Len_removed_BVF_5.ief Note: ### denotes **Defended** or **Undefended** case. #### denotes return period. DDMMM######## denotes event.

Return period	Defended	Undefended
5	26Dec31401000	-
10CC	15Jan55021300	-
20	12Dec57910900	07Feb45110300
30	13Nov19230100	-
50	28Nov31181200	-
75	18Nov27320000	-
100	09Jan50401500	18Feb61962000
100CC	09Jan50401500	18Feb61962000
250	16Dec24190800	-
1000	02Jan32620000	05Dec26370200

Model run parameters (as specified in .ief event files)	ISIS 1D timestep = 1.50s Save interval = 300s The parameters listed below were adjusted from defaults. An explanation for each is provided. **Automated Preissmann Slot for River Sections** Aids model stability during periods of low flow - required for the River Len. Given the magnitude of flows along the River Medway, the impacts on predicted flooding are considered to be minimal. **Maximum iterations = 13 (default is 6).** **= 19 for 1%+CC, 0.4% and 0.1% AEP defended and 0.1%+CC and 0.1% AEP undefended events** Increases the number of iterations at each timestep. This was increased to assist with model stability on the River Len. This is considered acceptable to allow greater iterations for the model to converge, and reduce the likelihood of periods of non-convergence. **dflood (m) = 8 (default is 3)** Height (m) of vertical walls added to the highest point on each river cross section to allow for flooding. This was increased during testing of stability improvements on the River Len. It is intended that this will be reduced for the final design run once agreement is reached on River Len modelling. It is not considered that the value of 8 should be impacting predictions from the hydraulic model.

4.2 TUFLOW

2D Control files (.tcf)	Medway_Model4_036_~e1~.tcf Medway_Model4_036b_Len_removed_~e1~_BVF_5.tcf
2D Boundary condition control file (.tbc)	Medway_Model4_013 Medway_Model4_013b_Len_removed
2D Geometry Control file (.tgc)	Medway_Model4_015 Medway_Model4_015b_Len_removed
1D/2D link files	1d_nd_ISIS_Model4_P_007.shp - all events 1d_x1d_isis_nodes_LEN_014.shp - events with River Len included 2d_bc_hxi_Model4_L_010.shp - events with River Len included 2d_bc_hxi_LEN_025_007.shp - events with River Len included 2d_bc_hxi_Model4_L_010b.shp - events with River Len removed 2d_bc_sx_underpasses_001_L.shp - events with River Len included
2D/2D link files	N/a
ESTRY culvert link files	N/a
Downstream boundary condition(s)	None
2D grid files	**Grid location** 2d_loc_Model4 _L_001.shp **Grid dimensions in metres (X,Y)** 10500, 7500 **Cell size in metres** 6m **Ascii grids**

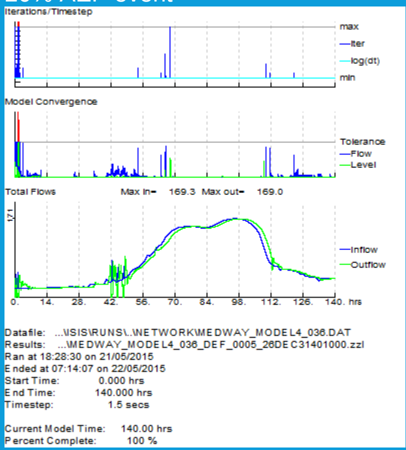
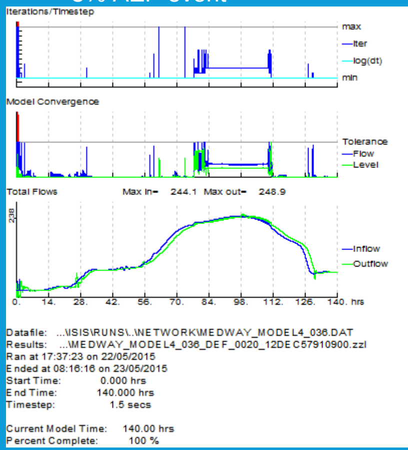
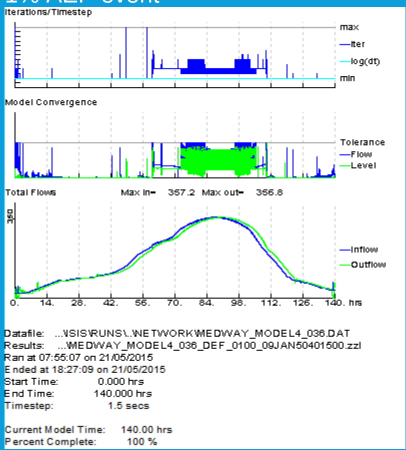
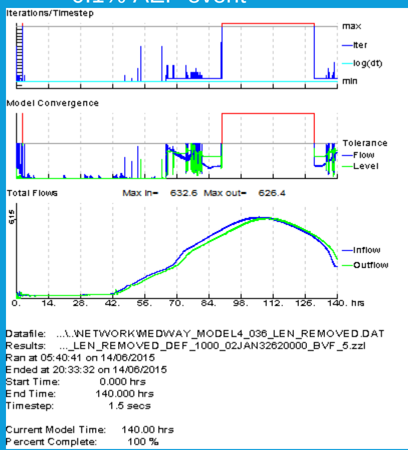
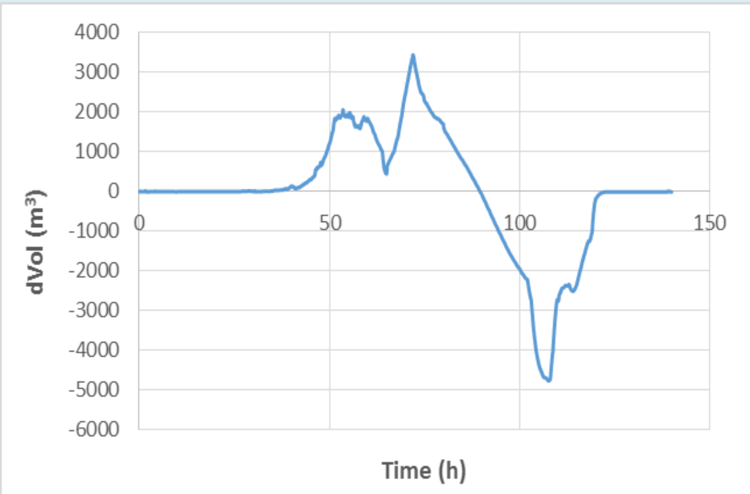
	LIDAR_filtered_Medway_Model4_50cm.asc 50cm resolution filtered LIDAR data used to update ground levels between upstream of Barming Bridge on the River Medway and on the River Len. LIDAR_filtered_Medway_Model4_25cm.asc 25cm resolution filtered LIDAR data used to update ground levels between Barming Bridge and Allington Lock. **Active area file** 2d_code_activate_Model4_R_006.shp - events with River Len included 2d_code_activate_Model4_R_006b.shp - events with River Len removed **Inactive area file** 2d_code_deactivate_Model4_R_009.shp - events with River Len included 2d_code_deactivate_Model4_R_009_Len_removed.shp - events with River Len removed
2D Model Geometry files	*All events* 2d_zln_banks_Model4_L_006.shp 2d_zln_banks_DTM_Model4_P_005.shp 2d_zln_banks_DSM_Model4_P_002.shp *River Len included only* 2d_zln_banks_Model4_Len_ISIS_L_002.shp 2d_zln_banks_Model4_Len_ISIS_P_002.shp 2d_zsh_bridge_decks_005_P.shp 2d_zsh_bridge_decks_005_L.shp 2d_zsh_bridge_decks_005_R.shp
Materials file (.tmf)	Medway_Model4_006

4.2.1 Run settings

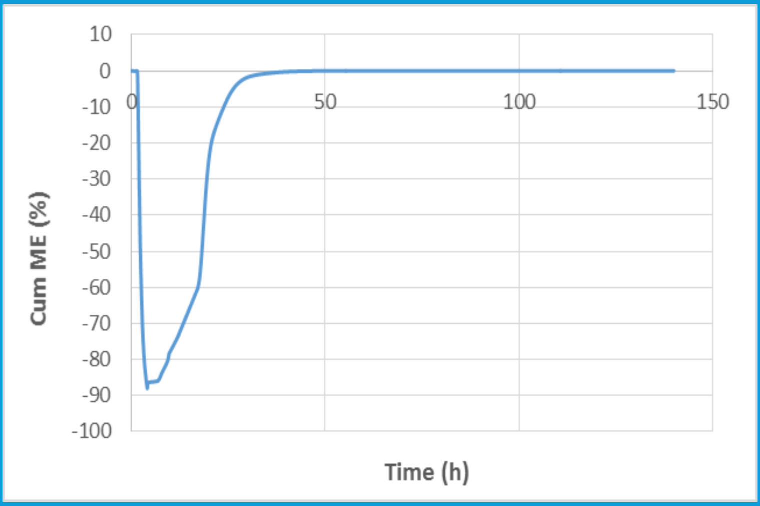
Model start time (hrs)	0	**Model end time (hrs)**	140
Map save interval (s)	1800	**Time series save interval (s)**	300
Map outputs (TUFLOW Flag) DAT format	d h q v MB1 MB2 ZUK0 Z0	**Time Step (s)**	3.00

4.2.2 Model stability

Comments on results	Refer to plots of Cumulative Mass Error (Cum ME %), dVol and ISIS convergence plots below. The ISIS convergence plots show that the ISIS model is stable. There is a period of non-convergence at the start of the simulation which is associated with initial oscillations at the upstream of the River Len at the start of simulation and therefore will not impact model results. The long period of non-convergence in the 0.1% AEP event is associated with bridge S10.003. Flow and level plots have been checked and oscillations are small and do not impact the results. The difference in volume at each save interval (dVol) displays an expected shape with the increase and subsequent reduction of flows entering the model. Some minor spikes/oscillations occur during the simulation but these are relatively minor. TUFLOW model mass balances show that the Cumulative Mass Error (Cum ME %) is initially very large (negative mass error). As very few of the total cells that become wet are flooded in this initial period it is considered that this higher mass balance error has no adverse impact on model predictions. As widespread

	flooding occurs this returns to within reasonable bounds ±1%.
ISIS convergence plots	20% AEP event  5% AEP event  1% AEP event  0.1% AEP event 
dVol (m³)	1% AEP 
Cum ME (%)	See next page.

1% AEP



Appendices

A Modelling approach and overview

A.1 Modelling Approach

A.1.1 Available Data

Cross-section survey	The 2008 River Medway model, which makes up a large majority of the ISIS model, is constructed from survey data collected by Flynn & Rothwell in 1995. A number of other survey datasets were used within the model, including Longdin & Browning (2001) gauging station survey (at Allington ultrasonic GS) and EDI Surveys Ltd (2013) gauging station survey (at East Farleigh GS). The sections including and downstream of Allington sluices were taken from the Lower Medway Flood Forecasting model (NFFS configuration from July 2014, ISIS model last updated August 2009). The 2010 River Len Modelling & Mapping study is constructed from the 2008 Longdin & Browning channel sections, CCTV survey of Maidstone culverts (collected in 2009) and other sources which contained structure dimensions. Survey data was commissioned for this study for a number of structures, and was conducted by Maltby Land Surveys Ltd, 2014. This information has been incorporated within the hydraulic model
Bank Top Survey	No bank top survey data was available.
LIDAR & other Topographic Data:	0.25cm filtered and unfiltered LIDAR data (flown March 2010) 0.50cm filtered and unfiltered LIDAR data (flown February 2009)
Map Data:	OS Open Data, OS 1:10,000, OS 1:25,000, OS 1:50,000 and OS MasterMap.

A.2 Model Overview

Figure A-1: ISIS Model Schematic (supplied with the model files as a .GXY file)

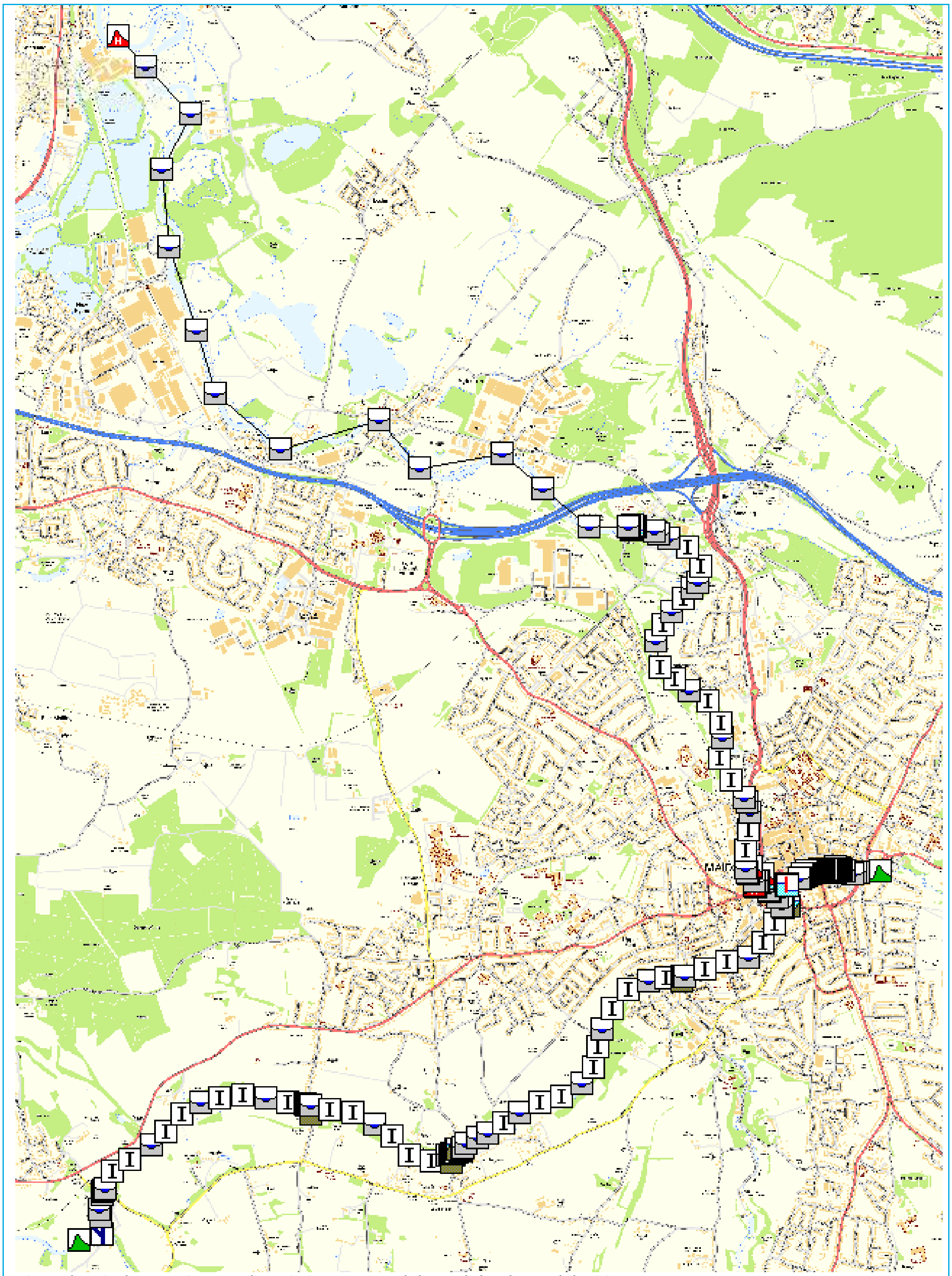
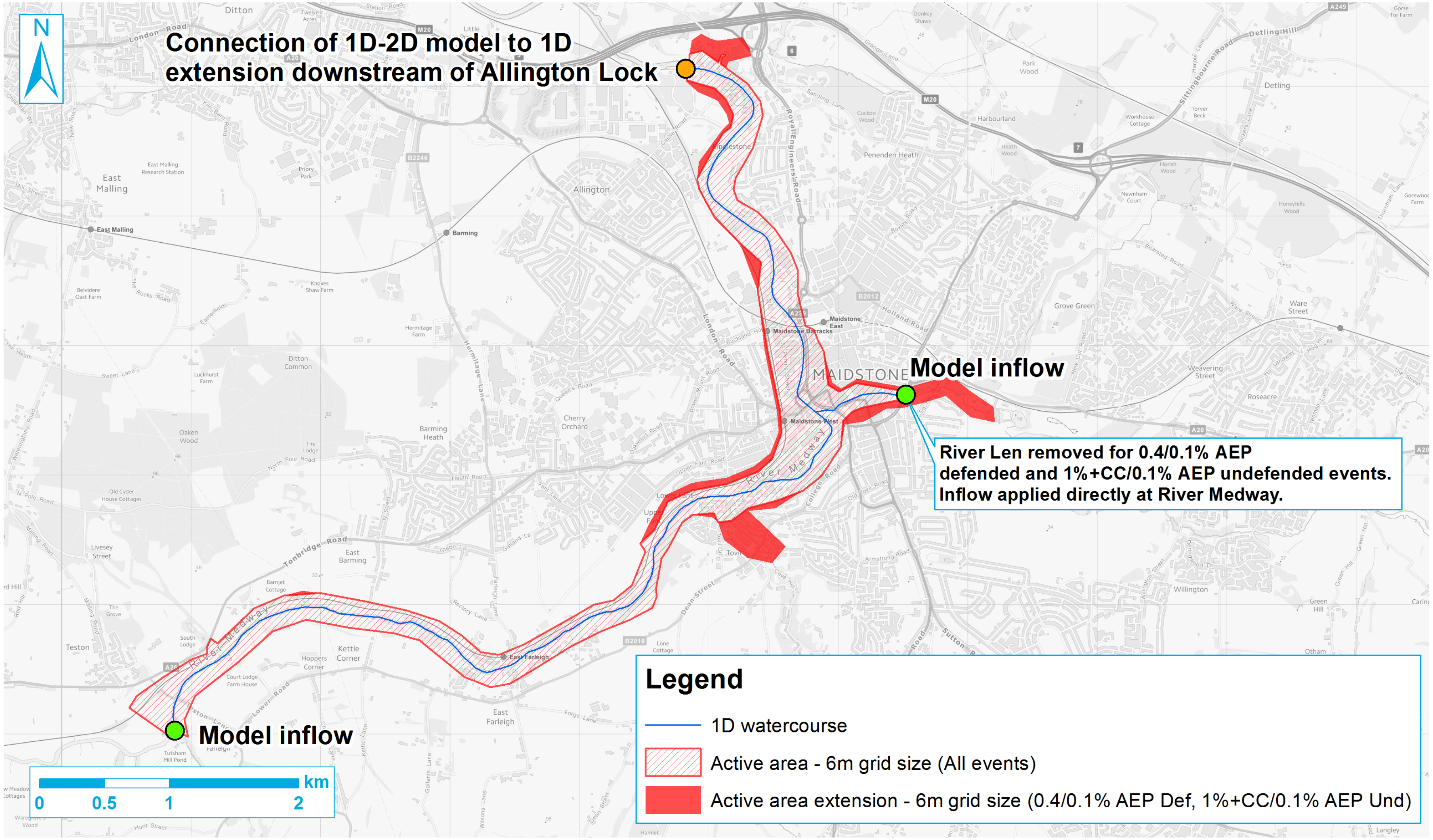


Figure A-2: ISIS-TUFLOW model schematic



A.2.2 Overview of 1D Model

Upstream Boundaries	River Medway: 200m upstream of Teston Lane bridge River Len: Downstream of Wat Tyler Way
Lateral Catchment Weighting	Two QTBDY inflows have been implemented. Both are at the upstream extents of the model, one represents the inflow on the River Medway (MED04), with flows based on continuous simulation outputs at East Farleigh and the other the inflow on the River Len (LEN01), with flows based on continuous simulation outputs at Lenside GS. There are no lateral inflows or sweetening inflows.
Downstream Boundary	**5.85km downstream of Allington Lock** A head-time boundary is applied at the downstream boundary. Downstream of, and including, Allington Lock is represented as a 1D only scheme, with section data extracted from the Lower Medway Flood Forecasting model. The operational rules from Allington Lock are taken from this model. A stage of 3.05mAOD, representing the mean high water spring (MHWS) level has been implemented at this location for the full simulation.
Total Number of nodes and structures	Medway_Model4_036.DAT consists of 241 nodes including: 80 River Sections 37 Interpolate units 12 Conduit section units 12 Spill units 10 Rectangular conduit units 9 Vertical Sluice units 7 Orifice units 6 HTBDYs (1 downstream boundary) 3 Bernouilli Loss units 3 Arch Bridges 2 Sprung conduit units 2 QTBDYs 1 USBPR Bridges 1 Round nosed broad crested weir units 1 Flat-V weir unit
Labelling/ Numbering System Used	Labelling conventions of the model generally remains as per the existing River Medway Modelling and Flood Mapping Updates (2008) model and the River Len Mapping and Modelling study Where new survey has been implemented the labelling follows from the survey cross section labels. An overview of sections nomenclature is provided below, in addition to a description of whether this was retained from the previous modelling (indicated by a 'R'), or adjusted or implemented as part of the model updates ('indicated by a 'U'). CS## (R) River Medway (Flynn & Rothwell, 1995) LEN01_#### (R) River Len (Longdin & Browning, 2008) BWAY_#### (R) Bishops Way Loop, River Len (Longdin & Browning, 2008) Me_## River Medway (Lower Medway Flood Forecasting model) S##.00# (U) River Medway structures (Maltby Land Survey Ltd, 2014) ALL_XS-0# (U) Allington ultrasonic gauge (Longdin & Browning, 2001) EF_XS-0# (U) East Farleigh gauging station (Longdin & Browning, 2001) T##### (U) East Farleigh gauging station (EDI Surveys Ltd, 2013)

Hydraulic roughness values used	Channel roughness values have been represented in the model by Manning's n. In order to determine the channel roughness, descriptions in Chow (1959)[1] were examined against photographic evidence, survey data and satellite imagery. Roughness values for sections along the River Medway were adjusted as part of the calibration process. Model calibration matched well at each of the gauging sites. Appendix D has more information relating to the roughness coefficients chosen for the new survey implemented. Sensitivity tests were undertaken to test the effect of increases and decreases in roughness. Please refer to the main study report for a summary of these tests.
Amendments to existing model	Please refer to the detailed model review for a list of model updates which were recommended and implemented, in addition to the model log spreadsheet, documenting how these updates were input into the hydraulic model.

A.2.3 Overview of 2D Model

Area of 2D domain	3.10 km^2 - with River Len 2.57 km^2 - without River Len.	**DTM data source**	LIDAR. Supplied by Geomatics Group Ltd
Resolution of grid	6m	**DTM resolution**	25cm / 50cm
Orientation of grid	WSW to ENE →		

Modifications to model topography

File	Description
2d_zln_banks_DTM_Model4_P_005.shp	Bank levels derived from 25cm / 50cm filtered LIDAR data at a maximum of 10m intervals.
2d_zln_banks_DSM_Model4_P_002.shp	Bank levels derived from 1m unfiltered LIDAR data in areas of poor filtering.
2d_zln_banks_Model4_Len_ISIS_L_002.shp | 2d_zln_banks_Model4_Len_ISIS_P_002.shp	Z-points updating ground levels along River Len taken from ISIS cross section bank levels.
2d_zsh_bridge_decks_005_R.shp | 2d_zsh_bridge_decks_005_L.shp | 2d_zsh_bridge_decks_005_P.shp	Z-shape from 2010 River Len Mapping and Modelling study. Implements bridge decks that were removed during the LIDAR filtering process.

Hydraulic roughness used within the 2D domain

Ordnance Survey MasterMap Topographic Area data was used to define the 2D floodplain roughness values for individual MasterMap feature classes. The Manning's *n* values used are tabulated below. These values have been informed from the roughness values applied to each of the four rating models developed for the current study at Colliers Land Bridge, Vexour Bridge, Stile Bridge and Stone Bridge. The values are typically greater than implemented on other studies previously, but given the evidence in the four models above that these values are required, these have been carried forward for the flood risk mapping models.

Table 4-1: Manning's n roughness values for the 2D domains, based on OS MasterMap land cover classes

Land cover	Manning's n
Building	0.300
General surface - multi surface	0.090
General surface - step	0.090
General surface	0.100
Glasshouse	0.200
Inland water	0.095
Landform	0.100
Boulders	0.105
Coniferous trees	0.160

[1] Chow V.T. (1959) Open Channel Hydraulics McGraw Hill

Land cover	Manning's n
Coniferous trees - scattered / Orchard	0.110
Coppice or osiers	0.130
Marsh reeds or saltmarsh	0.100
Non-coniferous trees	0.130
Non-coniferous trees - scattered	0.100
Rough grassland	0.100
Scrub	0.110
Path	0.090
Rail	0.080
Road	0.080
Roadside	0.090
Structure	0.300
Structure - upper level of communication	0.300
Structure - pylon	0.100
Tidal water	0.095
Unclassified	0.100
Rock	0.110
Heath	0.130
Stability	0.300

A.2.4 1D-2D Linking

JBA have retained the standard approach to linking 1D ISIS and 2D TUFLOW models in each domain. Within the TUFLOW model HX boundaries are defined for the left and right banks and the channel area in between classified as 'inactive' in the 2D grid. The HX boundaries are linked to the respective ISIS nodes using CN connection lines and are discontinued at structures and confluences. Along these boundaries, water levels in the channel and floodplain interact dynamically and thus control floodplain wetting and drying.

B List of structures

The tables within the following sections outline the structures included within the hydraulic model. Listed are those on the main River Medway and River Len channels.

Where the representation of the modelled structures differs from default (e.g. non-default parameters or coefficients) these are recorded. Links are also provided to structure photos where available.

.

B.1 River Medway

Structure name	Structure type	Structure updated	Upstream node	Downstream node	Survey reference	Model representation	Spill unit attached	Spill Weir coefficient	Spill Modular limit	Structure photo
Teston Lane bridge	Road bridge	No change	CS176BU	CS176BD	EA reference 11788	Bernoulli Loss unit	No	-	-	No photo available
Barming bridge	Footbridge	No change	CS182BU	CS184BD	EA reference 11788	Bernoulli Loss unit	Yes	1.20	0.90	No photo available
East Farleigh bridge	Road bridge	No change	CS186BU	CS188BD	EA reference 11788	Bernoulli Loss unit	Yes	0.90	0.90	No photo available
Lock at East Farleigh	Lock	Updated	CS188LU	CS188LD	T4180_East Farleigh.dwg and East Farleigh Lock, sluices and weir – general plan_L120.pdf	Vertical Sluice unit	Yes*	1.10	0.90	No photo available
Left vertical gate at East Farleigh	Sluice gate	Updated	CS188VU1	CS188VD1	Farleigh-proposed lifting sluice gates_223_10.pdf and Farleigh-proposed lifting sluice gates L121.pdf	Vertical Sluice unit	Yes*	1.10	0.90	No photo available
Right vertical gate at East Farleigh	Sluice gate	Updated	CS188VU2	CS188VD2	Farleigh-proposed lifting sluice gates_223_10.pdf and Farleigh-proposed lifting sluice gates L121.pdf	Vertical Sluice unit	Yes*	1.10	0.90	No photo available
Weir at East Farleigh	Weir	No change	CS188WU	CS188WD	East Farleigh Lock, sluices and weir – general plan_L120.pdf	Round nosed broad crested weir	Yes*	1.10	0.90	No photo available
-	Footbridge	Implemented	S10.004BU	S10.004BD	Maltby Land Surveys Ltd 2014	Bridge (USBPR 1978)	Yes	1.00	0.90	Section **C.1**
-	Footbridge	Implemented	S10.003BU	S10.003BD	Maltby Land Surveys Ltd 2014	Bridge (Arch)	Yes	1.00	0.90	Section **C.1**
Broadway Road bridge	Road bridge	Implemented	S10.002BU	S10.002BD	Maltby Land Surveys Ltd 2014	Bridge (Arch)	Yes	1.00	0.90	Section **C.1**
-	Subway	Implemented	Sub1_1D	Sub1_2D	None - dimensions assumed	Orifice unit	No	-	-	No photo available
-	Subway	Implemented	Sub2_1D	Sub2_2D	None - dimensions assumed	Orifice unit	No	-	-	No photo available
-	Subway	Implemented	Sub3_1D	Sub3_2D	None - dimensions assumed	Orifice unit	No	-	-	No photo available
-	Subway	Implemented	Sub4_1D	Sub4_2D	None - dimensions assumed	Orifice unit	No	-	-	No photo available
St Peter's bridge	Road bridge	Implemented	S10.001BU	S10.001BD	Maltby Land Surveys Ltd 2014	Bridge (Arch)	Yes	1.20	0.90	Section **C.1**
Lock gate at Allington	Lock gate	Implemented	S_Lock_US	S_Lock_DS	Lower Medway Flood Forecasting model	Vertical Sluice unit	Yes*	1.70	0.90	No photo available
Left sluice gate at Allington	Sluice gate	Implemented	S_Left_US	S_Left_DS	Lower Medway Flood Forecasting model Operation derived from 06 Jan 2014 operation document: 2015-01-07 - Allington Sluice - Basic Operating Procedure.doc	Vertical Sluice unit	Yes*	1.70	0.90	No photo available
Centre sluice gate at Allington	Sluice gate	Implemented	S_Centre_US	S_Centre_DS	Lower Medway Flood Forecasting model Operation derived from 06 Jan 2014 operation document: 2015-01-07 - Allington Sluice - Basic Operating Procedure.doc	Vertical Sluice unit	Yes*	1.70	0.90	No photo available
Right sluice gate at Allington	Sluice gate	Implemented	S_Right_US	S_Left_DS	Lower Medway Flood Forecasting model Operation derived from 06 Jan 2014 operation document: 2015-01-07 - Allington Sluice - Basic Operating Procedure.doc	Vertical Sluice unit	Yes*	1.70	0.90	No photo available

*Spill used to represent bypassing flow

B.2 River Len

Structure name	Structure type	Structure updated	Upstream node	Downstream node	Survey reference	Model representation	Spill unit attached	Spill Weir coefficient	Spill Modular limit	Structure photo
Lenside Gauging Station weir	Flat-V Weir	No change	LEN01_0597u	LEN01_0597d	EA reference 11794 and 11649	Flat-V Weir[2]	N/a	-	-	Section **C.2**
-	Road bridge culvert	Updated	LEN01_0586c	LEN01_0577c	EA reference 11794	Symmetrical culvert	Yes	1.30	0.90	Section **C.2**
Chequers Centre culvert	Culvert (5 openings, one outlet)	Updated	LEN1_0567c1 LEN1_0567c2 LEN1_0567c3 LEN1_0567c4 LEN1_0567c5	LEN1_0385c	EA reference 11794	Upstream section: 3 no. Symmetrical culverts and 2 no. Rectangular culverts Mid-section: 1 no. Rectangular culvert Downstream section: 1 no. Sprung Arch culvert	No	-	-	Section **C.2**
Access bridge in Palace Avenue car park	Access bridge	Updated	LEN01_0351ou	LEN01_0348od	EA reference 11794	Orifice unit	Yes	1.30	0.90	Section **C.2**
Culvert under Palace Avenue garage	Culvert	Updated	LEN01_0342c	LEN01_0278	EA reference 11794	Symmetrical culvert	Yes	1.30	0.90	Section **C.2**
-	Weir	No change	LEN01_0170s1	LEN01_0170s1d	EA reference 11794	ISIS Spill unit	N/a	1.60	0.90	Section **C.2**
Bishops Way (northern channel)	Culvert	Updated	LEN01_0170s1d	LEN01_0161c1d	EA reference 11794	Orifice unit	No	-	-	Section **C.2**
Sluice at Mill Street (Left)	Sluice gate	No change	LEN01_0170s2	LEN01_0170s2d	EA reference 11794	Vertical Sluice unit	No	-	-	Section **C.2**
Sluice at Mill Street (Right)	Sluice gate	No change	LEN01_0170s3	LEN01_0170s3d	EA reference 11794	Vertical Sluice unit	No	-	-	Section **C.2**

2 A warning message occurs at the structure: 'Flat-V weir equations not validated for V slope milder than 1:20 and downstream face of 1:2'. The V-slope within the unit is 1:23.39. It is considered that the influence of this on model predictions is likely to be limited given that the V-slope specified is not far outside the recommended range. Adjusting the V-slope to 1:20, to remove the warning message, would remove greater confidence in the results compared with retaining surveyed dimensions.

C Structure photos

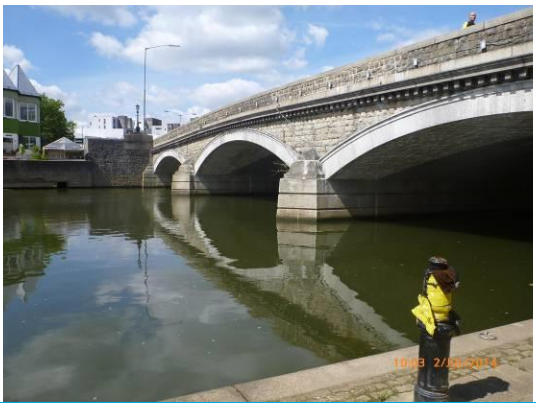
C.1 River Medway

Return to section **B.1**.

S10.004BU (downstream face)

S10.003BU (downstream face)

S10.002BU



S10.001BU

C.2 River Len

Return to section **B.2**

LEN01_0597u

LEN01_0586c

LEN1_0567c1/2/3/4/5

LEN01_0351ou

LEN01_0342c

LEN01_0170s1 and LEN1_0161s1d (weir directly into culvert)

LEN01_0170s2 and LEN01_0170s3

D Roughness values used within the 1D hydraulic model

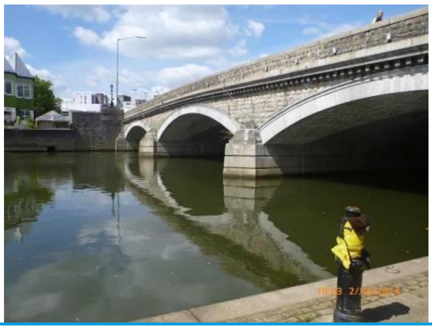
D.1 Introduction

Model 4 consists of an updated part of the River Medway Catchment Modelling and Flood Mapping Updates (2008) project, part of the River Len Modelling and Mapping study (2010) and new survey. Roughness values for River Medway sections retained from previous models were typically 0.03 for the river bed and 0.05 for banks. These values were adjusted through the hydraulic model calibration process and modelled vs observed water levels match closely. Model inflows for calibration were observed flows at East Farleigh, so confidence is held in the parameterisation of roughness to match observed water levels at gauging sites

The purpose of this section is to document the selection of roughness values within Model 4 for the additional information collected by Maltby Land Surveys Ltd 2014 for the Medway Catchment Mapping and Modelling study as well as the additional survey implemented at gauging sites. There are a number of sources of reference for channel roughness values. Here, the main point of reference was Chow's (1959)[3] description of natural streams – minor streams. In order to determine the roughness of channel cross sections, photographic evidence, survey data and satellite imagery was used.

Unless otherwise stated the photographic evidence from survey conducted by Maltby Land Surveys Ltd in 2014 for the purpose of the River Medway Catchment Mapping and Modelling study has been used in conjunction with calibration to observed data. Survey was taken in June/July 2014. Given that vegetation may typically be high during summer months consideration has been given to whether the section conditions are representative of typical conditions.

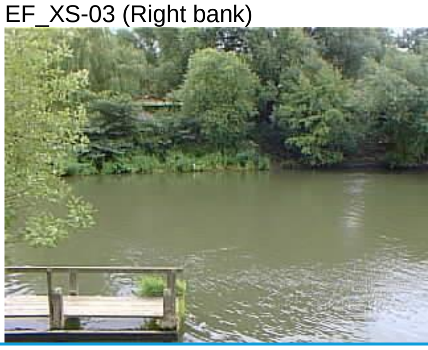
D.2 Maltby Land Surveys Ltd

Node label(s)	Manning's n	Photograph(s)
S10.001	Bed = 0.028 Banks = 0.050	S10.001 
S10.002	Bed = 0.028 Banks = 0.050	S10.002 
S10.003	Bed = 0.028 Banks = 0.050	S10.003 (channel)

3 Chow V.T. (1959) Open Channel Hydraulics McGraw Hill

		 S10.003 (right bank) 
S10.004	Bed = 0.040 Banks = 0.050	S10.004 (upstream face)  S10.004 (downstream face) 

D.3 Gauging stations

Node label(s)	Manning's n	Photograph(s)
EF_XS-03 **(East Farleigh)**	Bed = 0.040 Banks = 0.055	EF_XS-03 (channel)  EF_XS-03 (Right bank) 
T11648 **(East Farleigh)**	Bed = 0.040 Banks = 0.045	T11648 (Channel and Right bank)  T11648 (Left bank) 
EF_XS-01 **(East Farleigh)**	Bed = 0.040 Banks = 0.065	EF_XS-01 
ALL_XS-03 **(Allington**	Bed = 0.028 Banks = 0.050	ALL_XS-03 (channel)

Ultrasonic)		 ALL_XS-03 (Left bank) 
ALL_XS-02 (Allington Ultrasonic)	Bed = 0.028 Banks = 0.050	ALL_XS-02 (channel)  ALL_XS-03 (Left bank) 
ALL_XS-01 (Allington Ultrasonic)	Bed = 0.028 Banks = 0.050	ALL_XS-01 (channel)  ALL_XS-03 (Left bank)

Offices at

Coleshill

Doncaster

Edinburgh

Exeter

Haywards Heath

Limerick

Newcastle upon Tyne

Newport

Saltaire

Skipton

Tadcaster

Thirsk

Wallingford

Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE

t:+44(0)1756 799919
e:info@jbaconsulting.com

Jeremy Benn Associates Ltd
Registered in England
3246693

Visit our website
www.jbaconsulting.com